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SHIELDS RIVER WATERSHED WATER QUALITY PLANNING FRAMEWORK AND SEDIMENT TMDLS

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Montana Department of Environmental Quality

Montana Department of Environmental Quality
P.O. Box 200901
Helena, MT 59620-0901

Lisa Kusnierz, Project Manager

Pete Schade, Project Manager

Cooperators:

Park Conservation District
5242 Highway 89 South
Livingston, MT 59047

Shields Valley Watershed Group
5242 Highway 89 South
Livingston, MT 59047

Significant Contributors:
Confluence Consulting, Inc

ERRATA SHEET FOR THE "SHIELDS RIVER WATERSHED WATER QUALITY PLANNING FRAMEWORK AND SEDIMENT TMDLS"

This TMDL was approved by EPA on June 30, 2009. Several copies were printed and spiral bound for distribution, or sent electronically on compact disks. The original version has a minor change that is explained and corrected on this errata sheet. If you have a bound copy, please note the correction listed below or simply print out the errata sheet and insert it in your copy of the TMDL. If you have a compact disk please add this errata sheet to your disk or download the updated version from our website.

Appropriate corrections have already been made in the downloadable version of the TMDL located on our website at: http://deq.mt.gov/wqinfo/TMDL/finalReports.mcpx

The following table contains corrections to the TMDL. The first column cites the page and paragraph where there is a text error. The second column contains the original text that was in error. The third column contains the new text that has been corrected for the "Shields River Watershed Water Quality Planning Framework and Sediment TMDLs" document. The text in error and the correct text are underlined.

Location in the TMDL	Original Text	Corrected Text
Page 9, Section 1.3, Table 1-1, Shield River (headwaters to Cottonwood Cr.) MT43A001-012, Probable Cause column	Sedimentation; Siltation; Suspended Solids	Sediment/Siltation
Page 9, Section 1.3, Table 1-1, Shield River (Cottonwood Cr to mouth) MT43A001-011, Probable Cause column	Sedimentation; Siltation; Suspended Solids	Sediment/Siltation

Table of Contents

List of Appendices

List of Tables

List of Figures

EXECUTIVE SUMMARY

The Shields River Watershed lies in south-central Montana, just north of Livingston and 13 miles northeast of Bozeman. The watershed encompasses 855 square miles (547,048 acres), mostly within Park County, but includes portions of Gallatin and Meagher counties. The Bridger and Bangtail Mountains confine the watershed to the west and the Crazy Mountains form the eastern watershed boundary. The Shields River flows in a southerly direction for approximately 62 river miles to the confluence with the Yellowstone River near Livingston, Montana. Major tributaries to the Shields River include Elk Creek, Cottonwood Creek, Rock Creek, Potter Creek, and Smith Creek. Elevations in the watershed range from approximately 10,850 ft (3307 m) in the Crazy Mountains to 4,386 ft (1337 m) at the mouth of the Shields River.

The Clean Water Act (CWA) requires the development of Total Maximum Daily Loads (TMDLs) that will provide conditions that can support all identified uses. This document combines a generalized watershed restoration strategy along with creation of TMDLs. The designated water uses include drinking, culinary and food processing after conventional treatment; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply. CWA objectives include restoration and maintenance for all of these uses. In the Shields River Watershed, the most sensitive uses are the fishery and aquatic life.

A TMDL is a pollutant budget identifying the maximum amount of a particular pollutant that a water body can assimilate without causing applicable water quality standards to be exceeded. Section 303 of the Federal CWA and Section 75-5-703 of the Montana Water Quality Act (WQA) require development of TMDLs for impaired water bodies that do not meet Montana water quality standards. Section 303(d) also requires identification of impaired water bodies on a list, referred to as the 303(d) List. This 303(d) List is updated every two years and submitted to the U.S. Environmental Protection Agency (EPA) by the Montana Department of Environmental Quality (DEQ[1]).

On the 2006 303(d) List, four water body segments are listed for sediment impairment. Those water body segments include the upper and lower segments of the Shields River, Antelope Creek, and Potter Creek. TMDLs are provided for the upper and lower segments of the Shields River and Potter Creek. Several other water body segments are listed only for low flow alterations and/or habitat alterations, which do not require TMDL development but may contribute to sediment impairment. This document takes a watershed scale approach to TMDL implementation and those listing causes are addressed within the document via BMP recommendations in the Implementation and Monitoring Strategy (**Section 8.0**).

Source assessments identify agriculture, historical timber harvest, historical riparian vegetation removal, bank erosion, and roads as the primary sources of human caused pollutants in the Shields River watershed. Restoration strategies for the Shields River TPA focus on implementing agricultural and road management BMPs, timber harvest BMPs, and other land, soil, and water conservation practices that relate to near stream channel and vegetation

[1] DEQ refers to the Montana Department of Environmental Quality unless otherwise noted.

conditions. Restoring instream flow to dewatered tributaries is another critical component to restoration of the Shields River Watershed.

The restoration process identified in this document is voluntary, cannot divest water rights or private property rights, and does not financially obligate identified stakeholders unless such measures are already a requirement under existing Federal, State, or local regulations.

Restoration strategies identified in this document are intended to balance the varying uses of water while adhering to Montana's water quality and water use laws. This document should be considered dynamic, by providing an "adaptive management strategy" approach to restore water quality in the Shields River Watershed. This water quality plan is intended to identify the knowledge we have at present and to identify a future path for water quality restoration. As more knowledge is gained through the restoration process and future monitoring, this plan may change to accommodate new science and information. Montana's water quality law provides an avenue for using the adaptive management process by providing for future TMDL reviews.

The state is required to support a voluntary program of reasonable land, soil, and water conservation practices. DEQ's approach to this program recognizes that the cumulative impacts from many nonpoint source (NPS) activities are best addressed via voluntary measures with DEQ and/or other agency or other forms of professional assistance. This often applies to agricultural situations or small landowner activities along or near streams. The State's voluntary program does not cover all NPS activities since there are local, state and/or federal regulations that apply to certain NPS activities within Montana. Examples where a non-voluntary approach is applicable due to existing regulations include but are not limited to streamside management zone requirements for timber production, minimum septic design and location requirements, local zoning requirements for riparian or streambank protection, and compliance with 310 Law.

The document structure provides specific sections that address TMDL components and watershed restoration. **Sections 1.0 through 4.0** provide background information about stakeholder involvement, the Shields River Watershed, Montana's water quality standards, and Montana's 303(d) Listings. **Section 5.0** provides TMDL targets, existing data, and the impairment status for each water body. **Sections 6.0 and 7.0** review sediment source assessments, TMDLs, and allocations. Generalized restoration strategy and follow up monitoring approach are provided in **Section 8.0**. **Section 9.0** is a review of stakeholder and public comment periods during the TMDL process. Many of the detailed technical analyses are provided in appendices. **Table E-1** provides a very general summary of the water quality restoration plan and TMDL contents.

Table E-1. Water Quality Plan and TMDL Summary Information.	
Impaired Water Body Summary	• The focus of this document is sediment-related impairments. Three of the four water body segments listed on the 2006 303(d) List as impaired from sediment-related causes have TMDLs presented in this document. The following TMDLs are included in this Water Quality Planning Framework: o Shields River (upper and lower segments) and Potter Creek • Data suggest the Antelope Creek listing is likely related to nutrient sources, and a TMDL has not been prepared at this time. Additional monitoring is recommended to determine whether a sediment and/or nutrient TMDL is necessary.
Impacted Uses	• Coldwater fishery and aquatic life beneficial uses are negatively impacted from sedimentation
Pollutant Source Descriptions	• Roads and transportation: Forest, Federal, and County roads. Sediment production from unpaved roads, stream crossings, and stream encroachment from all road types. • Agriculture: Historic harvest of riparian vegetation. Extensive areas of grazing, cultivation, and irrigation. • Silviculture: Historic logging practices.
TMDL Target Development Focus	• Fine sediment in riffles and spawning substrate compared to reference condition • Channel conditions that affect sediment transport compared to reference condition • Biological indicators compared to reference condition • Presence of significant human caused sources
Other Use Support Objectives (non-pollutant & non-TMDL)	• Improve native riparian vegetation cover. • Improve instream fishery habitat. • Improve instream flow. • Eliminate unnatural fish passage barriers based on fishery goals.
Sediment TMDL and Allocation Summary	• Load allocations (LA) provided for roads, hillslope erosion (by subwatershed and land cover), bank erosion, and natural background. • An overall percent sediment load reduction is provided for the TMDL and is based on individual percent reduction allocations and also natural background estimates. Estimated annual sediment LAs to all significant source categories are also provided. Reductions are based on estimates of BMP performance. The annual TMDL is the sum of the allocations. Numeric sediment load based daily TMDLs and daily allocations are also estimated and provided in an appendix. • Manage the stream corridor to facilitate transport of excess historical sediment loads through the system (not a “formal” TMDL load allocation, but an important load consideration).
Sediment Restoration Strategy	• The restoration strategy identifies general restoration approaches for assessed sources. Addressing the sources in the restoration strategy will likely achieve TMDLs. An adaptive management component is also provided for determining if future restoration will meet targets provided in the document.

SECTION 1.0
INTRODUCTION

1.1 Watershed Overview

The Shields River Watershed is located in south-central Montana, just north of Livingston and 13 miles northeast of Bozeman. The watershed encompasses 855 square miles (547,048 acres) mostly within Park County, but includes portions of Gallatin and Meagher counties. The major water body in the watershed is the Shields River, which flows from North to South for approximately 62 river miles to the confluence with the Yellowstone River near Livingston, Montana. Major tributaries to the Shields River include Elk Creek, Cottonwood Creek, Rock Creek, Potter Creek, and Smith Creek. Additional characteristics of the Shields River Watershed are discussed in **Section 3.0** of this document (Watershed Characterization).

The Shields River Watershed (also referred to in this document as the Shields River TMDL Planning Area, or TPA) is one of more than 90 TPAs in Montana in which water quality is listed as impaired. In each of these TPAs, the State of Montana is required to develop TMDLs to reduce pollutant loading and eliminate other negative impacts to water quality in impaired water bodies.

1.2 TMDLs and the Water Quality Planning Framework Process

A TMDL is the total amount of pollutant a stream may receive from all sources without exceeding water quality standards. A TMDL is also a reduction in pollutant loading resulting in attainment of water quality standards. Section 303 of the Federal CWA and the Montana WQA (Section 75-5-703) requires development of TMDLs for impaired water bodies that do not meet Montana water quality standards. Although water bodies can become impaired from pollution (e.g. flow alterations and habitat degradation) and pollutants (e.g. nutrients, sediment, and metals), the EPA limits TMDL development to waters impaired by pollutants (Dodson 2001). Section 303 also requires states to submit a list of impaired water bodies to the EPA every two years. Prior to 2004, the EPA and the Montana DEQ referred to this list as the 303(d) List. Since 2004, the EPA has requested that states combine the 303(d) List with the 305(b) Report containing an assessment of Montana's water quality and its water quality programs. The EPA refers to this new combined 303(d)/305(b) Report as the Integrated Water Quality Report.

The TMDL development process is a problem-solving approach that results in a framework for water quality improvement. The primary objective is to develop an approach to restore and maintain the physical, chemical, and biological integrity of streams in the TPA so they will support all uses identified in state water quality standards. The uses include drinking, culinary, and food processing purposes after conventional treatment; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply. The major steps of the TMDL development process generally include defining the problem, quantifying the pollutant sources, determining the pollutant loading conditions needed to solve the problem, and developing a monitoring strategy.

Although not a required TMDL development step, most Montana TMDL development documents include a section on implementation and restoration planning.

These TMDL development steps are further summarized below. Although they are presented sequentially, some of the steps tend to overlap due to the nature of this problem solving approach.

Defining the Problem:

First, the water quality problems of concern are thoroughly evaluated and described. This includes understanding the characteristics and function of the watershed, documenting the location and extent of the water quality impairments, and identifying the likely causes and sources of impairment. Water quality targets are developed for each pollutant of concern during this step to gain a better understanding of stream health. These targets typically include a suite of in-stream measures that link directly to the impacted beneficial use(s) and applicable water quality standard(s). The water quality targets help define the desired stream conditions and are used to provide benchmarks to evaluate overall success of restoration activities. The water quality targets also provide a means to evaluate the extent of the problem by comparing existing stream conditions to the desired target values.

Quantifying Pollutant Sources (Source Assessment):

Second, all significant pollutant sources, including natural background loading, are quantified so that the relative pollutant contributions can be determined. Source assessments often have to evaluate the seasonal nature and ultimate fate of the pollutant loading since water quality impacts can vary throughout the year. The source assessment usually helps to further define the extent of the problem by putting human caused loading into context with natural background loading.

A pollutant load is usually quantified for each point source permitted under the MPDES program. Most other pollutant sources, typically referred to as nonpoint sources, are quantified by source categories such as unpaved roads and/or by land uses such as crop production or forestry. These source categories or land uses can be further divided by ownership such as Federal, State, or private. Alternatively, a sub-watersheds or tributaries approach can be used whereby most or all sources in a sub-watershed or tributary are combined for quantification purposes.

The source assessments are performed at a watershed scale because all potentially significant sources of the water quality problems must be evaluated. The source quantification approaches may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading (40 CFR Section 130.2(G)). Montana TMDL development often includes a combination of approaches depending on the level of desired certainty for setting allocations and guiding implementation activities.

Determining Acceptable Pollutant Loading Conditions:

The next step is defining the allowable loading for each pollutant of concern. This allowable loading is the TMDL. The TMDL is the assimilative capacity for the water body and reflects the sum total of acceptable loading conditions for all of the pollutant loading sources. This sum total of acceptable loading is typically sub-divided into individual allocations applied to human activities and natural background loading in the watershed, often expressed in the form of a percent load reduction. The allocations are based on the existing pollutant loading conditions determined during source assessment and a determination of practical and achievable load reductions via application of reasonable land, soil, and water conservation practices.

TMDL Implementation and Restoration Planning:

Most of Montana's TMDL documents also include an implementation section. Once the necessary pollutant loading conditions to solve the problem are identified, implementation of measures to reduce pollutant loading is vital to the achievement of the TMDL. The allocations provide the basis for TMDL implementation since the allocations are based on the application of reasonable land, soil, and water conservation practices.

Although DEQ provides TMDL implementation assistance and some implementation components may be regulatory, TMDL implementation primarily relies on the support of watershed landowners and various stakeholders. Montana DEQ supports a policy of voluntary compliance for addressing many of the nonpoint sources of pollutants emanating from private lands. Water quality protection measures are not considered voluntary where such measures are already a requirement under existing Federal, State, or local regulations.

For prioritizing implementation efforts, watershed groups and other stakeholders can focus on the sources that have the highest achievable loading reductions captured within the allocations, and apply the reasonable land, soil, and water conservation practices that were used to determine the load reduction potential. The applicable land, soil, and water conservation practices in many watersheds, such as the Shields, are similar or equivalent to best management practices (BMPs) that can be applied to agricultural or other land management activities. In some cases, additional conservation practices may be necessary to achieve compliance with water quality standards and restore beneficial uses.

Developing a Monitoring Strategy:

A monitoring strategy is a primary part of adaptive management and usually considered part of the TMDL margin of safety (MOS), which is a required TMDL component. The monitoring strategy typically includes a monitoring design to evaluate progress in meeting the water quality targets established during TMDL development. A variety of monitoring recommendations regarding progress toward meeting allocations is also typically included so that relationships between pollutant load reductions and in-stream water quality target parameters can be evaluated over time. This information can be used to help fine-tune TMDL implementation and restoration planning as discussed above.

1.3 303(d) List Summary and TMDLs Written

Table 1-1 includes all water body segments on the 2006 303(d) List. The focus of this document is sediment-related impairments, and there are three water bodies within the Shields River TPA that have sediment-related listings on the 2006 303(d) List: the Shields River, which consists of two separate water body segments, Potter Creek, and Antelope Creek (**Table 1-1**; DEQ, 2006a). All 303(d) listing probable causes shown in **bold** in **Table 1-1** (i.e. siltation, sedimentation, suspended solids, etc) are associated with sediment and will be addressed as sediment-related impairments within this document.

TMDLs have been completed for the Shields River and Potter Creek. Sediment-related impairment can be associated with siltation, sedimentation, and suspended sediment and is further discussed for each water body in **Section 5.0**. Although TMDLs address pollutant loading, implementation of land, soil, and water conservation practices to reduce pollutant loading will inherently address some pollution impairments (e.g. habitat and low flow alterations) in the listed water bodies. Data collected to assist with TMDL development suggest the Antelope Creek sediment-related listing is actually more likely due to nutrient-related sources instead of sediment sources, and a TMDL has not been prepared at this time. Additional monitoring is recommended to determine whether a sediment and/or nutrient TMDL is necessary.

Table 1-1. Summary of 2006 303(d) Listings and TMDL Status
Pollutant-related causes of impairment are in bold. Other listings are for forms of pollution.

Stream Assessment Unit	Probable Cause	2006 303d	TMDL Development Schedule	2008 TMDL Review	TMDL Completed	Further Impairment Review Recommended
Antelope Creek MT43A002_020	**Solids (suspended/bedload)**	X	2012	X	No	Yes
	Alteration in streamside or littoral vegetative covers	X	N/A*	N/A	N/A	N/A
	Excessive algal growth**	X	2016	No	No	Yes
Cottonwood Creek (Trespass Cr to mouth) MT43A002_031	Low flow alteration	X	N/A*	N/A	N/A	N/A
Elk Creek MT43A002_040	Alteration in streamside or littoral vegetative covers	X	N/A*	N/A	N/A	N/A
Potter Creek MT43A002_10	**Sedimentation/Siltation; Solids (suspended/bedload)**	X	2012	X	Yes	No
Rock Creek (USFS boundary to mouth) MT43A002_051	Low flow alteration	X	N/A*	N/A	N/A	N/A
Shields River (headwaters to Cottonwood Cr) MT43A001_012	**Sedimentation/Siltation**	X	2012	X	Yes	No
	Low flow alteration	X	N/A*	N/A	N/A	N/A
	Other habitat alterations; Alteration in streamside or littoral vegetative covers; Physical substrate habitat alterations	X	N/A*	N/A	N/A	N/A
Shields River (Cottonwood Cr to mouth) MT43A001_011	**Sedimentation/Siltation**	X	Yes	X	Yes	No
	Low flow alteration	X	N/A*	N/A	N/A	N/A
	Other habitat alterations; Alteration in streamside or littoral vegetative covers; Physical substrate habitat alterations	X	N/A*	N/A	N/A	N/A

* - TMDLs are not required for pollution-related impairment.
** - Algal growth is often linked to an excess in nutrient pollutant loading. Therefore, a nutrient TMDL could be required to satisfy future TMDL schedule requirements.

1.4 Potential Future TMDL Development

Additional data collection and analysis was completed for pollutants within several water bodies where impairment conditions were suspected, but had not been previously confirmed during application of DEQ's assessment process using methods consistent with State Law (75-5-702). The results from this work will be made available in the DEQ files, and could lead to additional TMDL development at a later time for these and possibly other water body – pollutant combinations. The water body – pollutant combinations that underwent additional assessment include:

Shields River (upper segment) – nutrients
Shields River (lower segment) – nutrients
Elk Creek – sediment
Cottonwood Creek (lower segment) – sediment
Rock Creek (lower segment) – sediment

1.5 Document Organization

This document is a water quality planning framework that includes TMDLs. This document focuses on sediment-related water quality impairments in the Shields River TPA. The document is structured to address all of the required components of a TMDL and also includes an implementation and monitoring strategy as well as a discussion on public involvement. It is organized as follows:

- Stakeholder and Public Participation: **Section 2.0**
- Watershed Characterization: **Section 3.0**
- Application of Montana's Water Quality Standards for TMDL Development: **Section 4.0**
- Comparison of Existing Data to Water Quality Targets: **Section 5.0**
- Pollutant Sources and Load Estimates: **Section 6.0**
- TMDL, Allocations, and Margin of Safety: **Section 7.0**
- Restoration and Monitoring Strategy: **Section 8.0**
- Stakeholder and Public Comments: **Section 9.0**

Additionally, several appendices are included to provide supporting information to the restoration plan. These include:

Appendix A: Maps
Appendix B: Regulatory Framework and Reference Condition Approach
Appendix C: Reference Value Development and Target Justification
Appendix D: Sediment Contribution from Roads
Appendix E: Sediment Contribution from Hillslope Erosion
Appendix F: Sediment Contribution from Streambank Erosion
Appendix G: Daily TMDLs
Appendix H: Shields Valley Watershed Group Restoration Priorities
Appendix I: Sediment and Habitat Assessment Methods and Data
Appendix J: Response to Public Comments

SECTION 2.0
STAKEHOLDER AND PUBLIC PARTICIPATION

Stakeholder and public involvement is a component of TMDL planning efforts supported by EPA guidelines and Montana State Law. This section describes State laws and policies pertaining to public participation in the Montana TMDL process and presents specific information about recent water quality restoration efforts by stakeholders within the Shields River Watershed. Development of the Shields River Watershed Water Quality Planning Framework and Sediment TMDLs has been led by DEQ in association with the Park County Conservation District (CD) and the (SVWG – previously the Upper Shields Watershed Association and the Southern Crazy Mountain Watershed Group). In addition to providing feedback during the TMDL process, the SVWG and Park County CD assisted with obtaining landowner access for data collection associated with TMDL development. Additional stakeholders involved in the TMDL development process include the U.S. Forest Service (USFS); Natural Resources Conservation Service (NRCS); Department of Natural Resources and Conservation (DNRC); and Fish, Wildlife, and Parks (FWP). Details about the stakeholder and public comment process are contained in **Section 9.0**.

2.1 State Policy

Local community and stakeholder participation and support are invaluable to the TMDL planning process. Public participation is especially important in implementing TMDLs because many plans rely heavily on voluntary cooperative approaches. The Montana WQA directs DEQ to consult with CDs and watershed groups, farmers, ranchers, environmentalists, recreationists, the Montana DNRC, the USFS, Bureau of Land Management (BLM), municipalities, and the forest, tourism and mining industries during all phases of water quality restoration planning. Because of specific considerations for each TPA, public involvement may differ with different levels of stakeholder interests.

The Montana WQA requires DEQ to administer a voluntary program of reasonable land, soil, and water conservation practices for TMDL implementation elements pertaining to nonpoint sources of pollution. Further, Montana TMDL plans must not interfere with water rights or private property rights, and do not financially obligate participants unless such measures are already a requirement under other existing Federal, State, or local regulations.

DEQ strongly believes that voluntary approaches are the most practical means of addressing the cumulative impacts of many diffuse nonpoint sources in a watershed. However, there may be exceptions for certain activities that are regulated through existing local, State, and Federal regulations. These include, but may not be limited to, streamside management zone requirements for timber harvest, minimum septic design standards and location criteria, local zoning requirements for riparian or stream bank protection, and requirements of the Montana 310 Law, which affords protection to natural stream beds and banks. Regardless of the approach, DEQ staff pledge to work with landowners, other agencies, and all stakeholders to select and implement water quality improvement measures that are compatible with local needs while achieving the attainment of water quality standards and full support of designated water uses.

2.2 Recent Restoration Projects

Management improvements have already been implemented in recent years in many parts of the watershed. The SVWG, in conjunction with the Park County CD, has helped increase awareness of water quality issues, foster watershed stewardship, and implement numerous BMPs on private land throughout the watershed (**Table 2-1**). Also, the USFS has decommissioned over 100 miles of historical logging roads and implemented several other BMPs throughout the Gallatin National Forest (GNF) in recent years, and FWP has completed several projects to improve stream habitat (**Table 2-2**). The USFS is currently prioritizing additional road improvement projects to decrease road-related sediment on several tributaries in the upper Shields River Watershed (Shuler, pers. comm.., 2007). Additionally, the USFS recently revised its Travel Management Plan (USFS 2006a) to reduce riparian habitat degradation and sediment loading to streams from roads and motorized/non-motorized trails. Although not all of the completed projects are on 303(d) listed water bodies, many issues are pervasive throughout the watershed and because impacts are cumulative, these improvements are still very beneficial to the Shields River Watershed.

Table 2-1. Recent Restoration Projects on Private Land and Activities to Promote Watershed Stewardship

Action	Purpose	Date of Action
Constructed 8 off-stream watering systems	Reduce bank erosion, habitat protection	1999-2002
Aerial assessment of upper Shields River Watershed	Assess existing conditions, for fish habitat, in particular	1999
Irrigation efficiency management workshops	Increase irrigation efficiency	2000-2001
Completed a noxious weed map and conducted noxious weed spraying	Monitor and manage spread of noxious weeds	2001
Completed 7 bank stabilization/restoration projects	Habitat restoration	2000-2006
Completed a watershed plan	Develop a comprehensive approach to watershed management	2001
Purchased soil moisture data loggers	Increase irrigation efficiency	2002
Conducted an irrigation efficiency study	Study existing conditions and options for increasing irrigation efficiency	1999-2005
Constructed off-stream watering system and riparian fencing on Chicken Creek	Reduce bank erosion, habitat protection	2006
Riparian fencing, habitat enhancement, and off-stream watering on Elk Creek and Daisy Dean Creek	Reduce bank erosion, habitat protection	In Progress
Habitat improvement and change in grazing management practices on N. Fork Horse Creek	Reduce bank erosion, habitat protection	In Progress

Table 2-2. Recent Restoration Projects Lead by the USFS and FWP

Water Body	Action	Purpose	Length Affected	Date of Action	Lead Agency
Bennett Creek	Streambank stabilization	Reduce bank erosion, habitat protection	1 mile	1995	USFS
Brackett Creek	Streambank stabilization	Habitat Restoration	0.5 miles	1999	USFS
Deep Creek	Habitat enhancement	Increase pool frequency	2 miles	1995	USFS
Deep Creek	Grazing allotment management plan revisions	Reduce riparian utilization, habitat protection	1 mile	1999	USFS
N.F. Willow Creek	Riparian protection/Streambank restoration	Habitat Restoration	1 mile	1996-1999	USFS
N.F. Willow Creek	Pool Habitat Development	Habitat Restoration	0.5 miles	1996	USFS
Shields River	Grazing allotment management plan revisions	Habitat protection, reduce sediment	1 mile	1994	USFS
Shields River	Streambank stabilization	Reduce bank erosion, habitat protection	1 mile	1995	USFS
Shields River	Moratorium on large timber sales	Habitat protection	30 miles	1993	USFS
Shields River	Bank stabilization	Stream habitat improvement	1,830 feet	1999-2000	FWP
Shields River upper watershed	Road closures and obliteration	Reduce sediment	50 miles	1993-1995	USFS
Shields River/Elk	Riparian fencing and water development	Riparian habitat protection	2.5 miles	1998	FWP

Table 2-2. Recent Restoration Projects Lead by the USFS and FWP

Water Body	Action	Purpose	Length Affected	Date of Action	Lead Agency
Creek					
Shields River	Bank stabilization and riparian fencing	Stream habitat improvement	1 mile	1999	FWP
Shields River	Bank stabilization	Stream habitat improvement	1 mile	2001	FWP
unnamed tributary to Smith Creek	Habitat enhancement	Stream habitat improvement	1 mile	2005	USFS
S.F. Shields River	Culvert and bridge replacement; Streambank stabilization	Reduce sediment, habitat protection	1 mile	2005	USFS
Shields River	Channel restoration and riparian fencing	Stream habitat improvement	1 mile	2005	FWP
Willow/Bangtail Creeks and other tributaries	Road closures and obliteration	Reduce sediment	63 miles	2006-2007	USFS
Smith Creek	~53 armored drainage dips and road improvements around 11 stream crossings	Reduce sediment	N/A	2007	USFS
Brackett/Flathead Creeks and other tributaries	Grazing allotment management plan revisions	Habitat protection, reduce sediment	1 mile	2007	USFS

SECTION 3.0
WATERSHED CHARACTERIZATION

This section describes the physical, biological, and social characteristics of the Shields River TPA. The following is a synopsis of the key factors in the basin with influence on water quality, habitat condition, and beneficial uses:

- The five major soil units consist primarily of loams although clay, cobbly, and stony textures are also present. Nearly 90% of the TPA is mapped with soils that have moderate-low susceptibility to erosion. Moderate-high susceptibility is limited to 1.4% of the TPA.
- The geology of the watershed is characterized by broad exposures of the Tertiary Fort Union Formation, composed of nonmarine mudstone, sandstone and coal. These rocks are weakly consolidated, and generally more prone to erosion than the more consolidated rocks underlying the higher elevations at the watershed margin. Quaternary alluvial, colluvial and glacial deposits are locally present throughout the watershed, and range in texture from unsorted bouldery tills to well-sorted fine-grained alluvium.
- The largest proportion of the watershed lies in private ownership, followed by USFS, Montana State lands and Bureau of Land Management (BLM).
- The watershed is mostly agricultural with primary land uses including grazing and crop production.
- Hydrology in the Shields watershed is typical of snowmelt driven systems, with peak runoff occurring in May and June. Hydrology within the watershed has been affected by a moderate to severe drought which started in 2000 and persisted until late 2005, when conditions generally started to recover.
- There is an extensive irrigation network within the watershed and demand often exceeds supply from mid-July until the end of the irrigation season (late September). Stream dewatering occurs in some tributaries and portions of the main stem Shields River, especially upstream of Wilsall.
- Although some of the riparian vegetation at lower elevations in the Shields River TPA is woody species such as cottonwood, willow, and alder, much of the woody vegetation in agricultural areas was historically removed and has been replaced by a mix of herbaceous vegetation and shrubs. At higher elevations, riparian vegetation is a mix of deciduous and coniferous trees with a shrub understory.
- The watershed contains Yellowstone cutthroat trout, a Montana species of special concern.

3.1 Physical Characteristics

3.1.1 Location and Description of the Watershed

The Shields River Watershed lies in south-central Montana, just north of Livingston and 13 miles northeast of Bozeman (**Map A-1**). The watershed encompasses 855 square miles (547,068 acres) mostly within Park County, but includes portions of Gallatin, Meagher, and Sweetgrass counties. The eastern and western boundaries of the watershed are higher elevation and contained within the Middle Rockies level 3 ecoregion. The lower elevation areas of the watershed are contained within the Northwestern Great Plains ecoregion (**Map A-2**). The entire watershed was formerly part of the Montana Valley and Foothill Prairies ecoregion, a designation that was eliminated in 2002 and split between the Middle Rockies and Northwestern Great Plains ecoregions. However, most of the streams in the watershed are coldwater streams flowing out of the mountains, as indicated by the B-1 classification of all waterbodies in the TPA (discussed further in **Section 4.0**), resulting in different flora and fauna within the lower elevations of the watershed when compared to other aquatic communities with the Northwestern Great Plains ecoregion (Omernik, pers. comm.., 2008). The Bridger and Bangtail mountains confine the watershed to the west from which Flathead, Antelope, Brackett, Canyon, and Willow creeks flow. The Crazy Mountains form the eastern watershed boundary in which Elk, Cottonwood, Porcupine, Rock, and Daisy Dean Creeks originate. Potter and Smith Creeks flow into the Shields River from the north. The Yellowstone River flows along the southeast boundary of the watershed. The Shields River is the only major river flowing into the Yellowstone River from the north. The main stem of the Shields River is approximately 63 miles long, and its average gradient is 0.6 %, or 31 ft per mile (SCS 1983). Elevations in the watershed range from approximately 10,940 ft (3,335 m) in the Crazy Mountains to 4,380 ft (1,336 m) at the mouth of the Shields River (**Map A-3**).

3.1.2 Geology

The Shields River TPA is located at the western margin of the Crazy Mountains basin, an asymmetric bowl-like structure filled with Cretaceous and Tertiary sediments. The basin is bounded by the Bridger Range to the west, the Beartooth Range to the south, and the Pryor Range to the southeast. The Crazy Mountains Basin, therefore, is considerably more extensive than the Shields River TPA. Older, more consolidated sedimentary rocks are found along the eastern margin of the Bridger Range and beneath the basin at great depth. Early Tertiary (~50 million years ago) igneous rocks intruded the basin and form the core of the Crazy Mountains. These mountains interrupt the basin and form the eastern edge of the Shields River TPA.

Thick sequences of Tertiary, and especially Cretaceous, terrestrial, estuarine, and marine sediments fill the basin (**Map A-4**). The Cretaceous marine rocks produced economically significant amounts of hydrocarbons (oil and gas), which are generally hosted in Cretaceous clastic rocks (*e.g.* sandstone) found at depth. Hydrocarbon exploration began in the 1920s and continues to the 2000s. The Tertiary rocks, and the Fort Union Formation in particular, are noted for significant amounts of coal. The potential for coal-bed methane has attracted recent exploration to the Crazy Mountains basin and the Shields TPA.

The oldest rocks in the Shields River Watershed are Paleozoic and Mesozoic limestone, sandstone, siltstone, and shale exposed in the western portion of the watershed. These ancient rocks form the crest and eastern flank of the Bridger Mountain range from south of Brackett Creek to Flathead Creek. Various Cretaceous (140-65 million year old) shale, sandstone, mudstone, and volcanic rocks form a northeast-trending belt of rocks extending from the flanks of the Bridger Mountain range into Meagher County. These rocks fold into a series of weakly plunging anticlines and synclines in the northernmost portion of the basin, and these geologic features are visible in the basin topography. The Tertiary Fort Union Formation (65-35 million year old) outcrops over the remainder of the TPA, including the high country of the Crazy Mountains. The Fort Union Formation consists of nonmarine shale, sandstone, mudstone, and coal. Tertiary intrusive rocks core and uplift the Crazy Mountains. Quaternary (less than 1.6 million year old) pediment gravels and glacial till cover portion of the west flank of the Crazy Mountains, and Quaternary alluvium fills much of the valley bottoms along the Shields River and its tributaries.

The geology of the Shields River Watershed has implications for water quality and quantity. The limestone exposed on the flanks of the Bridger Range is part of a karst aquifer. This type of rock has local zones of high secondary permeability, and allows for greater infiltration than a porous media aquifer (e.g. sandstone). The structure of the Bridger Range is such that much of the water in the karst aquifer passes underneath the watershed boundary and emerges on the west side of the Bridger Range, in the Gallatin River watershed. As a result, streams draining the Bridger Mountain range such as Brackett and Flathead creeks have lower flows than would be expected from drainage areas this size.

The rocks exposed in the watershed are generally weakly consolidated and more prone to erosion than the harder rocks at the watershed margins. This difference in erodibility is the primary factor controlling the watershed morphology. The Cretaceous and Tertiary rocks are also prone to development of saline seep due to naturally-occurring salts in the sediments and soils derived from them.

3.1.3 Soils

Soils data for the Shields River planning area are available through the NRCS state soil geographic database (STATSGO), which provides a method for consistent assessments of generalized soil characteristics for medium-scale studies. The Shields River Watershed has 27 soil units with five types comprising 57% of the watershed (**Table 3-1, Map A-5**). The five major soil units consist primarily of loams although clay, cobbly, and stony textures are also present. Approximately 7% of the watershed contains unweathered bedrock outcrop. Collectively, the soil units making up the Shields River Watershed are well drained and not hydric or likely to develop wetlands and are not classified as prime farmland. Almost all soil units have an estimated six foot depth to water table.

Table 3-1. Percentages of Major Soil Units in the Shields River Watershed

Map Unit Name	Percent Area	Surface Texture
Castner-Chama-Regent (Mt113)	12.8%	Loam
Castner-Savage-Chama (Mt112)	12.7%	Clay
Savage-Work-Chama (Mt522)	12.4%	Cobbly Clay Loam
Castner-Regent-Big Timber (Mt118)	11.7%	Stony Loam
Garlet-Cowood-Rock Outcrop (Mt213)	7.0%	Unweathered Bedrock

The USGS Water Resources Division (Schwartz and Alexander, 1995) created a dataset of hydrology-relevant soil attributes, based on the STATSGO soil database. The STATSGO data is intended for small-scale (watershed or larger) mapping and is too general to be used at scales larger than 1:250,000. It is important to realize, therefore, that each soil unit in the STATSGO data may include up to 21 soil components. Soil analysis at a larger scale should use NRCS Soil

Survey Geographic (SSURGO) data. The soil attributes considered in this characterization are erodibility and slope.

Soil erodibility is based on the Universal Soil Loss Equation (USLE) K-factor (Wischmeier & Smith 1978). K-factor values range from 0 to 1, with a greater value corresponding to greater potential for erosion. Susceptibility to erosion is mapped on **Map A-6**, with soil units assigned to the following standard ranges: low (0.0-0.2), moderate-low (0.2-0.29) and moderate-high (0.3-0.4). Values of >0.4 are considered highly susceptible to erosion. No values greater than 0.33 are mapped in the Shields TPA. Nearly 90% of the TPA is mapped with soils that have moderate-low susceptibility to erosion. Moderate-high susceptibility is limited to 1.4% of the TPA.

Slope varies widely across the TPA (**Map A-7**). Slopes over 50° are mapped on the flank of the Bridger Range, at the western edge of the watershed. The most common slope ranges are 10°-20°, mapped over 37% of the TPA, and 30°-40°, accounting for 29% of the TPA. Very low slopes (1°-2°) are mapped along the floodplains of the Shields River and Potter Creek. As these slopes are averages for soil units mapped at a scale of 1:250,000, slopes are much more variable at a larger scale, particularly in dissected uplands and mountains. Slope analysis at a finer scale, using a USGS 1-arc second digital elevation model (DEM), reveals that the mean slope across the TPA is 8°, and more than half the TPA is characterized by slopes less than 10°.

3.1.4 Hydrology

The Shields River Watershed has one active USGS stream gage which lies on the lower main stem of the Shields River near Livingston (**Map A-8**). This gage has been operational since 1979 and has recorded mean daily stream flows for the past 25 years with the exception of the 2002 water year. Supplemental historic flow records are available from two gages that are no longer operational, including one near Wilsall (#6193000) and one near Clyde Park (#6193500) (**Table 3-2, Map A-8**). The Wilsall gage was operational between 1935 and 1957, and the Clyde Park gage has discontinuous stream flow records from 1921-1967. Between 1967 and 1979, no USGS gaging stations were operational in the Shields River Watershed. Hydrologic data for the basin are therefore spatially limited, and the available USGS dataset includes a 12-year long gap in stream flow records between 1967 and 1979.

Table 3-2. USGS Gaging Stations in the Shields River Watershed

USGS Gage Number	Gage Name	Drainage Area (sq mi)	Period of Record	Flood of Record
USGS 6193000 discontinued	Shields River near Wilsall	88	1935-1957	1770 cfs (1948)
USGS 6193500 discontinued	Shields River at Clyde Park	544	1921-1967 (discontinuous)	4500 cfs (1948)
USGS 6195600 active	Shields River at Livingston	852	1978-present (missing WY 2002)	5600 cfs (1979)

Stream flow patterns within the Shields River basin reflect typical snowmelt runoff cycles of the region. Stream flows typically begin to rise in April, and mean monthly discharges tend to peak in May or June. Mean monthly May/June flows are typically about 750-850 cfs at Livingston, 500 cfs at Clyde Park, and 250 cfs at Wilsall. Although the largest flows occurred at the mouth of the river near Livingston, water yield per square mile is much higher at the Wilsall gage, reflecting the importance of snowmelt runoff to overall basin water yield (**Figure 3-1**). The lowest recorded 7-day minimum flow values at each gage indicate that, at Livingston, average 7-day low flows have exceeded 20 cfs for the entire period of record at that gage. Further upstream, minimum recorded 7-day flows at Clyde Park and Wilsall are less than 10 cfs (**Figure 3-1**).

Numerous major flood events have occurred within the Shields River Watershed. The largest flood recorded on the Shields River occurred in 1948 when measured flows at Clyde Park were 4,500 cfs (**Figure 3-2**). The estimated return interval for this event is 50-75 years (NRCS 1998). Twenty five-year flood events occurred in 1943, 1979, 1981, 1992, and 1996 (NRCS 1998). A major flood event also occurred in the watershed in 1975, and, although this event occurred during the gap in flow records, a measured peak discharge is not available. Climate records indicate that in 1975 over 8 inches of precipitation fell at Wilsall during May and June (NOAA climate station Wilsall 8 ENE #249023). The 1975 flood apparently had a major influence on the Shields River channel morphology as local residents have indicated that the modern geomorphic character of the Shields River reflects the effects of that event (Inter-Fluve 2001).

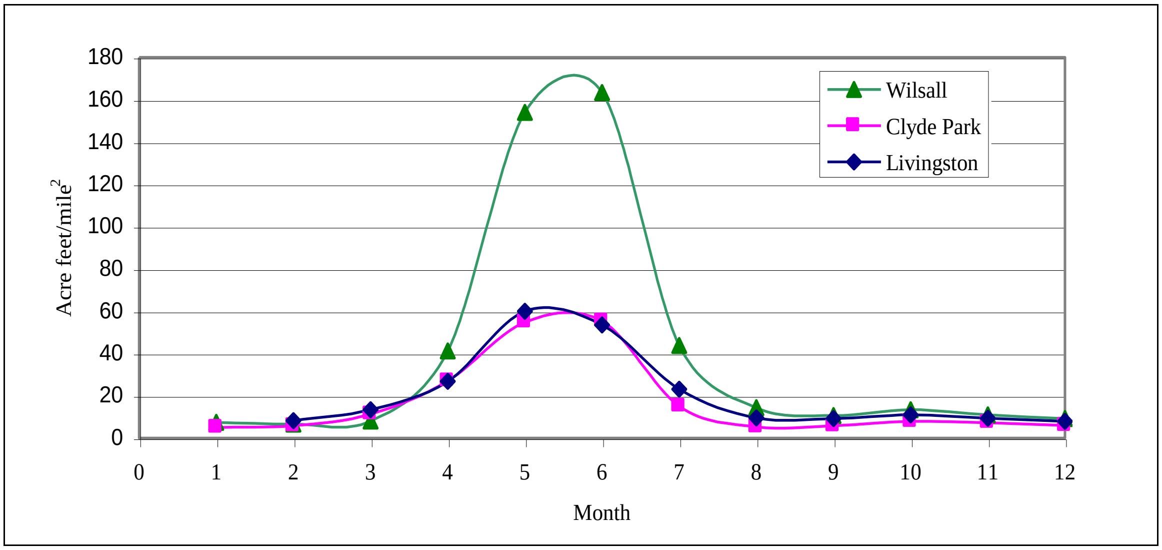

Figure 3-1. Peak Flows Measured at Shields River Gaging Stations for Periods of Record

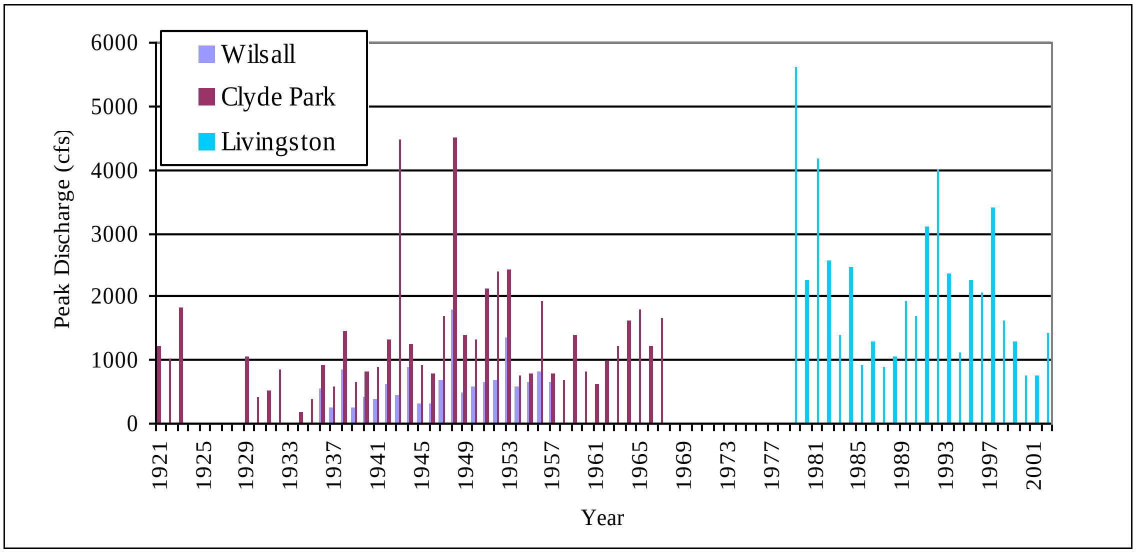

Figure 3-2. Mean Monthly Water Yield for Gaging Stations on the Shields River

3.1.5 Climate

Within the Shields River TPA, the National Oceanographic and Atmospheric Administration (NOAA) operates one climate station (Wilsall 8ENE) and the NRCS operates four Snowpack Telemetry (SNOTEL) stations (Brackett Creek, Sacajawea, Porcupine and S. Fork Shields) (**Map A-8**). There is a decommissioned NOAA climate station at Wilsall that operated from 1950-1969. The current station has been in operation since 1957 and is located at an elevation of 5,840 feet.

May and June are typically the wettest months. NOAA climate data indicate the average total precipitation is 20.3 inches per year with 99.2 inches total snowfall. However, precipitation and temperature within the watershed vary with elevation, which ranges from approximately 10,940 to 4,380 feet. According to Oregon State University's PRISM data (PRISM 2004), average annual precipitation ranges from 15 to 53 inches in the Shields River TPA. Precipitation in the valley is generally less than 20 inches, but is greater than 40 inches in the Bridger and Crazy Mountains (**Map A-6**). NOAA data include monthly snowfall, precipitation, maximum temperatures, and minimum temperatures (**Table 3-3**). January is typically the coldest month with an average temperature of 22.8 °F and July is typically the hottest month with an average temperature of 61.6 °F. The watershed has generally been recovering for the past couple of years from severe drought conditions that started in 2000 and persisted to late 2005 (NRIS, 2007).

Table 3-3. Monthly and Annual Climate Summary from NOAA Station Wilsall 8ENE for the Period of Record from April 1957 through September 2007

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max Temp (F)	33.4	36.7	42.2	50.8	60.8	69.6	79.0	78.4	67.2	55.9	41.2	34.4	54.1
Average Min. Temp. (F)	12.1	14.6	19.0	26.2	34.1	41.1	46.0	44.8	37.5	30.0	20.3	14.0	28.3
Average Total Precip. (in.)	0.9	0.7	1.4	1.9	3.2	3.4	1.8	1.7	1.8	1.5	1.0	0.9	20.3
Average Snowfall (in.)	15.8	12.9	18.1	13.3	5.8	0.4	0.0	0.0	2.1	4.9	10.3	14.4	99.2

3.2 Social Characteristics

According to the 2000 census, the Shields River Watershed has a population of over 1,900 people. Two small towns, Wilsall and Clyde Park, contain 237 and 310 people, respectively. The watershed is primarily rural farms and ranches ranging in size from less than 50 acres to over 1,000 acres. The primary agricultural products in the valley are beef, hay, and grain production, including wheat, barley, and oats. According to an NRCS general resource assessment (NRCS 1998), the average cattle herd size (cows and calves) in the watershed is greater than 200 head.

3.2.1 Land Ownership

Private land comprises the majority of the Shields River Watershed at over 80% (**Map A-9**). Of the remaining 19% land ownership, the USFS manages 16.5%, 2.6% is State lands, and the BLM manages less than 1% (**Table 3-4**). Some of the USFS lands represent private lands acquired in the 1990s, including the purchase of over 90,000 acres of private inholdings under the Gallatin Land Consolidation Act of 1993 and 1998 (USFS, 2004).

Table 3-4. Land Ownership in the Shields River Watershed

Land Ownership	Percent of Watershed Area
Private Land	80.9%
US Forest Service	16.5%
Montana State Trust Lands	2.6%
US Bureau of Land Management	<1%

3.2.2 Land Use

Land use in the Shields River Watershed is typical of a south-central Montana rural, agrarian valley with almost 75% of the area used for farming or ranching (**Map A-10, Table 3-5**). Based on the USGS national land cover database (NLCD), the most prevalent cover type in the Shields River Watershed is grass rangeland (56.8%), followed by coniferous and deciduous forest (23.0%). Developed lands, including residential areas, account for less than 0.1% of the watershed. Almost a third of the population in the watershed lives in Wilsall and Clyde Park. Although land is more commonly being subdivided, most other residents of the watershed live on widely spaced ranches. Although much of the USFS land cover is evergreen forest, most timber harvest occurred historically (on public or previously private land), and land use within

GNF is shifting to recreational use (USFS 2006a; USFS 2006b). Recreational uses include off-road vehicles, horseback riding, fishing, hunting, hiking, and camping. Some timber harvesting has and will continue to occur on private land (USFS 2006a; USFS 2007). A very small amount of historic mining for calcite has occurred within the watershed.

Table 3-5. Land Use in the Shields River Watershed

Land Use/Coverage	Percent Area
Grass Rangeland	56.8%
Coniferous and Deciduous Forest	23.0%
Crop/Pasture	14.1%
Brush Rangeland	2.7%
Timber Harvest	<1%
Developed	<1%
Other Agriculture	<1%

3.2.2.1 Irrigation

Irrigation of agricultural lands in the Shields River Valley constitutes a primary use of surface water in the region. The main surface water diversions occur on Cottonwood Creek (upper Cottonwood system), Flathead Creek (Shields Canal Company ditch), and on the main stem Shields River (lower Shields River Canal Company ditch, and Shields River Ranch ditch). Big Ditch is the largest canal in the upper watershed, supplying water to approximately 2,200 irrigated acres. Much of the area irrigated by Big Ditch is located on the Jordan Bench, which is approximately 150 feet above the Shields River Valley (DNRC 2005). Big Ditch feeds a system of smaller ditches, including Meyers Ditch, and Jordon Reservoir which can store approximately 900 acre-feet of water for late season releases. Approximately 40,000 acres of land are irrigated throughout the watershed, 72% with flood irrigation and 28% with sprinkler irrigation (NRCS 1998). Between both methods, the overall irrigation efficiency for the watershed is an estimated 40%.

Irrigation water deficiencies are common in late July and August in the Shields River Valley. Pre-1900 water rights appropriations total 493.4 cfs on the Shields River (NRCS 1998), and these appropriations have the potential to exceed available supply, depending on the timing of flow diversions. Stream dewatering has occurred in some tributaries and reaches of the main stem Shields River, especially upstream of Wilsall (Inter-Fluve 2001; DNRC 2005). Periods of dewatering in portions of the upper Shields River were observed every summer from 2000-2004 (DNRC 2005). Limited flow and dewatering in this part of the river results from a combination of the Big Ditch and other smaller diversions. The Shields River gradually picks up more return flows as it heads downstream towards Wilsall (Dolan, pers. comm.., 2008). In an effort to optimize stream flows for fish, wildlife, and agricultural users in the basin, an evaluation was performed in 1999-2000 to assess relationships between water supply, water demands, and irrigation system efficiencies (DNRC 2005). Results from that analysis showed that for a median flow year, the water supply of the upper Shields River is probably only sufficient to meet current demands until about mid-July. The shortage in water supply for irrigation needs has prompted consideration of several water management alternatives, including increased irrigation efficiency, more extensive flow measuring devices, and increased reservoir storage (DNRC 2005, Compston 2002).

3.3 Ecological Characteristics

3.3.1 Vegetation

As evidenced in its land use, crops and grassland/shrub land range comprise the majority of the watershed (**Table 3-6, Map A-11**) (Wildlife Spatial Analysis Lab, 1998). The second largest vegetation class is coniferous and deciduous forests (23%) including lodgepole pines, Douglas firs, and mixed mesic and subalpine forest species. Native vegetation in the Shields River Valley is consistent with elevation-based gradients in mountain valleys of the northern Rocky Mountains. As elevation increases, the vegetation turns to mesic and xeric shrub lands dominated by sagebrush, transitions to grasslands and, eventually, culminates in coniferous forests characterizing the second largest vegetation class type.

Table 3-6. Percentages of Major Vegetation Cover Types in the Shields River Watershed

Vegetation Cover Type	Percent Area
Agricultural (crops)	10.19%
Coniferous and Deciduous Forest	23.45%
Grasslands	36.90%
Mesic and Xeric Shrubs	11.40%
Riparian	7.45%
Rock, Badlands, Snow or Ice	10.49%
Urban	<1%
Water	<1%

Although some of the riparian vegetation at lower elevations in the Shields River TPA is woody species such as cottonwood, willow, and alder, much of the woody vegetation in agricultural areas (**Map A-11**) was historically removed and has been replaced by a mix of herbaceous vegetation and shrubs (Inter-Fluve, 2001). At higher elevations, riparian vegetation is a mix of deciduous and coniferous trees with a shrub understory.

Invasive weeds are a growing concern in the Shields River TPA. Priority species include Russian and spotted knapweed (*Acroptilon repens* and *Centaurea maculosa*, respectively), leafy spurge (*Euphorbia esula*), Dalmation toadflax (*Linaria vulgaris*), and whitetop (*Cardaria* sp.) (NRCS 1998). The Montana Noxious Weed Trust Fund has identified Russian and spotted knapweeds, Dalmatian toadflax, leafy spurge, and sulfur cinquefoil as weeds the Montana noxious weed survey and mapping system must monitor on a section basis (Montana Noxious Weed Trust Fund 1998). The Park County Extension Office and Park County Weed Board have been active in public education for noxious weeds and have sprayers available for free for public use (Park County Extension 2007). The Park County Weed Board has a weed plan that is updated annually, requires new subdivisions to develop a weed management plan, and encourages landowners to use biocontrol or large animal grazing. Also, the SVWG developed a noxious weed map in 2001 that it is in the process of updating (SVWG, pers. comm. 2008).

Fire activity has been limited in recent decades. The USFS Region 1 office and the USFS remote sensing applications center provides data on fire locations from 1940 to the present (**Map A-12**). Three fires are mapped in the TPA, ranging from 374 to 1,385 acres. The largest fire occurred in the southern Castle Mountains in 1994 and is unnamed. This fire straddled the watershed boundary between the TPA and the Musselshell basin with just under 50% of the burned area inside the Shields River TPA. The other fires were both in the western Crazy Mountains. The Sugarloaf fire (2000) burned 374 acres and the Slippery Rock fire (2003) burned 1,078 acres. Two small fires burned briefly in 2006, one north of Clyde Park and one near Highway 86 in the upper reaches of Flathead Creek.

3.3.2 Fisheries

The Shields River Watershed supports eleven species among four families of fishes (**Table 3-7**). Native salmonids are the Yellowstone cutthroat trout and mountain whitefish. The basin also supports three introduced salmonids, brook trout, rainbow trout, and brown trout. Two species of cyprinids or members of the minnow family present in the Shields River Watershed are lake chub and longnose dace. Three species of catostomid or sucker occur in the watershed including mountain sucker, white sucker, and longnose sucker. The mottled sculpin is the sole member of its family in the watershed. No stocking has occurred in the watershed since the early 1970s (Shepard 2004).

Table 3-7. Fishes Present in the Shields River Watershed

Family/Common Name	Scientific Name	Introduced/Native
Salmonidae		
Yellowstone cutthroat trout	*Oncorhynchus clarki bouvieri*	Native
Yellowstone cutthroat trout ×rainbow trout hybrid	*O. clarki bouvieri ×O. mykiss*	
Brook trout	*Salvelinus fontinalis*	Introduced
Rainbow trout	*O. mykiss*	Introduced
Brown trout	*Salmo trutta*	Introduced
Mountain whitefish	*Prosopium williamsoni*	Native
Cyprinidae		
Lake chub	*Cousieus plumbeus*	Native
Longnose dace	*Rhinichthys cataractae*	Native
Catostomidae		
Mountain sucker	*Catostomus platyrhynchus*	Native
White sucker	*Catostomus commersoni*	Native
Longnose sucker	*Catostomus catostomus*	Native
Cottidae		
Mottled sculpin	*Cottus bairdi*	Native

Yellowstone cutthroat trout (YCT) is considered a sensitive species by Region 1 of the USFS and a Species of Special Concern by the State of Montana. A recent status assessment for Yellowstone cutthroat trout concluded that the watershed has 453 miles of habitat; 277 miles are also inhabitated by non-native species and 176 miles have native fish species only (May et al. 2007). The total available habitat for Yellowstone cutthroat trout roughly corresponds to the ownership breakdown of the watershed with 77% of habitat being on private land, 21% being on USFS land, and 2% being on State land (May et al. 2007). This proportion of historically occupied habitat still supporting YCT is the greatest among 4th order hydrologic units in Montana, making the Shields River watershed a stronghold for the species (Endicott, pers. comm., 2008). A growing concern in the Shields River watershed is whirling disease; YCT are highly susceptible to it, and sediment loading and organic enrichment are factors that influence the abundance of *Tubifex tubifex*, the intermediate host for whirling disease (Endicott, pers. comm., 2008).

SECTION 4.0
APPLICATION OF MONTANA'S WATER QUALITY STANDARDS FOR TMDL DEVELOPMENT

This section and **Appendix B** present details about TMDL development requirements, applicable Montana water quality standards, and a general description of how narrative standards are interpreted and applied to assess water quality and set targets.

4.1 TMDL Development Requirements

Section 303 of the Federal CWA and the Montana WQA (Section 75-5-703) requires development of TMDLs for impaired water bodies that do not meet Montana water quality standards. Although water bodies can become impaired from pollution (e.g. flow alterations and habitat degradation) and pollutants (e.g. nutrients, sediment, and metals), the CWA and Montana State Law (75-5-703) both require TMDL development for waters impaired only by pollutants. Section 303 also requires states to submit a list of impaired water bodies to the EPA every two years. Prior to 2004, the EPA and the Montana DEQ referred to this list as the 303(d) List.

Since 2004, the EPA has requested that states combine the 303(d) List with the 305(b) Report containing an assessment of Montana's water quality and its water quality programs. The EPA refers to this new combined 303(d)/305(b) Report as the Integrated Water Quality Report. The 303(d) List also includes identification of the probable cause(s) of the water quality impairment problems (e.g. pollutants such as metals, nutrients, sediment or temperature) and the suspected source(s) of the pollutants of concern (e.g. various land use activities). State law (MCA 75-5-702) identifies that a sufficient credible data methodology for determining the impairment status of each water body is used for consistency; the actual methodology is identified in DEQ's Water Quality Assessment Process and Methods (DEQ 2006b). This methodology was developed via a public process and was incorporated into the EPA-approved 2000 version of the 305(b) Report (now also referred to as the Integrated Report).

Under Montana State Law, an "impaired water body" is defined as a water body or stream segment for which sufficient credible data show that the water body or stream segment is failing to achieve compliance with applicable water quality standards (Montana WQA; Section 75-5-103(11)). State Law and Section 303 of the CWA require states to develop all necessary TMDLs for impaired or threatened water bodies. There are no threatened water bodies within the Shields TPA.

A TMDL is a pollutant budget for a water body identifying the maximum amount of the pollutant that a water body can assimilate without causing applicable water quality standards to be exceeded. TMDLs are often expressed in terms of an amount, or load, of a particular pollutant (expressed in units of mass per time such as pounds per day). TMDLs must account for loads/impacts from point and nonpoint sources, in addition to natural background sources, and must incorporate a MOS and consider influences of seasonality on analysis and compliance with water quality standards.

To satisfy the Federal CWA and Montana State Law, TMDLs will be developed for each water body-pollutant combination identified on Montana's 303(d) List of impaired or threatened waters in the Shields River TPA. State Law (Administrative Rules of Montana (ARM) 75-5-703(8)) also directs Montana DEQ to "...support a voluntary program of reasonable land, soil, and water conservation practices to achieve compliance with water quality standards for nonpoint source activities for water bodies that are subject to a TMDL…" This is an important directive that is reflected in the overall TMDL development and implementation strategy within this plan. It is important to note that water quality protection measures are not considered voluntary where such measures are already a requirement under existing Federal, State, or local regulations.

4.2 Applicable Water Quality Standards

Water quality standards include the uses designated for a water body, the legally enforceable standards that ensure that the uses are supported, and a nondegradation policy that protects the existing high quality of a water body. The ultimate goal of this TMDL plan, once implemented, is to ensure that all sediment-related water quality standards are met for streams identified on Montana's 303(d) List. Water quality standards form the basis for the water quality targets described in **Appendix C**.

4.2.1 Classification and Beneficial Uses

Classification is the assignment (designation) of a single or group of uses to a water body based on the potential of the water body to support those uses. Designated Uses or Beneficial Uses are simple narrative descriptions of water quality expectations or water quality goals. There are a variety of "uses" of state waters including growth and propagation of fish and associated aquatic life; drinking water; agriculture; industrial supply; and recreation and wildlife. The Montana WQA directs the Board of Environmental Review (BER, i.e., the State) to establish a classification system for all waters of the state that includes their present (when the Act was originally written) and future most beneficial uses ARM 17.30.607-616 and to adopt standards to protect those uses (ARM 17.30.620-670). **Appendix B** provides additional detail on water body classification and beneficial uses under Montana Law.

All water bodies within the Shields River Watershed are classified as B-1. The Montana B-1 classification states that, "Waters classified B-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply," (ARM 17.30.623(1)). On the 2006 303(d) List, six streams encompassing seven stream segments failed to support all of their beneficial uses (**Table 4-1; Map A-13**). The upper segments of Cottonwood and Rock Creeks were fully supporting all beneficial uses. All other stream segments were either fully supporting or not assessed for agricultural and drinking water uses, and partially supporting aquatic life, coldwater fishery, and (primary) contact recreation uses.

Table 4-1. 2006 Beneficial Use Status for 303(d) Listed Streams in the Shields River Watershed
Streams in shaded cells are not meeting uses because of pollution-related causes.

Stream Name	Water Body ID	Listing Year	Beneficial Use Support					
			Agriculture	Aquatic Life	Coldwater Fishery	Drinking Water	Industry	Contact Recreation
Antelope Creek	MT43A002_020	2006	F	P	P	F	F	P
Cottonwood Creek	MT43A002_031	2006	F	P	P	F	F	P
	MT43A002_032	2006	F	F	F	F	F	F
Elk Creek	MT43A002_040	2006	X	P	P	X	X	P
Potter Creek	MT43A002_010	2006	F	P	P	F	F	F
Rock Creek	MT43A002_051	2006	F	P	P	F	F	P
	MT43A002_052	2006	F	F	F	F	F	F
Shields River	MT43A001_011	2006	X	P	P	X	X	P
	MT43A001_012	2006	X	P	P	X	X	P

F = Fully Supporting; P = Partially Supporting; X = Not Assessed (Lacking Sufficient Credible Data)

4.2.2 Standards

In addition to the Use Classifications described above, Montana's water quality standards include numeric and narrative criteria as well as a nondegradation policy. **Section B.2.2** in **Appendix B** provides details on these standards, with narrative standards being applicable to the Shields River TPA sediment-related impairment causes. These narrative standards include the beneficial use support standard (17.30.623[1]) for a B-1 stream, and the standards in **Table B-2** that can be applied to excess sediment concentrations in the Shields River and Potter Creek.

Sediment (i.e., coarse and fine bed sediment) and suspended sediment are addressed via the narrative standards identified in **Appendix B** (**Table B-2**). The narrative criteria do not allow for harmful or other undesirable conditions related to either (a) increases above naturally occurring levels of sediment or (b) municipal, industrial, and agricultural discharges to state surface waters. This is interpreted to mean that water quality goals should strive toward a reference condition that reflects a water body's greatest potential for water quality given current and historic land use activities where all reasonable land, soil, and water conservation practices have been applied and resulting conditions are not harmful, detrimental, or injurious to beneficial uses. As discussed in **Section B.1.2**, reasonable land, soil, and water conservation practices generally include best management practices (BMPs), but additional conservation practices may be required to achieve compliance with water quality standards and restore beneficial uses.

4.3 Developing Water Quality Targets

Quantitative water quality targets and supplemental indicators are developed to help define the problem and help determine successful TMDL implementation. This document outlines water quality targets for sediment in the Shields River TPA. TMDL water quality targets help translate the applicable numeric or narrative water quality standards for the pollutant of concern. For pollutants with established numeric water quality standards, the numeric values are used as TMDL water quality targets. For pollutants with only narrative standards, the water quality targets help to further interpret the narrative standard and provide an improved understanding of impairment conditions. In the Shields River TPA, sediment has narrative standards and will require the selection of appropriate TMDL water quality targets and supplemental indicators (discussed in detail in **Section 5.0**). Specific values for targets and supplemental indicators are determined from the most applicable reference condition approach(es).

4.3.1 Defining Reference Conditions

DEQ uses the reference condition to evaluate compliance with many of the narrative water quality standards. The term "reference condition" is defined as the condition of a water body capable of supporting its present and future beneficial uses when all reasonable land, soil, and water conservation practices have been applied. In other words, reference condition reflects a water body's greatest potential for water quality given existing and historic land use activities.

When possible, reference sites are used to determine the difference between a potentially impacted area and a "natural" or least impacted water body. Reference sites may include a similar water body within the region, a nearby watershed, or a least impacted section of the stream of interest. Historical data can also provide useful reference site information for an impaired stream reach if the historical data is from a period that precedes impairment causing activities. Water bodies used to determine reference condition are not necessarily pristine or perfectly suited to giving the best possible support to all possible beneficial uses. Because the intention is to differentiate between natural conditions and widespread or significant alterations of biology, chemistry, or hydrogeomorphology due to human activity, reference conditions should reflect minimum impacts from human activities.

The preferred approach for determining reference condition is the use of regional, internal, or historical reference data, but when appropriate reference data are sparse or non-existent, secondary reference approaches can be applied. These secondary approaches include modeling, literature reviews, and professional judgment. In many situations, a combination of reference site and secondary reference approaches are used to establish reference conditions. The DEQ approach to determining reference conditions and using reference sites for the Shields River system is included in **Appendix C** and DEQ's Water Quality Assessment Process and Methods (DEQ 2006b).

4.3.2 Water Quality Target Development

Since there is no single parameter that can be applied to provide a direct measure of beneficial use support associated with sediment, a suite of water quality targets and supplemental indicators have been selected to be used in combination with one another. The water quality targets are considered to be the most reliable and robust measures of the pollutant. Supplemental indicators are typically not sufficiently reliable to be used alone as a measure of support. These are used as supplemental information, in combination with the water quality targets, to better define potential problems caused by a pollutant.

By being related to both the pollutant of concern and the most sensitive beneficial use(s), water quality targets provide a quantitative way to assess beneficial use support and they provide a link between the pollutant of concern and the suspected impaired beneficial use. Reference data are used for target development to establish a threshold value representing “naturally occurring” conditions where all reasonable land, soil, and water conservation practices are in place. The comparison of existing data to water quality targets (based on sufficient data) can either support the water quality impairment listings on the 303(d) list and aid in TMDL development or help identify the need for additional data collection. Water quality targets also serve as goals by which to measure the progress of future restoration efforts.

SECTION 5.0
EXISTING CONDITION AND COMPARISON TO WATER QUALITY TARGETS

The following sections provide a summary of available data and water quality targets for the Shields River, Antelope Creek, and Potter Creek. Although placement onto the 303(d) list indicates impaired water quality, a comparison of water quality targets to existing data helps define the level of impairment and helps guide the development of TMDL allocations. It also establishes a starting point from which to measure future water quality restoration success.

5.1 Water Bodies and Pollutants of Concern

The focus of this document is sediment-related impairments; these impairments relate to excessive sediment deposited on stream bottoms and in the water column. There are four water body segments within the Shields River TPA that have sediment-related listings on the 2006 303(d) List: the upper and lower Shields River, Potter Creek, and Antelope Creek. The specific sediment-related listing causes of impairment in the Shields River Watershed include sedimentation, siltation, solids (suspended/bedload), habitat alterations, and alterations in streamside or littoral vegetative cover (**Table 5-1**). Data collected to assist with TMDL development suggest the Antelope Creek listing is actually from suspended organic matter related to excess nutrient loading, and a TMDL has not been prepared at this time. The impairment cause will probably be addressed during future development of nutrient-related TMDLs within the Shields River TPA.

Table 5-1. Probable Sediment Sources for 2006 303(d) Listed Water Bodies

Water Body Segment	Probable Cause(s)	Probable Source(s)
Antelope Creek MT43002_020	Solids (suspended/bedload)	Agriculture, Livestock, Source unknown
Potter Creek MT43A002_010	Sedimentation/siltation, Solids (suspended/bedload)	Impacts from Hydrostructure flow regulation/modification
Shields River (upper) MT43A001_012	Sedimentation/siltation, Physical substrate habitat alteration, Alteration in streamside littoral vegetative cover	Riparian grazing, Silviculture, Streambank modification/destabilization
Shields River (lower) MT43A001_011	Sedimentation/siltation, Physical substrate habitat alteration, Alteration in streamside littoral vegetative cover	Agriculture, Bank modification/destabilization

5.1.1. Effects of Sediment on Aquatic Life and Coldwater Fisheries

Erosion and sediment transport and deposition are natural functions of stream channels. Sediment deposition is needed to build streambanks and floodplains. Regular flooding allows sediment deposition to build floodplain soils and prevents excess scour of the stream channel. Riparian vegetation and natural instream barriers such as large woody debris (LWD), beaver dams, or overhanging vegetation help trap sediment and build channel and floodplain features. When these barriers are absent or excessive erosion takes place due to altered channel morphology or riparian vegetation, excess sediment is transported through the channel. The excess sediment may be deposited in critical aquatic habitat areas not naturally characterized by high levels of fine sediment, or a combination of coarse and fine sediment can accumulate in pools and decrease available habitat.

Excess sediment often has detrimental effects on various aspects of aquatic life within streams. For instance, elevated suspended sediment levels reduce light penetration, which may cause a decline in primary production. As a result, aquatic invertebrate communities may also decline, which may trigger a decline in fish populations. Deposited particles may obscure sources of food, habitat, hiding places, and nesting sites for invertebrates and fish.

Excess sediment may also impair biological processes of individual aquatic organisms. When present in high levels, sediment may clog the gills of fish and cause other abrasive damage. Abrasion of gill tissues triggers excess mucous secretion, decreased resistance to disease, and a reduction or complete cessation of feeding (Wilber 1983; McCabe and Sandretto, 1985; Newcombe and MacDonald 1991). High levels of benthic fine sediment can also impair reproductive success of fish. In addition to decreasing the availability of spawning sites, an accumulation of benthic fine sediment reduces the flow of water through gravels harboring salmonid eggs, depleting oxygen supply to embryos, and causing metabolic wastes to accumulate around embryos, resulting in higher mortality rates (Armour et al., 1991). This accumulation of fine sediment also can also prevent the emergence of a significant percentage of newly hatched fish.

5.2 Inventory and Summary of Pollutant Sources

All streams have a sediment load that is associated with natural sources such as landslides, wildlife grazing, channel migration, flooding, and natural upland erosion. Flooding, in particular, has been a prominent natural source of erosion within the Shields River Watershed (NRCS 1998). Sediment production can easily be increased and/or depositional processes altered because of human activities that reduce vegetation or increase runoff such as grazing, roads, silviculture, urban development, crop production, or other activities. For flood events, for example, human activities can lead to significant negative impacts such as increased runoff rates, increased streamflow velocities, increased upland and streambank erosion, and a constricted floodplain. More generally, sediment is delivered to streams from upland/hillslope erosion, roads, streambank erosion, and direct disturbance of the stream bottom.

Because there are no point sources requiring discharge permits within the Shields River Watershed, all human-related sources of sediment are categorized as nonpoint sources, originating from various land uses. As discussed in **Section 3.2.2**, the watershed is primarily agricultural with land cover being a mix of rangeland, cropland, and forest. Historically, logging practices and associated road construction in the upper watershed increased water and sediment yields, but practices changed in the early 1990s and vegetation has stabilized soils and water yield (Shuler, pers. comm.., 2007). Historical removal of riparian vegetation has occurred along many streams in the watershed (NRCS 1998). This can cause problems by lessening the watershed's ability to filter out sediment and other pollutants transported from upland sources and also by weakening streambank stability. The primary source categories within the Shields River Watershed include unpaved roads, streambank erosion, and hillslope erosion. Mechanisms for sediment loading include natural erosion, improperly maintained roads, channel manipulation, removal of riparian vegetation, bank trampling, overgrazing of riparian vegetation, and flow manipulation.

As discussed in **Section 3.2.2.1**, flow alterations from water diversions and irrigated agriculture are prominent in the Shields River Watershed. During several recent summers, demand exceeded supply from mid-July through late September, and dewatering has been observed in several tributaries and portions of the Shields River (DNRC 2005). Below a certain threshold, water loss can be detrimental to aquatic life and also to a stream's ability to transport sediment. Although irrigation return flows add water back to stream systems, if surface water returns contain excess sediment and other pollutants, they can degrade the quality of the receiving water body.

5.3 Pollutant Transport and Seasonality

All TMDL/Water Quality Planning Framework documents must consider the seasonal variability, or seasonality, on water quality impairment conditions, maximum allowable pollutant loads in a stream (TMDLs), and LAs. Sediment loading varies considerably with season. For example, delivery increases during spring months when snowmelt delivers sediment from upland sources and resulting higher flows scour streambanks. However, these higher flows also scour fines from streambeds and sort sediment sizes, resulting in a temporary decrease in the proportions of deposited fines in critical areas for fish spawning and insect growth. The ability of a water body to transport sediment and flush deposited fine sediment can be lessened by factors such as altered channel form (e.g. an overwidened channel) and hydrologic. Because both fall and spring spawning salmonids reside in the Shields TPA, streambed conditions need to support spawning through all seasons. Therefore, sediment targets are not set for a particular season and source characterization is geared toward identifying average annual loads.

The sediment conditions of concern in the Shields River Watershed are (1) sedimentation and (2) stream channel instability that affects sediment transport. Sediment delivery to the stream network is periodic and highly dependent upon weather conditions. Increased sediment loading during runoff events from nonpoint sources have a slow, cumulative influence on sedimentation in fish spawning areas. Likewise, sediments will flush out of spawning areas gradually after implementation of restoration practices. The stream channel's stability is also a slowly changing, long-term condition which can affect sediment transport and instream sediment sorting. Unless catastrophic flooding occurs, sedimentation and stream channel stability conditions do not fluctuate a great extent over a year's timeframe in the Shields River Watershed. Sediments (sand) that impact beneficial uses move through the stream network slowly and therefore an average annual timeframe for TMDLs is appropriate for the Shields River Watershed.

5.4 Water Quality Standards Target Development

The water quality targets presented in this section are based on the best available science and information available at the time this document was written. TMDL targets are not stagnant components of this plan. Targets will be assessed during future TMDL reviews for their validity when new information may provide a better understanding of reference conditions.

Since natural variability in streams is high, detecting departures from the "naturally occurring" condition is often very difficult. In most stream systems it is not possible to rely on any single indicator to define the extent of the sediment problem. Thus, a suite of water quality targets and supplemental indictors will be used to assess sediment impacts in the Shields River Watershed. The sediment targets try to address the following questions:

1. Are there fish/aquatic life data that suggests an impact from sediment?
2. Have anthropogenic sources increased sediment erosion and/or delivery?
3. Is there a sediment supply problem (i.e., too much or too little sediment)?
4. Is there an indication of an in-channel sediment transport problem?

The first question is often difficult to answer without answering the other three questions, which is the reason target (and supplemental indicator) development often focuses on Questions 2 through 4.

5.4.1 Sediment Water Quality Targets and Supplemental Indicators

For the Shields River TPA, a suite of water quality targets and supplemental indicators are presented to assess the effect of sediment derived from anthropogenic sources on beneficial use support. Water quality targets and supplemental indicators for sediment impairments include measures of the width/depth ratio, entrenchment ratio, percent of fine sediment on the stream bed and in pool tail-outs, risk and percentage of eroding banks, and macroinvertebrate metrics. The proposed water quality targets and supplemental indicators to help define sediment impairments are summarized in **Table 5-2** and are described in the sections which follow. No fine sediment targets (i.e. percent surface fines in riffles and pools) will be applied to the low gradient E streams in the Shields River TPA because these stream types naturally have high amounts of fine sediment, regional reference sediment values vary greatly, and there is insufficient internal reference data. Future surveys should document stable (if meeting criterion) or improving trends. Additional details regarding reference conditions and target development are contained in **Appendix C**. The target values will be compared to measured values for each sediment impaired stream segment. If the results are consistent with the existing impairment determination, a TMDL will be provided. Site-specific conditions such as recent wildfires, natural conditions, and flow alterations within a watershed may warrant the selection of unique indicator values that differ slightly from those presented below, or special interpretation of the data relative to the proposed sediment indicator values.

Table 5-2. Targets for Sediment in the Shields River TPA

Water Quality Targets	**Proposed Criterion**
Percentage of fine surface sediment <6mm based on riffle pebble counts.	Comparable with reference values based on Rosgen Stream type. [a]
Percentage of fine surface sediment <2mm based on riffle pebble counts.	The value must not exceed **10-15%**.
Percentage of fine surface sediment <6mm based on a reach **average** from 49-point grid toss in pool tails.[b]	The value must not exceed **20%**.
Width/depth ratio, expressed as a reach **median** from channel cross-section measurements.[c]	Comparable with reference values based on Rosgen Stream type. [a]
Macroinvertebrates.	Mountain MMI $\geq$ 63 Low Valley MMI $\geq$ 48 Plains MMI $\geq$ 37 RIVPACS $\geq$ 0.80
Supplemental Indicators	**Proposed Criterion**
Entrenchment ratio, expressed as a reach **median** from channel cross-section measurements.[c]	Comparable with reference values. [a] This target only applies to B, C, and E stream types. An entrenchment ratio >5.1 will be considered to meet the water quality target for C channels and >3.7 for E channels.
BEHI hazard rating, expressed as a reach **average**.[b]	Comparable with reference values based on Rosgen Stream type. [a]
Percentage of eroding banks, based on the sum of both left and right bank lengths per reach.	Eroding banks for less than **15%** of reach for B, C, and E type streams.
Anthropogenic sediment sources.	No significant sources identified based on field and aerial surveys.

[a] Based on the USFS channel morphology dataset and contained in **Appendix C**.
[b] The total number of measurements per reach was dependent on the number of features (i.e. pools and eroding banks).
[c] There were 5 cross section measurements per reach.

In addition to the sediment criteria listed above, Rosgen channel type departure was determined for all assessed reaches. Departure from natural stream type is used as an additional indicator of impairment, taking into account the variables driving the departure. Departure is determined based on morphological variables, such as entrenchment, width/depth ratio, sinuosity, or high enough percent fines to change the stream type.

Several of the water quality targets for sediment in the Shields TPA are based on regional reference data. It should be noted that the Montana DEQ defines "reference" as the condition of a water body capable of supporting its present and future beneficial uses when all reasonable land, soil, and water conservation practices have been applied. In other words, reference condition reflects a water body's greatest potential for water quality given historic and current land use activities. Water bodies used to determine reference conditions are not necessarily pristine or perfectly suited to giving the best possible support to all possible beneficial uses. In addition, this reference condition approach also does not reflect an effort to "turn back the clock" to conditions that may have existed before human settlement, but is intended to accommodate natural variations due to climate, bedrock, soils, hydrology, and other natural physiochemical differences when establishing threshold values for sediment indicators. The intention is to differentiate between natural conditions and widespread or significant alterations of biology, chemistry, or hydrogeomorphology due to human activity.

5.4.1.1 Water Quality Targets

Percent Surface Fine Sediment in Riffles
The percent of surface fines less than 6 mm and 2 mm is a measurement of the fine sediment on the surface of a stream bed and is directly linked to the support of the cold water fishery and aquatic life beneficial uses. Increasing concentrations of surficial fine sediment can negatively affect salmonid growth and survival (Magee et al. 1996; Suttle et al. 2004) and macroinvertebrate abundance and taxa richness (Relyea et al. 2000; Mebane 2001; Zweig et al. 2001). The water quality target for the percent of fine sediment <6 mm and <2 mm on the streambed is based on feasibility, literature values for fish and other aquatic life, and departure beyond the regional reference. The target for sediment <6 mm varies from 12-29% depending on the Rosgen stream type (see **Appendix C, Table C-1**), and the target for sediment <2 mm is less than 10-15% for B and C stream types.

Percent Surface Fines in Pool Tail-Out Gravels
A particle size of 6 mm is commonly used to define fine sediment because of its potential to clog spawning redds and smother fish eggs by limiting oxygen availability (Irving and Bjornn 1984; Shepard et al. 1984). As an area where fish commonly spawn and excess sediment may accumulate if there are excess sediment loads and/or inadequate stream transport capacity, the percentage of surface fines in pool tails can indicate sediment supply/transport problems and support of coldwater fishery and aquatic life beneficial uses. Based on conditions within the Shields River TPA and available reference data, the water quality target for percent surface fine sediment <6 mm in pool tails is a reach average less than 20% for B and C stream types.

Width/Depth Ratio
The width/depth ratio is a fundamental aspects of channel morphology and provides a measure of channel stability, as well as an indication of the ability of a stream to transport and naturally sort sediment into a heterogeneous composition of fish habitat features (i.e. riffles, pools, and near bank zones). The reference values range from 7 to 31 depending on the Rosgen stream type (**Appendix C, Table C-1**), and a departure of the reach median width/depth ratio beyond the appropriate reference range will be used as a water quality target for sediment impairments.

Macroinvertebrates
Macroinvertebrate assemblages respond predictably to siltation with a shift in natural or expected taxa to a prevalence of sediment tolerant taxa over those that require clean gravel substrates. Macroinvertebrate bioassessments scores are an assessment of the macroinvertebrate assemblage at a site and are used by the Montana DEQ to evaluate impairment condition and the ability of a water body to support the aquatic life beneficial use. In 2006, Montana DEQ adopted impairment thresholds for bioassessment scores based on two separate methodologies: the Multi-Metric Index (MMI) method and the River Invertebrate Prediction and Classification System (RIVPACS) method. The macroinvertebrate target is to be equal to or greater than the applicable thresholds provided in **Table 5-2**.

5.4.1.2 Supplemental Indicators

Entrenchment Ratio
The entrenchment ratio describes the vertical containment of a stream, or how easily it can access its floodplain. Entrenchment is not as responsive to land-use changes within the watershed as the width/depth ratio, but a negative shift in entrenchment (toward a more entrenched state) is an indicator of channel instability. A departure of the reach median entrenchment ratio beyond the reference range for the appropriate stream type (**Appendix C, Table C-1**) will be used as a supplemental indicator for sediment impairments. The entrenchment ratios range from 1.8 to 5.1 and values greater than the reference range indicate the channel is not entrenched.

Bank Erosion Hazard Index (BEHI)
Stream flows, sediment loads, riparian vegetation, and streambank material all influence bank stability, which, in turn, influences sediment contribution to the stream. A bank erosion hazard index (BEHI) value beyond the reference range for the appropriate stream type (**Appendix C, Table C-1**) will be used as a supplemental indicator for sediment impairments. The reference BEHI values range from 23.6 to 31.7. Values less than the reference range indicate a low potential for bank erosion.

Percentage of Eroding Banks
The percent of eroding streambanks within a survey reach will be applied as a supplemental indicator for sediment impairments. Since streambank erosion is a natural process, this indicator will be used with caution. For example, just because eroding banks are present does not necessarily mean the erosion is human-induced or that there is an in-stream sediment problem. Additional information, such as observed bank trampling, removal of stabilizing vegetation, or increased water yield from timber harvest, will be considered. Departure from reference condition will apply when the percent of eroding banks within a survey reach exceeds 15% for B, C, and E type streams.

Significant Human Caused Sediment Sources
When there are no significant identified anthropogenic sources of sediment within the watershed of a 303(d) listed steam, no TMDL will be prepared since Montana's narrative criteria for sediment cannot be exceeded in the absence of human causes. Human induced and natural sediment sources will be evaluated using recently collected data in comparison with the reference dataset, along with field observations and watershed scale source assessment information obtained using aerial imagery and GIS data layers. Source assessment analysis will be provided by 303(d) listed water body in the Pollutant Sources and Loads Section (**Section 6.0**), with additional information in **Appendices E, F, and G**.

5.5 Summary of Existing Data

This section provides brief summaries of all available relevant sediment and habitat related water quality data for water bodies in the Shields River TPA appearing on the 2006 303(d) List.

5.5.1 Shields River

5.5.1.1 Aerial Surveys, Riparian Condition, and Stream Morphology

Most of the existing data for the Shields River is for the upper segment (MT43A001_012), upstream of Cottonwood Creek and the town on Clyde Park. In 1999, Montana Fish, Wildlife, and Parks documented conditions in the Shields River Watershed upstream of Clyde Park based on an aerial survey performed using a NRCS Rapid Aerial Assessment protocol (Tohtz 1999a). The survey noted extensive historical logging and removal of LWD near the headwaters, especially in the tributaries. The vegetation removal and an associated increase in runoff within the upper watershed were attributed to channel braiding and numerous depositional features. Downstream of the historically logged areas, agricultural land use (e.g. grazing, hay, and crop production) along the riparian corridor was cited as the primary cause of stream degradation. There was a clear distinction between sinuosity, frequency of pools and riffles, and the number of actively eroding banks in stretches with a healthy riparian zone versus those with degraded riparian vegetation. The conditions observed along the Shields River during the aerial assessment were very similar to those seen along most tributaries and are described in detail within the report.

In 2001, an aerial survey was conducted in the upper segment over the 41 river miles from Clyde Park to the boundary of the GNF (Inter-Fluve 2001). The survey divided the river into 12 sub-reaches based on geomorphic and hydrologic changes and was followed up by ground-truthing of riparian vegetation, identification of eroding banks, and collection of geomorphological characteristics at a minimally impacted section within each sub-reach. The study concluded that most of the upper segment of the Shields River is sediment transport limited as a result of irrigation practices and long-term drought. In addition to the effects of dewatering on fisheries habitat and the vigor of the riparian vegetation, historical clearing of native woody vegetation and continued encroachment by agriculture are also major factors in bank instability. The study also cited the role of episodic flooding in channel avulsion and downcutting within the highly erodible alluvial outwash that forms much of the river corridor in the upper segment.

In 2004, Confluence Consulting used USGS Digital Orthophoto Quarter Quad (DOQQ) aerial photos and GIS tools to assess sediment sources and stratify both 303(d) Listed segments of the Shields River based on existing versus potential Rosgen channel type, existing versus potential near bank vegetation type and density, and adjacent land use. After stratification, water quality monitoring and assessment tasks were conducted within ten representative reaches (**Map A-14**) with the intent of characterizing instream sediment conditions and bank erosion (Confluence 2004). The upper three reaches are on USFS land within the GNF and the remaining seven reaches are surrounded by private land. All but the lower two reaches are within the upper segment (MT43A001_012). Data collected during this effort are presented and compared to sediment targets in **Section 5.6.1**.

5.5.1.2 Biological Data

Twelve macroinvertebrate samples have been collected at 5 sites between 1992 and 2005. Four of the sites are in the upper segment (above Cottonwood Creek) and one is in the lower segment by the mouth of the Shields River (**Map A-15**). All but one sample was collected by DEQ personnel according to the DEQ Standard Operating Procedures for Aquatic Macroinvertebrate Sampling (Bukantis 1998). The non-DEQ sample was collected at a Montana State University (MSU) site following USFS protocols (Heitke et al. 2006). Assessment reports from samples collected in 2000, 2001, and 2003 generally concluded that the composition of macroinvertebrate assemblages reflected a mixture of reach-scale habitat disturbance and minor effects from sedimentation (Bollman 2001; Bollman 2002a; Bollman 2004b). Habitat assessments were conducted during sampling and noted substrate embeddedness, fine sediment in pools, and a layer of fine sediment on the substrate. The bioassessment scores (MMI and RIVPACS) are presented in **Section 5.6.1**.

Algal samples were collected by DEQ personnel at two sites in 2000 and again in 2003 following DEQ protocol. Conclusions drawn in the summary reports (Bahls 2001a; Bahls 2004), however will not be used as part of this document because the index used to assess algal impairment from sediment is currently being modified by DEQ.

Fish surveys conducted throughout the Shields River Watershed from 1999 to 2003 found that YCT are distributed throughout the watershed and are abundant in many tributaries (Tohtz 1999b; Shepard 2004). In general, YCT are most abundant in the tributaries in the eastern part of the watershed. In 1999 (Tohtz 1999b), population estimates in four eastern tributaries ranged from 280 to 958 YCT per mile, and Tohtz concluded the populations were well established, self-sustaining residents. Within the main stem Shields River, YCT abundance is low and mountain whitefish, brown trout, and brook trout are the dominant species. The YCT population within the watershed has had no to little introgression with rainbow trout (Shepard 2004; May et al. 2007). The Chadborne irrigation diversion on the main stem in the lower part of the watershed serves as a fish barrier that has limited upstream migration of rainbow trout and other species. During the fish surveys (Shepard 2004), habitat was noted to be generally good in most tributaries but low flows were seen in the lower portions of many tributaries and attributed to a combination of irrigation withdrawals and drought. Impacts from livestock grazing were widespread but areas of recovery were noted and likely a result of land use management changes and restoration projects including those listed in **Section 2.0**. Other prominent observed impacts to fish habitat included roads, and timber harvest. Additionally, high levels of fine sediments were identified in several streams, but sources were unknown.

5.5.2 Antelope and Potter Creeks

5.5.2.1 Aerial Surveys, Riparian Condition, and Stream Morphology

In 2004, Antelope and Potter Creeks were evaluated and stratified in the same method as the Shields River. From this process, two representative reaches were selected for Antelope Creek and four were selected for Potter Creek (**Map A-14**). Riparian vegetation for both streams is typical of prairie streams, containing mostly grasses and upland shrubs; a comparison of photos from 1954 to 1998 indicated a minimal reduction in riparian woody vegetation along both streams. The aerial assessment of Antelope Creek noted that the channel has a very limited riparian buffer surrounded by irrigated hayfields. Minor evidence of grazing was seen during field reconnaissance in 2004, but streambanks were predominantly vegetated with little erosion. Aerial photo review and field visits in 2000 and 2004 confirmed that much of Antelope Creek is ephemeral, and the upper third of Potter Creek is ephemeral and well vegetated. During field visits, there were few signs of grazing in some areas, but extensive hoof shear and localized channel widening in others. In general, however, human-caused bank erosion is minimal and sources are limited to road sediment and grazing upstream of Cottonwood Reservoir, while hydromodification has resulted in actively eroding banks and channel widening downstream of the reservoir.

5.5.2.2 Biological Data

Both Antelope and Potter Creeks had one macroinvertebrate sample collected in August 2000 (**Map A-15**). Samples were collected by DEQ personnel according to the DEQ Standard Operating Procedures. The Antelope Creek macroinvertebrate sample showed some evidence of sediment deposition, but predominantly suggested nutrient enrichment and/or elevated water temperatures (Bollman 2002b). The Potter Creek macroinvertebrate sample included several taxa very tolerant of sediment and also suggested large-scale habitat disturbance and dewatering (Bollman 2002c). Habitat assessments performed during sampling noted moderate fine sediment deposition in Antelope and Potter Creeks. The bioassessment scores (MMI and RIVPACS) are presented in **Section 5.6.1**. One algal sample was also collected on both creeks in 2000 (Bahls 2001b), but, as with the Shields River, sediment-related conclusions drawn from the algal samples will not be used as part of this document because the index used to assess algal impairment from sediment is currently being modified by DEQ.

A fisheries survey of Antelope Creek in 2002 concluded flows in the lower portion of the stream are likely too low to support fish (Shepard 2004). Within the lower 7 miles of Potter Creek, white suckers, longnose sucker, longnose dace, and sculpins were found. Habitat observations during the fish survey included little to no riparian shade, a streambed mostly covered in silt, and impacts from Cottonwood Reservoir flows and livestock.

5.5.3 Other Data Sources

Other pertinent data and sources not listed above include that information found in Montana DEQ's Sufficient and Creditable Data (SCD) files. These files represent an aggregation of data utilized during the 303(d) assessment process. Where appropriate, these files will be referenced within this document.

5.6 Sediment Impairments Summary

This section presents summaries and evaluations of all available sediment related water quality data for the Shields River TPA appearing on the Montana 2006 303(d) List. A suite of water quality targets and supplemental indicators have been applied to either support the need for developing TMDLs or to suggest that more information is needed prior to TMDL development.

5.6.1 Water Body Comparisons to Targets

As described in **Section 5.4.1** and **Appendix C**, water quality targets were developed to assess sediment conditions in the Shields River TPA and to help measure the success of ongoing and future efforts to implement the TMDLs. The existing data in comparison to the targets and supplemental indicators are summarized in **Tables 5-3 and 5-4**. Analysis, discussion, and TMDL development determinations follow for each 303(d) Listed water body.

Table 5-3. Summary of Sediment Targets and Supplemental Indicators for all 303(d) Listed Water Bodies
Reach IDs are listed in an upstream to downstream direction. Shields River sites with an asterisk (*) are on the lower segment (MT43A001_011) and other Shields River sites are on the upper segment (MT43A001_012). Shaded cells fail to meet their respective targets based on Rosgen Level II potential.

Water Body	Reach ID	Targets				Supplemental Indicators					
		Pebble Count		Grid Toss	Cross Section	Cross Section	Rosgen Level II		BEHI		
		Riffle % <6mm	Riffle % <2mm	Pool Tail % <6mm (mean)	W/D Ratio (median)	Entrenchment Ratio (median)	Existing	Potential	Score (mean)	Adjective Rating	% Eroding Bank
Shields	SR02	ND	ND	***87***	***19.2***	2.4	B3	B3	10.5	Low	4.4
Shields	SR02R	***32***	***27***	***92***	13.8	2.6	B3	B3	***36.0***	***High***	***19.4***
Shields	SR04	14	10	***30***	***33.3***	***3.3***	***D4/B4***	C4	0.0	Low	0.0
Shields	SR07	10	7	***37***	***34.4***	***2.6***	C4	C4	***40.2***	***High***	***17.0***
Shields	SR10	4	3	***56***	***39.2***	***3.2***	C4	C4	***35.7***	***High***	5.0
Shields	SR11	1	1	***85***	***31.3***	***1.5***	C4	C4	26.2	Mod	2.5
Shields	SR14	0	0	***75***	***46.5***	***2.0***	C4	C4	***35.5***	***High***	7.4
Shields	SR17	13	5	***77***	***55.3***	***1.5***	C4	C4	***31.1***	***High***	***16.5***
Shields	SR20*	2	2	***32***	***43.1***	***1.1***	***F4***	C4	***34.6***	***High***	***17.9***
Shields	SR22*	3	0	12	***40.2***	***2.4***	C4	C4	28.1	Mod	***17.8***
Antelope	AC04	ND	ND	ND	6.6	10.6	E	E	0.0	Low	0.0
Antelope	AC07	56	22	100	5.6	9.3	E4/6	E4/6	***37.0***	***High***	1.0
Potter	PT05	ND	ND	ND	5.6	10.9	E	E	0.0	Low	0.0
Potter	PT07	32	27	100	6.4	18.2	E4/5	E4	0.0	Low	0.0
Potter	PT08	30	29	99	***10.7***	***1.9***	***F4***	E4	***38.6***	***High***	9.3
Potter	PT08R	87	79	100	***11.1***	***1.4***	***F5***	E4	***39.1***	***High***	11.3

ND = no data collected
See **Appendices F and I** for raw data.

Table 5-4. Summary of Macroinvertebrate Indices for all 303(d) Listed Water Bodies
The Shields River sites near the mouth are in the lower segment (MT43A001_011) and all other Shields River sites are in the upper segment (MT43A001_012). Shaded cells fail to meet the target (Mountain MMI ≥ 63, Low Valley ≥ 48, Plains MMI ≥ 37, RIVPAC ≥ 0.80). Sites are listed in an upstream to downstream direction.

Biological Target					
Site ID	**Location Description**	**SiteClass**	**MMI**	**RIVPAC**	**Collected**
BKK128	Shields River near South Fork	Mountains	77.9	***0.46***	10/7/1992
MTST-006	Shields River near NFS land (MSU site)	Mountains	74.1	1.14	Unknown
Y02SHLDR01	Shields River below Hill Rd bridge	Low Valley	61.9	0.92	9/19/2000
Y02SHLR02	Shields River below Indian Creek Rd bridge	Low Valley	***25.7***	0.88	9/19/2000
Y02SHLR02		Low Valley	55.9	1.13	7/10/2003
BKK127	Shields River near mouth and Livingston	Low Valley	50.3	0.88	10/7/1992
Y03SHIER01		Low Valley	***45.4***	1.26*	7/23/2001
Y03SHIER01		Low Valley	***46.0***	1.13	8/28/2002
Y02SHLDR50		Low Valley	60.7	1.26*	7/10/2003
Y03SHIER01		Low Valley	***43.8***	1.01	7/18/2003
Y03SHIER01		Low Valley	62.7	1.38*	6/24/2004
Y03SHIER01		Low Valley	54.4	1.26*	7/16/2005
Y02ANTPC01	Antelope Creek near Clyde Park	Plains	38.8	1.01	8/11/2000
Y02POTRC01	Potter Creek above Cottonwood Reservoir	Plains	38.0	1.26	8/10/2000

*Meets the sediment target but suggests possible nutrient enrichment

5.6.1.1 Shields River

The Shields River originates at Fawn Creek in the GNF and flows in a southerly direction for approximately 62 river miles to the confluence with the Yellowstone River near Livingston, Montana. Approximately the first 7 miles flows through the Middle Rockies ecoregion, and the remainder of the river flows through the Northwestern Great Plains ecoregion. Aquatic life, coldwater fishery, and primary contact recreation beneficial uses in the Shields River (segments MT43A001_011 and MT43A001_012) were listed as impaired on the 2006 Montana 303(d) List because of alterations in stream-side or littoral vegetative covers, low flow alterations, physical substrate habitat alterations, and sedimentation/siltation.

Results and Discussion
In the upper segment (MT43A001_012), all but one site met the percent fines target for less than 6 mm and less than 2 mm in riffles, but all sites exceeded the percent fines target for pools by an average of 237%. In the lower segment (MT43A001_011), both sites met the percent fines target for less than 6 mm and less than 2 mm in riffles, and one of the sites exceeded the percent fines target for pools. Width to depth (W/D) ratios generally increase downstream, and all but one site near the top of the upper segment exceeded the target. Two sites with a B3 channel type in the upper segment met the entrenchment target but all eight sites with a potential Rosgen channel type of C4 failed to meet the entrenchment target and were on average 57% lower than the target of 5.1. For supplemental indicators, several sites in both the upper and lower segments exceeded the BEHI target with a high risk of erosion and five of the reaches exceeded the 15% target for eroding banks. Sites SR04 (upper segment) and SR20 (lower segment) had shifted from their potential Rosgen channel types.

The field data support the conclusions from the aerial surveys and field reconnaissance. Degradation of the riparian habitat has decreased bank stability, accelerated bank erosion, and resulted in channel widening and a decrease in entrenchment ratios throughout the river. This widening and reduction in access to the floodplain has concentrated flows within the channel, which can accelerate scouring during storm events. These factors coupled with drought and irrigation withdrawals make it difficult for the stream to effectively transport and deposit sediment from instream and upland sources. The channel in reach SR04 and other parts of the upper watershed have become braided; this was seen during 2004 sampling, but was also noted during the 1999 aerial assessment (Tohtz 1999a) and attributed to excess sediment from historical logging practices. Riparian degradation in the lower segment near SR20 led to high erosion rates and channel widening, and it caused the reach to become entrenched and shift from a C channel to an F channel. The high percentage of fine sediment in pool tails is an additional indicator that the Shields River is sediment transport limited. All of the above factors are consistent with the existing impairment determination for coldwater fisheries uses due to excess fines in potential spawning areas and the loss of desirable habitat typically linked to high W/D ratios and decreased entrenchment ratio.

Out of 5 macroinvertebrate samples in the upper segment (MT43A001_012), one sample from a “Mountain” site failed to meet the RIVPAC threshold (0.8) and one sample from a “Low Valley” sites failed to meet the MMI threshold (48). Out of the 7 “Low Valley” macroinvertebrate samples in the lower segment (MT43A001_011), all samples met the RIVPAC threshold but three samples failed to meet the MMI threshold (48). For both segments, however, aquatic life at the Low Valley sites is not necessarily impaired because the RIVPAC score should be given more weight in the Low Valley if the two indices disagree (Feldman 2006) and the corresponding RIVPAC scores are all above the threshold. Although the Mountain sample in the upper segment (site BKK128) has a very low RIVPAC score, the MMI and RIVPAC scores for the other Mountain sample and the rest of the Low Valley samples are above the targets; the low RIVPAC score could be a result of localized impairment or sample error. Despite degraded habitat and the composition of several macroinvertebrate samples indicating a community shift because of sediment, it does not appear that excess sediment is impairing the macroinvertebrates within the Shields River.

Four of the Low Valley samples from the lower segment (MT43A001_011) have a RIVPAC score greater than 1.2 and suggest there may be excess nutrients within the watershed. Although nutrients will not be addressed within this document, nutrients are often bound to sediment and may be indirectly influenced by a decrease in sediment inputs to the river.

TMDL Development Determination

Although excess sediment does not appear to be impairing macroinvertebrates, the high percentage of fines in the pools and impacted channel morphology results suggest that there is a reduction in the quality of and quantity of fish rearing and spawning habitat. Additionally, anthropogenic sources have increased sediment loading to both 303(d) listed segments of the Shields River and diminished its ability to transport sediment, leading to additional loss in fish habitat as well as potential loss to other aquatic life habitat. These findings support the 303(d) listings for sediment impairment, and TMDLs will be developed for sediment in the Shields River (segments MT43A001_011 and MT43A001_012).

5.6.1.2 Antelope Creek

Antelope Creek (MT43A002_020) originates east of the Bridger Mountains and flows 10 miles before its confluence with the Shields River between Wilsall and Clyde Park. The upper 2 miles flows through the Middle Rockies ecoregion, and the remainder of the stream flows through the Northwestern Great Plains ecoregion. Field reconnaissance concluded that almost three-fourths of the stream is ephemeral. Aquatic life and coldwater fishery beneficial uses were listed on the 2006 303(d) List as impaired because of solids (suspended/bedload) and alterations in stream-side or littoral vegetative covers.

The upper site on Antelope Creek (AC04) is approximately 7 miles from the headwater. The site is ephemeral and has sage brush growing in the channel; morphological data such as entrenchment ratio and W/D ratio were collected but no measurements of in-stream sediment were obtained.

Results and Discussion
Both sites on Antelope Creek were meeting their Rosgen channel type potential and were within the expected range for W/D ratio and entrenchment. The lower site had eroding banks with a high potential for erosion, but it only accounted for 1% of all the banks within the assessment reach. The percentage of fines in the riffles and pools was high, but is expected in an E4/E6 channel. There is only one macroinvertebrate sample from Antelope Creek, but both the MMI and the RIVPAC scores were above the impairment threshold, indicating no impairment to the macroinvertebrates. Although hay production and grazing are the primary land use along Antelope Creek and some riparian degradation has occurred, no significant anthropogenic sediment sources were identified.

Large floating algal mats were observed within Antelope Creek during field visits in 2000 and 2004 (**Figure 5-1**). Also, field reconnaissance and landowner contact during sampling in 2004 indicated that water within lower Antelope Creek is most likely irrigation return flow.

TMDL Development Determination
Field data and observations indicate that the suspended solids within Antelope Creek are actually suspended organic matter from an irrigation return and not excess anthropogenic sediment from the Antelope Creek watershed. As a result of this, a TMDL will not be developed for sediment in Antelope Creek. However, because this type of channel is extremely sensitive to riparian degradation, riparian best management practices identified in **Section 8.0** should be implemented to improve the riparian habitat and prevent further degradation. Additional monitoring is recommended to confirm that water quality issues within the lower part of Antelope Creek are associated with the irrigation return and determine the associated pollutants that may be impairing beneficial uses. Future development of a nutrient TMDL for Antelope Creek may be necessary.

Figure 5-1. Algal Growth in Antelope Creek during 2004 Assessment Work

5.6.1.3 Potter Creek

Potter Creek flows for 25 river miles from the headwaters to its mouth near Wilsall and is entirely contained within the Northwestern Great Plains ecoregion. Aquatic life and coldwater fishery beneficial uses in Potter Creek (segment MT43A002_010) were listed as impaired on the 2006 Montana 303(d) List because of low flow alterations, sedimentation/siltation, and solids (suspended/bedload).

Results and Discussion
The field data show significant changes between channel geomorphology and bank erosion upstream and downstream of Cottonwood Reservoir. Both reaches above the reservoir (PT05 and PT07) are achieving their potential Rosgen channel type, while those downstream of the reservoir (PT08 and PT08R) have both shifted from E channels to F channels. This shift is also illustrated in the difference between W/D ratios and entrenchment. The mean reach W/D ratios were 5.6 and 6.4 upstream of the reservoir, but 10.7 and 11.1 downstream of the reservoir. Upstream of the reservoir, the stream can easily access its floodplain, but downstream of the reservoir, the channel is entrenched. Although the percentage of eroding banks meets the target for all reaches, no actively eroding banks were seen upstream of Cottonwood Reservoir, but those found at the downstream reaches had a high erosion potential. Also, although there is no target for fine sediment in E channels, and Potter Creek is expected to have naturally high levels of fine sediment, the large difference among values suggest excess sedimentation. Reaches PT07 (upstream of Cottonwood Reservoir) and PT08 (downstream of Cottonwood Reservoir) had very similar percentages of riffle fines while site PT08R (downstream of the reservoir) had 87 % fines <6 mm and 79% fines <2 mm (compared to 32% and 27% at PT07 and PT08, respectively). These results suggest that flow releases from Cottonwood Reservoir have contributed to increased vertical and lateral erosion downstream of the reservoir.

Macroinvertebrates were collected above Cottonwood Reservoir, and both the MMI and RIVPAC scores are above the impairment threshold. Although macroinvertebrates downstream of Cottonwood Reservoir are likely under more stress than those at the sample site, the available sample indicates that the macroinvertebrate in Potter Creek are not impaired.

TMDL Development Determination
Sediment and habitat data support the 303(d) listing for sediment impairment on Potter Creek. Excess levels of fine sediment could definitely be impairing the aquatic life and coldwater fishery beneficial uses by reducing the quality of and decreasing the quantity of fish rearing and spawning habitat. Data suggest minor impacts upstream of Cottonwood Reservoir from grazing practices and roads and moderate impacts downstream of the reservoir caused primarily by flow modification. As a result, a sediment TMDL will be prepared for Potter Creek. Sediment targets will likely be modified in the future as additional data are collected.

5.6.2 TMDL Development Determination Summary

A summary of the 2006 303(d) listing status and TMDL development determination for each water body segment is shown below in **Table 5-5**. All sediment-related listing causes discussed in **Section 1.0** (**Table 1-1**) are listed as sediment in the table below.

Table 5-5. Summary of TMDL Development Determinations

Water Body Segment	Probable Cause	2006 303d	Pursue TMDL Development	Additional Monitoring and/or Further Impairment Review Recommended
Shields River (headwaters to Cottonwood Cr) MT43A001_012	**Sediment**	X	Yes	No
Shields River (Cottonwood Cr to mouth) MT43A001_011	**Sediment**	X	Yes	No
Antelope Creek MT43A002_020	**Sediment**	X	No	Yes
Potter Creek T43A002_10	**Sediment**	X	Yes	No

5.7 Data Gaps, Uncertainty, and Adaptive Management

5.7.1 Data Gaps

Within this section, the current condition of target and supplemental indicator variables was compared to reference conditions for each 303(d) Listed water body. The data collection effort for this TMDL collected as much pertinent data as possible given time and resource constraints. In some cases, there were low sample numbers or the distribution of sample sites was not ideal. Overall, the largest data gap is local reference data. Internal reference sites were sought along 303(d) Listed streams during project planning, but because sediment impairment can result from reach scale and watershed scale activities and large scale disturbances occurred throughout the watershed historically, no appropriate internal reference reaches were found. Data gaps are summarized within **Section 8.0**, and filling in the data gaps is part of the monitoring suggestions within that section.

5.7.2 Uncertainty and Adaptive Management

A degree of uncertainty is inherent in any study of watershed processes related to sediment. The assessment methods and targets used in this study to characterize impairment and measure future restoration are each associated with a degree of uncertainty. Field measurements were conducted by a team, so there is some inherent bias in the assessment methods because of having multiple observers. This bias is minimized, however, by all field personnel adhering to standard sampling procedures. Some parameters may over or under estimate the fraction of fine sediment, but a suite of targets and supplemental indicators is used to reduce bias by any single parameter, and parameters with a higher level of uncertainty are considered with less weight and used as supplemental indicators. While uncertainties are an undeniable fact of TMDL development, this document will include a monitoring and adaptive management plan to mitigate and reduce uncertainties in the field methods, targets, and supplemental indicators.

For the purpose of this document, adaptive management relies on continued monitoring of water quality and stream habitat conditions, continued assessment of impacts that human activities and natural conditions have on water quality and stream habitat conditions, and continued assessment of how aquatic life and cold-water fish, particularly cutthroat trout, respond to changes in water quality and stream habitat conditions. Adaptive management addresses important considerations, such as feasibility and uncertainty in establishment of targets. For example, despite implementation of all restoration activities (**Section 8.0**), the attainment of targets may not be feasible due to natural disturbance such as forest fires, flood events, or landslides. The targets established in the document are meant to apply under median conditions of natural background and natural disturbance. The goal is to ensure that management activities are undertaken to achieve loading approximate to the TMDLs within a reasonable time frame and to prevent significant excess loading during recovery from significant natural events. Additionally, it is possible that the natural potential of some streams will preclude achievement of some targets. For instance, natural geologic and other conditions may contribute sediment at levels that cause a deviation from numeric targets associated with sediment. Conversely, some targets may be underestimates of the potential of a given stream and it may be appropriate to apply more protective targets upon further evaluations. Supplemental indicators are used to help with these determinations. In light of all this, it is important to recognize that the adaptive management approach provides the flexibility to refine targets as necessary to ensure protection of the resource or to adapt to new information concerning target achievability.

As part of this adaptive management approach, increased land use activities should be tracked along with increased monitoring of target parameters before and after land use activities should always be considered. For example, coal bed methane development (CBM) is a concern for some stakeholders within the Shields River TPA, and there may be a future need for additional monitoring sites and targets to track CBM-associated changes to water quality. The extent of monitoring should be consistent with the extent of potential impacts, and can vary from basic BMP compliance inspections to a complete measure of target parameters below the project area before the project and after completion of the project. Cumulative impacts from multiple projects must also be a consideration. This approach will help track the recovery of the system and the impacts, or lack of impacts, from ongoing management activities in the watershed. Under these circumstances, additional targets and other types of water quality goals may need to be developed to address new stressors to the system, depending on the nature of the activity.

SECTION 6.0
POLLUTANT SOURCES AND LOAD ESTIMATES

This section presents a review of sediment source assessments conducted to facilitate the development of this TMDL. Significant sediment sources identified within the Shields watershed that were assessed for the purposes of TMDL development include:

- Unpaved roads
- Upland erosion
- Streambank erosion

For each impaired water body segment, sediment loads from each source category were estimated based on field surveys, watershed modeling, and load extrapolation techniques. Source assessment methods and results are given below.

6.1 Source Assessment Methods

6.1.1 Unpaved Roads

Improperly designed roads can directly affect aquatic ecosystems. Roads fundamentally disrupt natural drainage patterns by diverting water and preventing water infiltration into soil. Roads can affect both the volume of water available as surface runoff and the efficiency with which water flows through a watershed. Roads can also contribute sediment to waterways from direct erosion on cut-and-fill slopes. In addition, improperly designed roads can increase the magnitude and frequency of mass failures and landslides.

Sediment loading from unpaved roads was assessed in the Shields River TPA. This assessment employed GIS, field data collection and sediment modeling to estimate sediment inputs from the unpaved road network to the stream network. The GIS exercise identified 2,448 contributing road segments within a 200 foot buffer of streams. Of the contributing road segments, 59% were from stream crossings and 41% were from parallel road segments. Of the roads, 19% were on USFS land and the remaining roads were on private or State property.

Sediment delivery to streams from the identified roadways was estimated using the Washington Road Surface Erosion Model (WARSEM). WARSEM is an empirical model, and estimates sediment production and delivery based on road surfacing, road use, underlying geology, precipitation, road age, road gradient, road prism geometry, cut slope factors, and other factors. Most of the parameters must be field verified, and data were collected from 32 stream crossings throughout the Shields River Watershed. Data independent of site conditions were modified to reflect conditions within Montana. Results were extrapolated based on the road type (e.g. 4WD, local, ranch, and highway) and whether the road was parallel to the stream or crossed it. To address sediment from unpaved roads in the TMDLs and allocations that follow in **Section 7.0**, the WARSEM analysis was also run using several BMP scenarios. Sample locations and a more detailed description of this assessment can be found in *Sediment Contribution from Roads*, which is included as **Appendix D.**

While the TMDL was being prepared, the GNF completed several road decommissioning and road improvement projects in the TPA, particularly in the Bangtail, Willow, and Smith Creek watersheds (USFS 2004; USFS 2006a; USFS 2007). The analysis presented does not include these recent improvements.

6.1.2 Hillslope Erosion

Hillslope erosion occurs throughout the Shields River Watershed in areas ranging from steep, forested headwaters to relatively flat agricultural valley bottoms. Natural hillslope erosion rates can be accelerated as a result of human disturbances such as silviculture, urban development, and agricultural practices.

Upland sediment loading due to hillslope erosion was modeled using the Universal Soil Loss Equation (USLE) model and sediment delivery to the stream was predicted using a sediment delivery ratio. The USLE results are useful for source assessment as well as determining allocations for human-caused upland erosion. This model provided an estimate of existing sediment loading from upland sources and an estimate of potential sediment loading reductions through the application of best management practices (BMPs). Because the plant canopy and type of tillage practices can influence erosion, potential load reductions are calculated by adjusting factors within the model that are associated with land management and cropping practices (C-factors). Additional information on the upland erosion modeling can be found in *Sediment Contribution from Hillslope Erosion*, which is included as **Appendix E**.

6.1.3 Bank Erosion

Streambank erosion is an inherent part of channel evolution and contributes sediment to stream systems in response to a combination of climatic and physiographic factors. However, anthropogenic impacts, including poor land management, road systems, riparian vegetation removal, and/or channel alterations can result in elevated rates of streambank erosion and subsequent impacts to beneficial uses.

Sediment loading from streambank erosion was assessed in the Shields River TPA in 2004 by performing BEHI measurements and evaluating the Near Bank Stress (NBS) (Rosgen and Silvey 1996; Rosgen 2001). Measurements were made at 16 reaches along Potter Creek and the Shields River (discussed in **Section 5.0**) and at 13 additional tributary reaches within the TPA (**Map A-16**). BEHI scores were determined at each eroding streambank based on the following parameters: bank height, bankfull height, root depth, root density, bank angle, and surface protection. In addition to BEHI data collection, surrounding land use practices and adjacent streamside vegetation condition were recorded.

Assessment reaches were previously stratified using aerial photos and GIS tools as described in **Section 5.5.1** and **Appendix F**. Because riparian vegetation is crucial for bank stabilization, the existing and potential vegetation type and density were determined for all reaches. Average erosion rates associated with each reach type (based on land use and vegetation) were used to extrapolate bank erosion to each subwatershed within the TPA. To estimate the sediment reductions that could be achieved by the application of BMPs, the loading rate was calculated for the potential vegetation type and density of each reach type. A more detailed description of this assessment can be found in *Sediment Contribution from Stream Bank Erosion*, which is included as **Appendix F**.

6.2 Source Assessment Results

This section summarizes the current sediment load estimates from three broad source categories of road erosion, streambank erosion, and hillslope erosion. EPA sediment TMDL development guidance for source assessment states that the basic source assessment procedure includes compiling an inventory of all sources of sediment to the waterbody and using one or more methods to determine the relative magnitude of source loading, focusing on the primary and controllable sources of loading (EPA 1999). Additionally, regulations allow that loadings "...may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading," (Water quality planning and management, 40 CFR § 130.2(G)). The source assessment conducted for this TMDL evaluated loading from the primary sediment sources using standard DEQ methods, but the sediment loads presented herein represent relative loading estimates within each source category and, as no calibration has been conducted, should not be considered as actual loading values. Rather, relative estimates provide the basis for percent reductions in loads for each source category. Until better information is available and the linkage between loading and in-stream conditions becomes clearer, the loading estimates presented here should be considered as an evaluation of the relative contribution from sources and source areas that will be further refined in the future through adaptive management.

6.2.1 Roads

Based on the WARSEM analysis, roads contribute 280 tons of sediment per year to streams in the Shields River watershed. Of the total load from roads within the Shields River TPA, roads within the upper Shields contribute approximately 155 tons of sediment annually, including 11 tons from the Potter Creek watershed. In general, private/State roads are contributing most of the sediment from unpaved roads (**Table 6-1**), and unpaved road segments that are parallel to water bodies contribute a very small amount of sediment compared to unpaved road crossings (**Table 6-2**). Within the Shields River TPA, parallel road segments contribute less than 2% of the total sediment from roads. Sediment delivery from roads is highest in the lower Shields River with the Chicken Creek and Upper Brackett Creek subwatersheds contributing the most sediment (24 and 23 tons/year, respectively; **Figure 6-1**). However, if road-associated sediment from each subwatershed is normalized by the miles of contributing road, the Elk Creek and Rock Creek subwatersheds contribute the greatest annual load (1.6 and 1.4 tons/mile/year, respectively; **Appendix D, Table D-2**). **Appendix D** contains sediment loads for the Shields River TPA and by 6th code HUC (**Map A-17**), and it also includes the contribution within each 6th code HUC by road ownership and road type. Note, loads for the lower Shields are cumulative and include sediment loads from the upper Shields.

Table 6-1. Sediment Loads from Unpaved Roads in the Shields River and Potter Creek Watersheds by Road Ownership

Watershed	Road Ownership	Miles of Road Segments within 200 feet of a stream	Total existing sediment load (tons/year)
Upper Shields	Private/State	123	136
	USFS	25	19
Lower Shields	Private/State	233	255
	USFS	34	25
Potter Creek	Private/State	12	11

Table 6-2. Sediment Loads from Unpaved Roads in the Shields River and Potter Creek Watersheds by Road Orientation

Watershed	Road Orientation	Miles of Road Segments within 200 feet of a stream	Total existing sediment load (tons/year)
Upper Shields	Parallel	62	3
	Crossing	85	152
Lower Shields	Parallel	109	4
	Crossing	158	276
Potter Creek	Parallel	4	< 1
	Crossing	8	11

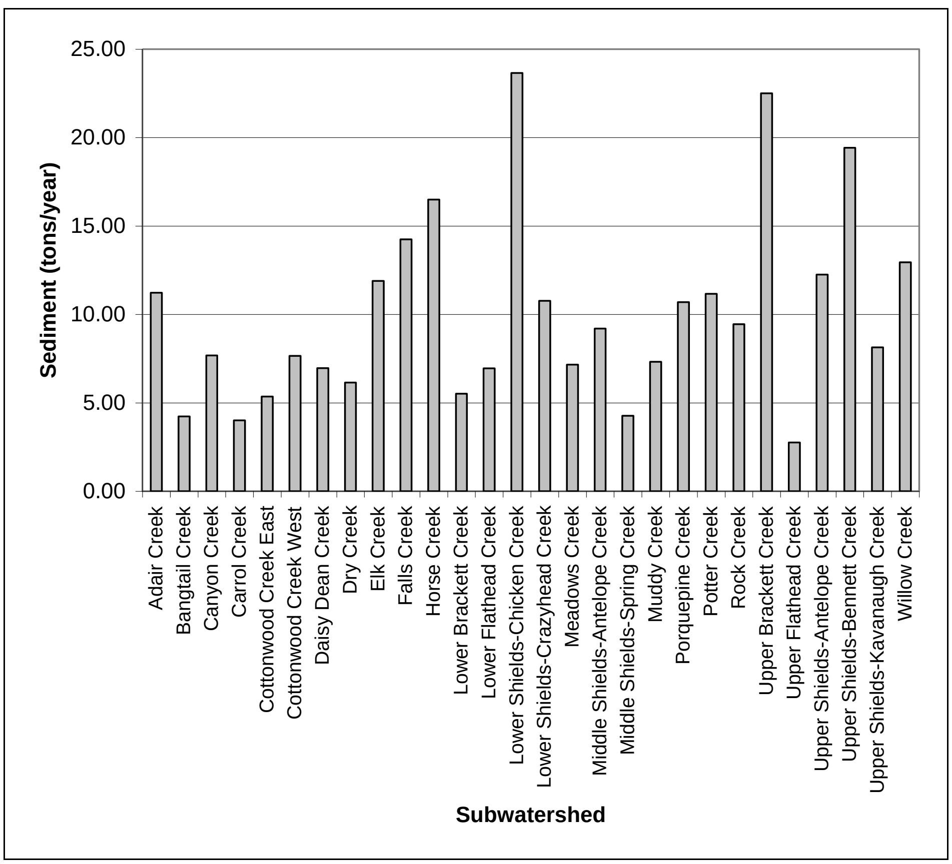

Figure 6-1. Existing Annual Sediment Load (ton/year) from Unpaved Roads in Subwatersheds within the Shields River TPA

6.2.2 Upland Erosion

Based on the USLE analysis, hillslope erosion contributes approximately 157,000 tons of sediment per year to streams in the Shields River Watershed, with 43% being attributable to anthropogenic sources that can be reduced through the application of BMPs. Approximately 88,000 tons of the sediment associated with hillslope erosion comes from the upper Shields, with 43% being attributable to anthropogenic sources that can be reduced through the application of BMPs. Within the Potter Creek Watershed, hillslope erosion contributes approximately 5,700 tons of sediment per year. Roughly 34% of that load is from controllable anthropogenic sources. Similar to the land cover breakdown, agriculture is the predominant source within the Potter Creek watershed and the Shields River watershed. **Table 6-3** shows the hillslope erosion by land cover type for both watersheds. By unit area, the loads from subwatersheds range from 0.11 to 0.65 tons/acre/year, with the greatest loads coming from the Bangtail Creek and Upper Brackett Creek watersheds in the southwestern part of the Shields River TPA (**Appendix E, Table E-5**). Total sediment loading from hillslope erosion was highest in the Upper Brackett Creek and Rock Creek watersheds (**Figure 6-2**), which are in the lower segment of the Shields River Watershed, just south of Clyde Park. Total and normalized loads are presented for each 6th digit HUC (**Map A-17**), by land cover, and by owner in **Appendix E.** Loads for the lower Shields are cumulative and include sediment loads from the upper Shields.

Table 6-3. Sediment Loads from Hillslope Erosion by Land Cover Type for Watersheds of 303(d) Listed Water Bodies

Land Cover Type	Sediment Load (tons/yr)		
	Upper Shields	Lower Shields	Potter Creek
Natural Sources	5,600	9,400	17
Grazing	57,000	110,000	4,200
Cropland	25,000	35,000	1,500
Silviculture	780	1,700	0
Total Load	88,000	157,000	5,700

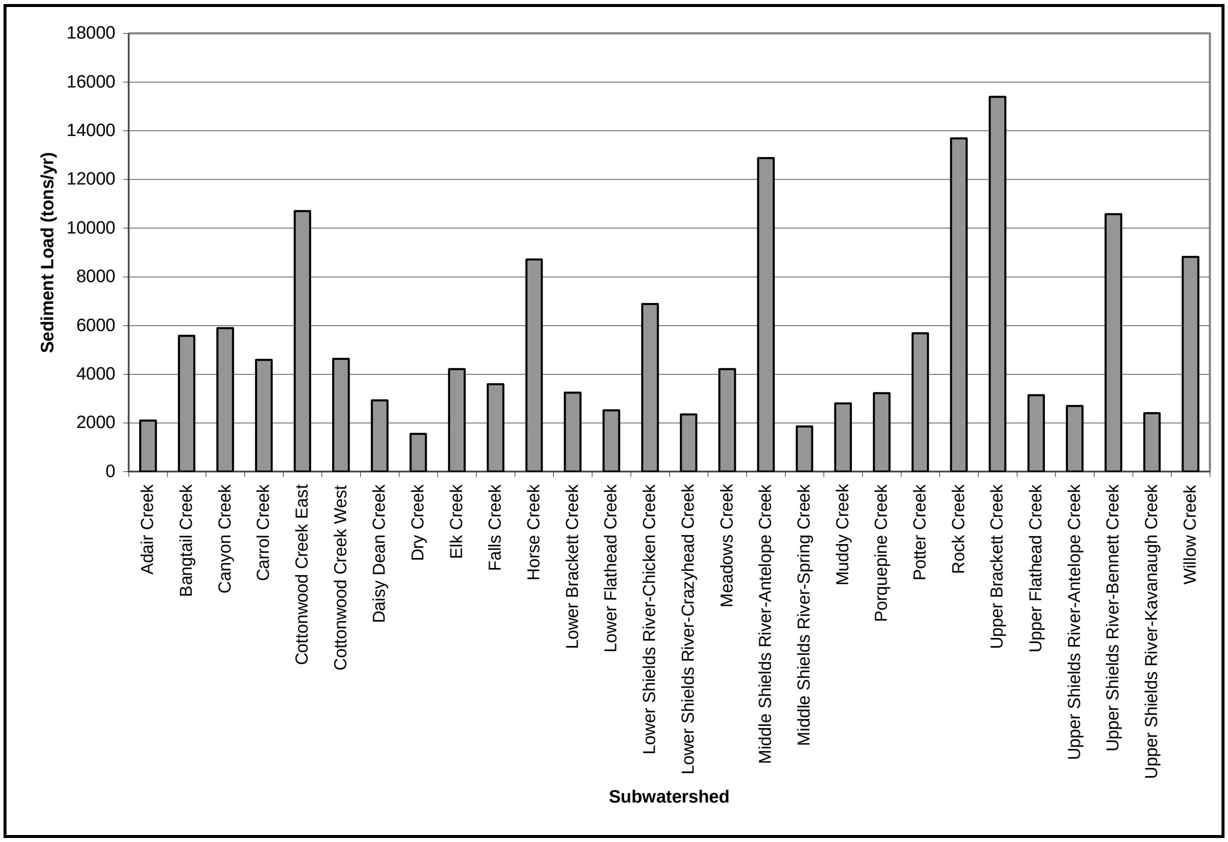

Figure 6-2. Existing Annual Sediment Load (tons/year) from Upland Erosion by Subwatersheds within the Shields River TPA

6.2.3 Bank Erosion

The assessment method excluded 100% naturally eroding banks from the extrapolation and potential loads are assumed to be a combination of natural loads and anthropogenic loads associated with the use of reasonable land, soil, and water conservation practices. Based on the BEHI analysis and extrapolation, bank erosion contributes 103,000 tons of sediment annually to water bodies within the Shields River TPA. Approximately 67,000 tons of the sediment associated with bank erosion is contributed from the upper Shields watershed. As with unpaved roads and hillslope erosion, the Rock and Chicken Creek subwatersheds within the lower Shields watershed are substantial sources, but the Potter Creek watershed in the upper Shields is also a large source of streambank erosion (**Figure 6-3**). When the miles of stream per subwatershed are taken into account, the Spring, Kavanaugh, and Chicken Creek subwatersheds contribute the most sediment from bank erosion (**Appendix F, Table F-4**). Approximately 8,100 tons of sediment is delivered to streams within the Potter Creek watershed from eroding banks each year. Loads are presented for each 6th digit HUC (**Map A-17**) and by ownership in **Appendix F**.

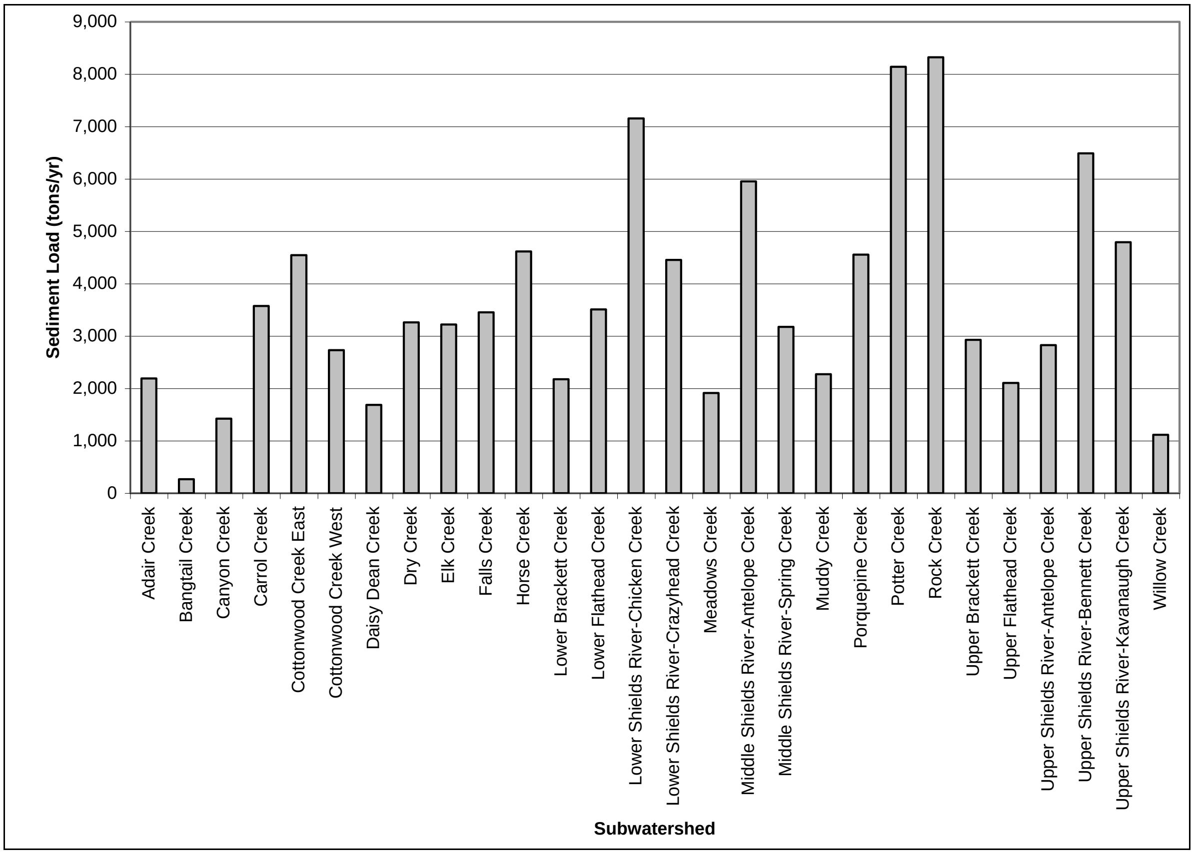

Figure 6-3. Existing Annual Sediment Load (tons/year) from Streambank Erosion by Subwatersheds within the Shields River TPA

6.3 Source Assessment Summary

From all assessed sources, the annual sediment load within the Shields River watershed is 260,000 tons, with 155,000 tons being contributed from the upper Shields watershed (**Table 6-4**). The upper Shields watershed makes up roughly 63 percent of Shields watershed and contributes approximately 60 percent of total annual sediment load. The annual sediment load within the Potter Creek watershed is 14,000 tons (**Table 6-4**). Each source type has different seasonal loading rates and the relative percentage from each source category does not necessarily indicate its importance as a loading source. For instance, the roads and hillslope assessments focus on annual sediment loading whereas the bank erosion assessment is based on bank retreat rates associated with large flow events. Additionally, the different source assessment methodologies introduce differing levels of uncertainty, as discussed in the following section (**Section 6.4**). However, the modeling results for each source category, and the ability to proportionally reduce loading with the application of improved management practices (**Appendices D, E, and F**), provide an adequate tool to evaluate the relative importance of loading sources (i.e. subwatersheds and/or source types) and to focus water quality restoration activities for this TMDL analysis.

Table 6-4. Summary of Existing Sediment Loads (tons/year) from Unpaved Roads, Hillslope Erosion, and Bank Erosion

Source	Upper Shields (tons/year)	Lower Shields (tons/year)	Potter Creek Watershed (tons/year)
Unpaved Roads	155	280	11
Upland Erosion	88,000	157,000	5,700
Streambank Erosion	167,000	103,000	8,100
Total Load	**155,000**	**260,000**	**14,000**

6.4 Uncertainty

A degree of uncertainty is inherent in any study of watershed processes related to sediment. Limited field work was conducted for the modeling effort and best professional judgment was used in conjunction with regional data and literature values during model development. Incorporating local empirical data into future modeling efforts could help decrease uncertainty associated with source assessments. Sediment limitations in many streams in the Shields River TPA relate to a fine sediment fraction found on the stream bottom, while sediment modeling employed in the Shields River TPA examined all sediment sizes. In general, roads and uplands produce mostly fine sediment loads, while streambank erosion can produce all sizes of sediment. Additionally, the USLE hillslope assessment predicts total sediment loads that arrive at the subwatershed or watershed outlet, while the streambank erosion assessment estimates the sediment yield entering the stream along its continuum. Therefore, since sediment source modeling may under-estimate or over-estimate natural inputs due to selection of sediment monitoring sections and the extrapolation methods used, model results should not be taken as an absolutely accurate account of sediment production within each watershed. Instead, source assessment model results should be considered used as a tool to estimate sediment loads and make general comparisons of sediment loads from various sources.

Cumulatively, the source assessment methodologies address average sediment source conditions over long timeframes. Sediment production from both natural and human caused sources is driven by storm events. Pulses of sediment are produced periodically, not uniformly through time. Separately, each source assessments methodology introduces differing levels of uncertainty. For example, the road erosion method focuses on sediment production and sediment delivery locations from yearly precipitation events. The analysis did not include an evaluation of road culvert failures, which tend to add additional sediment loading during large flood events and would therefore increase the average yearly sediment loading if calculated over a longer time frame. Road loading also tends to focus in upper areas of watersheds where there is often limited hillslope or bank erosion loading. The bank erosion method focuses on both sediment production and sediment delivery and also incorporates large flow events via the method used to identify bank area and retreat rates. Therefore, a significant portion of the bank erosion load is based on large flow events versus typical yearly loading. The hillslope erosion model focuses primarily on sediment production across the landscape during typical rainfall years. Sediment delivery is partially incorporated based on distance to stream (**Appendix E**). The significant filtering role of near stream vegetated buffers (riparian areas) is not fully incorporated into the hillslope analysis, resulting in proportionally high modeled sediment loads from hillslope erosion relative to the amount of sediment actually delivered to streams.

Undersized culverts are also a potential sediment source, but were not assessed within the scope of this project. The risk of culvert failure is related to the frequency and size of storm events. Total failure can result in a large sediment pulse, but for undersized culverts, even smaller events can flush excess instream sediment downstream and cause culverts to become fish passage barriers. Due to the uncertainty associated with sediment source assessment modeling, **Section 8.0** includes a monitoring and adaptive management plan to account for uncertainties in the source assessment results.

SECTION 7.0
TMDLS, ALLOCATIONS, AND MARGIN OF SAFETY

7.1 TMDLs and Allocations

Based on the sediment source assessment, TMDLs and LAs will be developed for the Shields River and Potter Creek. A TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards. More specifically, a TMDL is the sum of waste load allocations (WLAs) for point sources and LAs for nonpoint sources and natural background sources. In addition, the TMDL includes a MOS that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving stream. The allowable pollutant load must ensure that the water body being addressed by the TMDL will be able to attain and maintain water quality standards regardless of seasonal variations in water quality conditions, streamflows, and pollutant loading. Because there are no point sources within the Shields River TPA, WLAs are excluded and TMDLs are expressed by the following equation:

$$\text{TMDL} = \Sigma\text{LA} + \text{MOS}$$

The sediment TMDL process presented in the main document for the Shields River TPA will adhere to this TMDL loading function, but use an average annual sediment yield source assessment, a percent reduction in loading allocated among sources, and an inherent MOS. A percent reduction approach is used because there is uncertainty associated with the loads derived from the source assessment, and using the estimated sediment loads creates a rigid perception that the loads are absolutely conclusive. A percent reduction allocation also considers the whole watershed as a source area and fits into a watershed wide water quality restoration planning approach. The TMDL for each 303(d) listed water body is expressed as an overall percent reduction in the sediment load and is derived from the sum of the percent reduction allocations to varying sources.

Because there are no point sources and sediment generally has a cumulative effect on beneficial uses, an annual expression of the TMDLs was determined as the most appropriate timescale to facilitate TMDL implementation. EPA encourages TMDLs to be expressed in the most applicable timescale, but also requires TMDLs to be presented as daily loads (Grumbles 2006); daily loads are provided in **Appendix G**.

7.1.1 Deriving Allocations

The percent reduction allocations are based on the modeled BMP scenarios for each major source type (i.e. unpaved roads, upland erosion, and streambank erosion) and reflect reasonable reductions as determined from literature, agency and industry documentation of BMP effectiveness, and field assessments. Percent reductions are expected to be achieved through a combination of BMPs, and the most appropriate BMPs will vary by site. The allocation for roads was determined by assuming 40% of roads would be upgraded without paving and the contributing length would be reduced at 60% of roads – this combination of BMPs is not a formal goal, but an example of how reductions can be achieved. Based on literature values of the effectiveness of upgrading roads and reducing contributing lengths, this combination would reduce the contribution from road sediment by 60%. The health of vegetation near the stream is a major factor in streambank stability and erosion rates, and was used to allocate to streambank erosion. Near bank vegetation condition and corresponding erosion rates at banks of varying stability were used to determine percent reductions that could be achieved by applying BMPs within the riparian zone. Allocations for agricultural upland sources were derived by modeling the reduction in sediment loads that will occur by increasing ground cover through the implementation of BMPs. Examples include providing off-site watering sources, limiting livestock access to streams, conservation tillage, precision farming, and establishing riparian buffers. The allocation to agricultural sources includes both present and past influences, and is not meant to represent only current management practices. Many of the restoration practices that address current land use will reduce pollutant loads that are influenced from historic land uses. Additional information regarding BMPs is contained in **Section 8.0** and **Appendices D, E, and F**.

7.2 Shields River

The Shields River was listed as impaired due to siltation on the 2006 303(d) List (segments MT43A001_012 and MT43A001_011). The sediment contribution from unpaved roads, hillslope erosion, and eroding banks was assessed using methods summarized in **Section 6.0** and detailed in **Appendices D, E, and F**. Based on the results of the source assessment, the primary anthropogenic sources are bank erosion and upland sources associated with agriculture.

7.2.1 Upper Shields River

The current estimated sediment load from the upper Shields (MT43A001_012) is 155,000 tons per year. Through the application of BMPs, it is estimated that the sediment load could be reduced by 42% per year (**Table 7-1**). This reduction could be achieved by an allocation to roads for a 60% reduction and an allocation to eroding banks for 39% reduction. The allocation for upland sources includes a 31% reduction in grazing and 80% reduction in cropland. Logging is currently a very small source of sediment (<1% of the total load), and logging activity is anticipated to remain at the current intensity. Therefore, there is no formal reduction in sediment from logging activities, but logging practices should be conducted according to Forestry BMPs for Montana (MSU Extension Service 2001) and the Montana Streamside Management Zone (SMZ) law (77-5-301 through 307 MCA). The total maximum daily sediment load for the upper Shields River is expressed as a 42% reduction in total average annual sediment load.

Table 7-1. Sediment Allocations and TMDL for the upper Shields River (MT43A001_012)

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment LAs
Roads		155	60% reduction
Eroding Banks		167,000	39% reduction
Upland Sediment Sources	**Silviculture**	780	0% reduction
	Grazing	57,000	31% reduction
	Cropland	25,000	80% reduction
	Natural Sources	5,600	0% reduction
Total Sediment Load/TMDL		155,000	42% reduction

* A significant portion of bank erosion loads after BMPs is a component of the “natural load”, though the assessment methodology didn’t differentiate between sediment loads with all reasonable BMPs and “natural” loads.

7.2.2 Lower Shields River

Loads for the lower Shields are cumulative and include sediment loads from the upper Shields. The current estimated sediment load from the lower Shields (MT43A001_011) is 260,000 tons per year. Through the application of BMPs, it is estimated that the sediment load could be reduced by 42% per year (**Table 7-2**). This reduction could be achieved by an allocation to roads for a 60% reduction and an allocation to eroding banks for 39% reduction. The allocation for upland sources includes a 36% reduction in grazing and 80% reduction in cropland. Logging is currently a very small source of sediment (<1% of the total load), and logging activity is anticipated to remain at the current intensity. Therefore, there is no formal reduction in sediment from logging activities, but logging practices should be conducted according to Forestry BMPs for Montana (MSU Extension Service 2001) and the Montana Streamside Management Zone (SMZ) law (77-5-301 through 307 MCA). **Figure 7-1** contains the existing loads and percent reductions by subwatershed. The total maximum daily sediment load for the Shields River is expressed as a 42% reduction in total average annual sediment load.

Table 7-2. Sediment Allocations and TMDL for the lower Shields River (MT43A001_011)

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment LAs
Roads		280	60% reduction
Eroding Banks		103,000	39% reduction
Upland Sediment Sources	**Silviculture**	1,700	0% reduction
	Grazing	110,000	36% reduction
	Cropland	35,000	80% reduction
	Natural Sources	9,400	0% reduction
Total Sediment Load/TMDL		260,000	42% reduction

* A significant portion of bank erosion loads after BMPs is a component of the “natural load”, though the assessment methodology didn’t differentiate between sediment loads with all reasonable BMPs and “natural” loads.

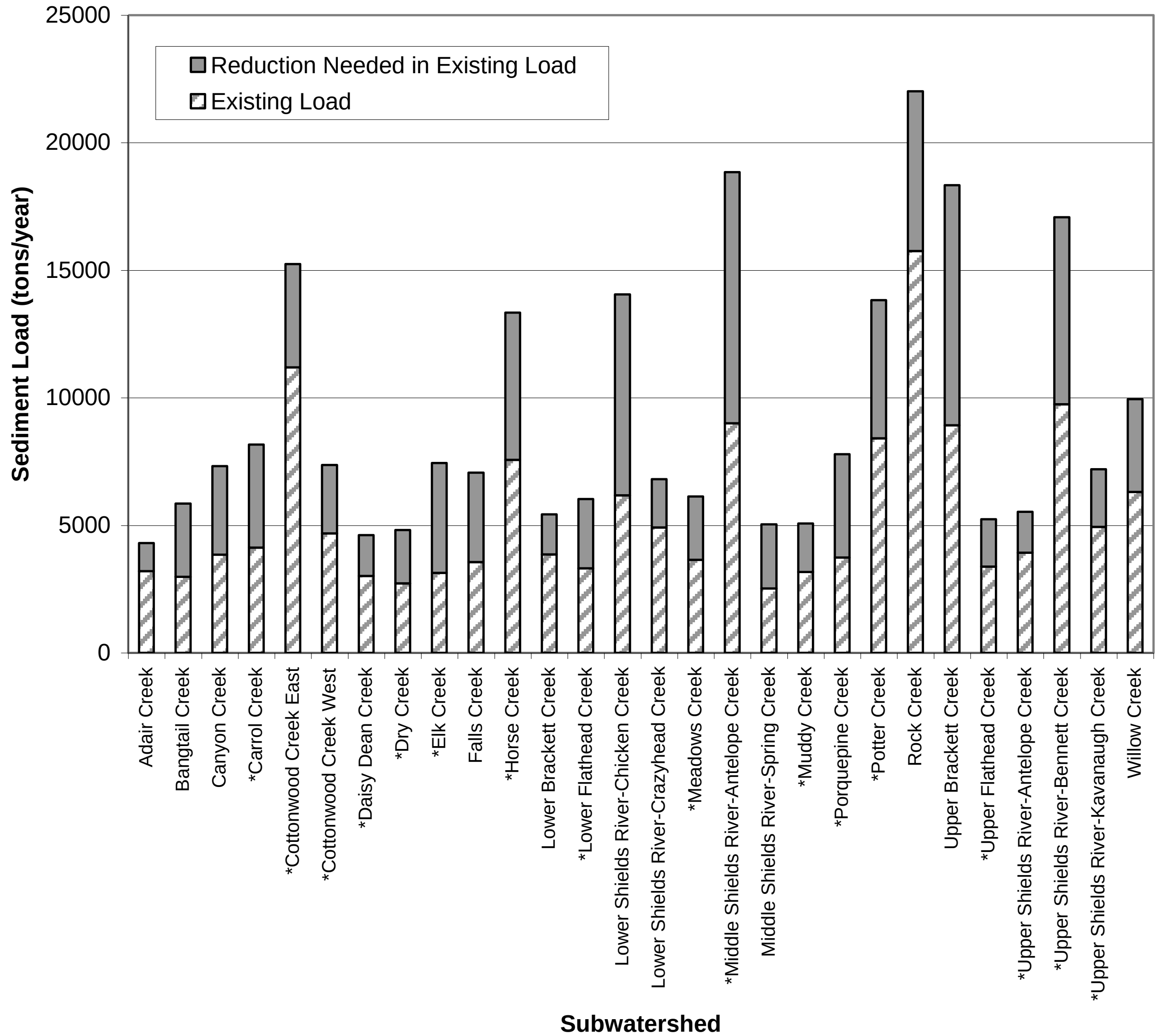

Figure 7-1. Existing Loads and Reductions Needed for Subwatersheds within the Shields River TPA. **Subwatersheds denoted with an asterisk (*) are within the upper Shields.**

7.3 Potter Creek

Potter Creek was listed as impaired due to siltation on the 2006 303(d) List (MT43A002_010). The sediment contribution from unpaved roads, hillslope erosion, and eroding banks was assessed. Based on the results of the source assessment, the primary anthropogenic sources are bank erosion and upland sources associated with agriculture. The current estimated sediment load is 14,000 tons per year. Through the application of BMPs, it is estimated that the sediment load could be reduced by 39% per year (**Table 7-3**). This reduction could be achieved by an allocation to roads for a 60% reduction and an allocation to eroding banks for 43% reduction. The allocation for upland sources includes a 19% reduction in sediment from grazing practices and a 78% reduction in sediment derived from cropland. The total maximum daily sediment load for Potter Creek is expressed as a 39% reduction in total average annual sediment load.

Table 7-3. Sediment Allocations and TMDL for Potter Creek (MT43A002_010)

Sediment Sources		Current Estimated Load (Tons/Year)	Potential Estimated Sediment Load with BMPs (Tons/Year)
Roads		11	60% reduction
Eroding Banks		8,100	43% reduction
Upland Sediment Sources	**Grazing**	4,200	19% reduction
	Cropland	1,500	77% reduction
	Natural Sources	17	0% reduction
Total Sediment Load/TMDL		14,000	39% reduction

* A significant portion of the remaining bank erosion loads after BMPs is also a component of the "natural load," though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

7.4 Future Growth and New Activities

There is potential for new sediment sources from future activities within the Shields River Watershed. Future developments within the Shields River Watershed may have a negative impact on beneficial use support of coldwater fisheries and aquatic life. Potential future development includes timber harvest, road construction and maintenance, subdivision development, and increased recreational pressure. Park, Meagher, and Gallatin Counties all have setback regulations in place for new subdivisions (DEQ, 2007) which should help limit encroachment onto streams and riparian areas. The GNF Travel Plan (USFS 2006a) discusses measures the USFS is taking to reduce existing and potential impacts to water quality from roads and recreational pressure within the GNF. Throughout the Shields River TPA, care should be taken to avoid practices such as road encroachment onto water bodies, the addition of riprap along stream banks, placement of undersized culverts, and the removal of LWD and riparian vegetation in the stream corridors. Other negative impacts with the potential to increase sediment loads may arise on a site specific basis. Future actions in the watershed that could increase sediment loads or further disturb stream channel sediment transport capacity should support the implementation strategy (**Section 8.1**) within this document and implement all reasonable land, soil, and water conservation practices to mitigate effects to beneficial uses of water bodies within the Shields River TPA.

7.5 Margin of Safety

Incorporating a margin of safety (MOS) is a required component of TMDL development. The margin of safety (MOS) accounts for the uncertainty between pollutant loading and water quality and is intended to ensure that load reductions and allocations are sufficient to sustain conditions that will support beneficial uses. The MOS may be applied implicitly by using conservative assumptions in the TMDL development process or explicitly by setting aside a portion of the allowable loading (EPA, 1999). This plan incorporates an implicit MOS in a variety of ways:

- The use of multiple targets to help verify beneficial use support determinations and assess standards attainment after TMDL implementation. Conservative assumptions were used during target development (see **Appendix C**).
- The use of supplemental indicators, including biological indicators, to help verify beneficial use support determinations and assess standards attainment after TMDL implementation. Conservative assumptions were used during supplemental indicator development (see **Appendix C**).
- The supplemental indicators may also provide an early warning method to identify pollutant-loading threats, which may not otherwise be identified, if targets are not met.
- Conservative assumptions were used for the source assessment process, including erosion rates, sediment delivery ratio, and BMP effectiveness (see **Appendices D, E, and F**).
- Standards, targets and TMDLs that address both course and fine sediment delivery.
- Consideration of seasonality (discussed in **Section 5.3**).
- The adaptive management approach evaluates target attainment and allows for refinement of load allocation, targets, modeling assumptions, and restoration strategies to further reduce uncertainties associated with TMDL development (discussed below and in **Section 8.6**).
- The use of "naturally occurring" sediment loads as described in ARM 17.30.602(17) (see **Appendix B**) to establish the TMDLs and allocations. This includes an allocation process that addresses all known human sediment causing activities, not just the significant sources.

7.6 Uncertainty and Adaptive Management

The source assessments used as the basis for the percent reduction allocation assessed all sizeable sediment sources, but a few small sources may have been overlooked because of budgetary and temporal limitations of the TMDL project. EPA sediment TMDL development guidance for source assessment states that the basic source assessment procedure includes compiling an inventory of all sources of sediment to the waterbody and using one or more methods to determine the <u>relative magnitude</u> of source loading, focusing on the primary and controllable sources of loading (EPA 1999). Additionally, regulations allow that loadings "...may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading," (Water quality planning and management, 40 CFR § 130.2(G)). If the allocations are followed, sediment loads are expected to be reduced to a degree that the sediment targets are met and beneficial uses are no longer impaired.

Because of the uncertainty in the source assessment, the allocations are established as percent load reductions rather than absolute load reductions. Sediment source assessment results are useful for determining the largest sources within each watershed and are useful, along with consideration of restoration costs, to determine an allocation strategy based on economic costs and environmental benefits. Due to current BMP implementation, allocated percent reductions may not be feasible at all locations. Conversely, the source assessment did not account for riparian buffers and associated reductions in sediment loading from upland erosion; the existing load from upland erosion may be lower due to current riparian conditions, and additional reductions will be achievable in many areas with the improvement of riparian buffers. Although the bank erosion assessment estimated percent reductions via improved riparian habitat, some eroding banks may require bank stabilization as well. Uncertainty in loading estimates is addressed through an adaptive management approach where the TMDL and allocations from this document can be revised as additional information is collected. Adaptive management is part of the MOS and requires long-term monitoring to track BMPs and track stream condition to determine if targets have been achieved. This approach allows management recommendations and practices to be revised if targets have not been met. Monitoring recommendations are detailed in **Section 8.0**.

The loads and allocations established in the document are meant to apply under median conditions of natural background and natural disturbance. Under some natural conditions, such as large wildfires or extreme flow events, it may not be possible to satisfy all targets, loads, and allocations. The goal is to ensure that management activities are undertaken to achieve loading approximate to the TMDLs within a reasonable time frame and to prevent significant excess loading during recovery from significant natural events.

Noticeable improvement in habitat and reduction in sediment loading will not occur until most types of restoration mechanisms or management based activities have been in place for several years or more. Habitat improvements due to grazing BMPs should be observable within 3 to 5 years after project implementation. Water quality improvement may not be noticeable within the first several years, as it may take up to 10 years for sediment to flush through the system, depending on flow management, climate, and the magnitude of excess deposition in different stream reaches. Therefore sediment reductions to meet the allocations will be a long-term goal.

SECTION 8.0
IMPLEMENTATION AND MONITORING STRATEGY

8.1 Introduction

This section includes the recommended restoration implementation and monitoring strategy for the Shields River TPA. Implementation of the restoration strategy and the continued and refined application of reasonable land, soil, and water conservation practices are expected to decrease pollutant loading to streams in the Shields River TPA. Implementation ensures that TMDL targets and Montana water quality standards are met over time, eventually resulting in full support of beneficial uses. The implementation strategy discusses BMPs by source type and implementation priorities. Although TMDLs specifically address pollutants and measures to reduce pollutant loading will often improve pollution issues, several BMPs within this section specifically address relevant sources of pollution included on the 2006 303(d) List (**Table 1-1**), such as flow and habitat alterations. Recommendations are based on the source assessment completed for this document as well as existing literature and stakeholder feedback. Just as the source assessment was performed at the watershed scale, TMDL implementation is expected to occur at the watershed scale and not be limited to the water body segments listed for sediment impairment.

A key component in the success of the implementation strategy is adaptive management. Adaptive management is essentially a loop in which restoration activities (i.e. BMPs) are implemented, monitoring is conducted to evaluate the success of restoration in meeting targets and supporting beneficial uses, and based on an assessment of monitoring results and lessons learned during implementation, adjustments are then made, if necessary, to the next phase of restoration.

A time element for nonpoint source restoration activities is not explicit in the document because most restoration projects rely upon public funding programs, local and private funding match, local efforts to apply for funds, and landowner participation. A time frame for restoration projects on public land is also not specified because annual budget fluctuations for the agencies are unpredictable. An objective of the TMDL project is to provide a tool to public land management agencies and private landowners to acquire funds for future restoration projects identified in the document. A list of watershed priorities as identified by the SVWG is contained in **Appendix H**.

The following are the primary goals of this restoration implementation strategy:

- Ensure full recovery of aquatic life beneficial uses to all impaired and threatened streams identified by the State of Montana within the Shields River TPA
- Avoid conditions where additional water bodies within the Shields River TPA become impaired
- Work with landowners and other stakeholders in a cooperative manner to ensure implementation of water quality protection activities

- Continue to monitor conditions in the watershed to identify any additional impairment conditions, track progress toward protecting water bodies in the watershed, and provide early warning if water quality starts to deteriorate

8.2 Role of DEQ

The DEQ does not implement TMDL pollutant reduction projects for most activities, but can provide technical and financial assistance for stakeholders interested in improving their water quality. The DEQ will work with participants to use the TMDLs as a basis for developing locally driven Watershed Restoration plans (WRP), administer funding specifically to help fund water quality improvement and pollution prevention projects, and can help identify other sources of funding. An implementation plan is usually part of a locally lead watershed restoration effort. The local implementation strategy, if developed, should consider the findings of the Shields River Watershed Water Quality Planning Framework and Sediment TMDLs and incorporate restoration approaches if feasible within the locally lead framework.

8.3 Agency and Stakeholder Coordination

Because most NPS reductions rely on voluntary measures, it is important that local landowners, watershed organizations, and resource managers continue to work collaboratively with local and state agencies to achieve water quality restoration and meet water TMDL targets and load reductions. Specific stakeholders and agencies that have been and will likely continue to be vital to restoration efforts include the SVWG (previously the Upper Shields Watershed Association and the Southern Crazy Mountain Watershed Group), Park County CD, USFS, NRCS, DNRC, FWP, and DEQ. Other organizations and non-profits that may provide assistance through technical expertise, funding, educational outreach, or other means include Montana Water Trust, Northern Plains Resource Council, Montana Water Center, University of Montana Watershed Health Clinic, and MSU Extension Water Quality Program.

8.4 BMP Recommendations by Source

General management recommendations are outlined for major sources of pollutants in the Shields River Watershed. BMPs form the foundation of the management recommendations, but are only part of the restoration strategy. Recommendations may also address evaluating current use and management practices. In some cases, a larger effort than implementing new BMPs may be required to address sources of impairment. In these cases BMPs are usually identified as a first effort, and an adaptive management approach will be used to determine if further restoration approaches are necessary to achieve all beneficial uses.

8.4.1 Agriculture

Agricultural BMPs include a wide range of management options for grazing and crop land that have broad application throughout the watershed. In general, these are sustainable agricultural practices that promote attainment of conservation objectives while meeting agricultural production goals. The BMPs aim to prevent availability, transport, and delivery of sediment by a combination of minimizing sediment delivery, reducing the rate of runoff, and intercepting sediment transport. The appropriate BMPs will differ by landowner and are recommended to be part of a comprehensive farm/ranch plan.

8.4.1.1 Grazing

The key strategy of the recommended grazing BMPs is to develop and maintain healthy riparian vegetation and minimize disturbance of the stream bank and channel. The primary recommended BMPs for the Shields River Watershed are providing off-site watering sources, limiting livestock access to streams and hardening the stream at access points, planting woody vegetation along stream banks, and establishing riparian buffers. Although bank revegetation is a preferred BMP, in some instances bank stabilization may be necessary prior to planting vegetation. Other general grazing management recommendations and BMPs to address grazing sources of pollutants and pollution are listed below (**Table 8-1**). Further information on grazing BMPs can be obtained from the sources listed in **Table 8-1** and in **Appendix A** of Montana's NPS Management Plan (DEQ, 2007).

Table 8-1. Example Grazing Best Management Practices.

BMP and Management Techniques	Sources
Design a grazing management plan and determine the intensity, frequency, duration, and season of grazing to promote desirable plant communities and productivity of key forage species.	MDNRC, 1999
Monitor livestock forage use and adjust grazing strategy accordingly.	MDNRC, 1999
Maintain adequate vegetative cover to prevent accelerated soil erosion, protect streambanks and filter sediments. Set target grazing use levels to maintain both herbaceous and woody plants. No grazing unit should be grazed for more than half the growing season of key species.	MDNRC, 1999 NRCS, 2002
Ensure adequate residual vegetative cover and regrowth and rest periods. Periodically rest or defer riparian pastures during the critical growth period of plant species.	MDNRC, 1999 Mosley et al., 1997
Distribute livestock to promote dispersion and decomposition of manure and to prevent the delivery of manure to water sources.	MDNRC, 1999
Alternate season of use from year to year in a given allotment or pasture.	MDNRC, 1999 NRCS, 2002
Time grazing to reduce impacts based on limiting factors for system recovery. For example, early spring use can cause trampling and compaction damage when soils and streambanks are wet. Fall and early winter grazing can encourage excessive browse on willows.	MDNRC, 1999 NRCS, 2002
Place salt and minerals in uplands, away from water sources (ideally ¼ mile from water to encourage upland grazing). Periodically rotate feed and mineral sites. Keep salt in troughs and locate salt and minerals in areas where soils are less susceptible to wind or water erosion.	MDNRC, 1999 Mosley et al., 1997
Create riparian buffer exclosures through fencing or develop riparian pastures to be managed as a separate unit through fencing. Fencing should be incorporated only where necessary. Water gaps can be included in riparian fencing.	MDNRC, 1999

8.4.1.2 Cropland

The primary strategy of the recommended cropland BMPs is to minimize the amount of erodible soil, reduce the rate of runoff, and intercept eroding soil before it enters water bodies. The main BMP recommendations for the Shields River Watershed are vegetated filter strips (VFS) and riparian buffers. Both of these methods reduce the rate of runoff, promote infiltration of the soil (instead of delivering runoff directly to the stream), and intercept sediment. Effectiveness is typically about 70% for filter strips and 50% for buffers (DEQ 2007). Filter strips and buffers are most effective when used in conjunction with agricultural BMPs that reduce the availability of erodible soil such as conservation tillage, crop rotation, stripcropping, and precision farming. Additional BMPs and details on the suggested BMPs can be obtained from NRCS and in **Appendix A** of Montana's NPS Management Plan (DEQ 2007).

8.4.2 Roads

Through the application of BMPs, it is estimated that the sediment load could be reduced by 57%. This road sediment reduction represents the estimated sediment load that would remain if 40% of the roads were upgraded by one level without paving (e.g. upgrading a native dirt road to a pitrun road) and all contributing road treads, cut slopes, and fill slopes were reduced on 60% of roads. This method of achieving a reduction in sediment load was selected as an example to illustrate the potential for sediment reduction through BMP application and is not a formal goal. Achieving this reduction in sediment loading from roads may occur through a variety of methods at the discretion of local land managers and restoration specialists. Road BMPs can be found on the Montana DEQ or DNRC websites and within Montana's NPS Management Plan (DEQ, 2007). Examples include:

- Providing adequate ditch relief up-grade of stream crossings.
- Constructing waterbars, where appropriate, up-grade of stream crossings.
- Instead of cross pipes, using rolling dips on downhill grades with an embankment on one side to direct flow to the ditch. When installing rolling dips, ensure proper fillslope stability and sediment filtration between the road and nearby streams.
- Insloping roads along steep banks with the use of cross slopes and cross culverts.
- Outsloping low traffic roads on gently sloping terrain with the use of a cross slope.
- Using ditch turnouts and vegetative filter strips to decrease water velocity and sediment carrying capacity in ditches.
- For maintenance, grading materials to the center of the road and avoiding removing the toe of the cutslope.
- Preventing disturbance to vulnerable slopes.
- Using topography to filter sediments; flat, vegetated areas are more effective sediment filters.
- Where possible, limit road access during wet periods when drainage features could be damaged.

8.4.2.1 Road Crossings

Although culverts were not part of the source assessment, they can be large sources of sediment, and should be included in the restoration strategy. A field survey should be conducted and combined with local knowledge to prioritize culverts for restoration. As culverts fail, they should be replaced by culverts that pass a 100 year flood on fish bearing streams and at least 25 year events on non fish bearing streams. Culverts should be at grade with the streambed, and inlets and outlets should be vegetated and armored. Some road crossings may not pose a feasible situation for upgrades to these sizes because of road bed configuration; in those circumstances, the largest size culvert feasible should be used.

Another consideration for culvert upgrades will be providing fish passage. Montana FWP is currently investigating ways to make the Chadborne irrigation diversion a complete barrier to rainbow trout while allowing genetically pure YCT to migrate upstream and throughout the Shields watershed. During the assessment and prioritization of culverts, additional crossings should be assessed for streams where fish passage is a concern. Because of the threat to Yellowstone cutthroat trout from non-native fish, each fish barrier should be assessed individually to determine if it functions as an invasive species and/or native species barrier. These two functions should be weighed against each other to determine if each culvert acting as a fish passage barrier should be mitigated. Montana FWP can aid in determining if a fish passage barrier should be mitigated, and, if so, it should be involved in culvert design. If funding is available, culverts should be prioritized and replaced prior to failure.

8.4.3 Irrigation and Flow Management

Irrigation and flow management is one of the biggest issues affecting water quality in the Shields River TPA. Three water bodies are on the 2006 303(d) List for flow alterations (**Table 1-1**), Shields River, Rock Creek, and Cottonwood Creek, and low flow regularly affects fisheries habitat in several other tributaries (Inter-Fluve 2001; Shepard 2004; FWP 2005). Increasing instream flows will not only improve fish and other aquatic life habitat, but will also increase the capacity of the Shields River and its tributaries to transport sediment. Local coordination and planning are especially important for flow management because State law indicates that legally obtained water rights cannot be divested, impaired, or diminished by Montana's water quality law (MCA 75-5-705).

Irrigation practices and water use efficiency have been studied within the Shields Watershed (Compston 2002; DNRC 2005). Some general recommendations from the studies include lining ditches with high seepage losses, installing measuring devices in ditches to better match need to usage, converting suitable areas to sprinkler irrigation, and changing points of diversion. Besides improving use efficiency and conveyance, water leasing can be used to promote water conservation and improve streamflow. Instream water leasing allows for the transfer of water rights from a consumptive use to instream flows to protect the fishery resource. Additionally, money earned from water leasing may help fund improvements to the irrigation network (Dolan, pers. comm., 2007). An appropriator may make a temporary change by simply changing the purpose and place of use, or by leasing the water right to another party. Entities that have programs for leasing water for instream flows include Montana FWP, Trout Unlimited, and the Montana Water Trust. Although Montana does not currently have the legal framework to allow water banking, it could be an additional option if the laws are modified in the future. Water banking allows a water right holder to move his right temporarily to a new use, new user, or new place of use within the same drainage and automatically revert to its original operation at the end of the temporary use. This practice transfers water, not water rights, and could be particularly useful during critical periods, such as drought or late-season. As with other BMPs, water conservation measures should be implemented on a case by case basis. In some instances, improving irrigation efficiency can reduce the amount of water returning to a stream and increase late-season demand (DNRC 2005); it is recommended that DNRC be consulted regarding projects to improve irrigation efficiency.

As a largely agricultural watershed containing unhybridized Yellowstone cutthroat trout, it is important to maximize water usage for both agricultural and aquatic life uses. This need is recognized by the SVWG and is included as a goal in its 2008 Work Plan (**Appendix H**). Because of the complexity of water usage and water rights, collaboration by stakeholders is very important. As recommended in the study by Dolan (2005), irrigators should develop a management plan for larger ditches within the Shields watershed (e.g. the Big Ditch) and also a drought plan. This level of organization will help irrigators to better manage water usage, track increased efficiency, identify areas that need improvement, and to ensure that efforts to save water for instream flow end up in the stream.

8.4.4 Other Issues

This section includes a discussion of issues that are not currently primary limiting factors to water quality, but are a consideration for long-term watershed management and restoration. All of the previous and following management issues are interrelated; therefore, a long-term holistic approach to watershed management will provide the most effective results.

8.4.4.1 Bank hardening/riprap/revetment/floodplain development

Bank hardening has historically occurred in several places throughout the watershed. Although it is necessary in some instances, it generally redirects channel energy and exacerbates erosion in other places. Bank armoring should be limited to areas with a demonstrated infrastructure threat. Where deemed necessary, apply bioengineered bank treatments to induce vegetative reinforcement of upper bank, reduce stream scouring energy, and provide shading and cover habitat. Limit infrastructure threats by reducing floodplain development through land use planning initiatives (e.g. the Park County Subdivision Regulations).

8.4.4.2 Logging

Currently, timber harvest is not significantly affecting sediment production in the Shields River TPA, but harvesting will likely continue in the future within the GNF and on private land. Future harvest activities should be conducted by all landowners according to Forestry BMPs for Montana (MSU Extension Service 2001) and the Montana SMZ Law (77-5-301 through 307 MCA). The Montana Forestry BMPs cover timber harvesting and site preparation, harvest design, other harvesting activities, slash treatment and site preparation, winter logging, and hazardous substances. While the SMZ Law is intended to guide commercial timber harvesting activities in streamside areas (i.e. within 50 feet of a water body), the riparian protection principles behind the law can be applied to numerous land management activities (i.e. timber harvest for personal use, agriculture, development). Prior to harvesting on private land, landowners or operators are required to notify the Montana DNRC. DNRC is responsible for assisting landowners with BMPs and monitoring their effectiveness. The Montana Logging Association and DNRC offer regular Forestry BMP training sessions for private landowners.

8.4.4.3 Noxious Weeds

Invasive weeds are a growing concern in the Shields River TPA and most areas of Montana. The Park County Extension Office and Park County Weed Board have been active in public education for noxious weeds and have sprayers available for free for public use (Park County Extension 2007). The Park County Weed Board has a weed plan that is updated annually, requires new subdivisions to develop a weed management plan, and encourages landowners to use biocontrol or large animal grazing. Also, the SVWG developed a noxious weed map in 2001 that it is in the process of updating (SVWG, pers. comm. 2008). The widespread effort to manage and combat noxious weeds across land ownership boundaries throughout the watershed should continue. NRCS and County Weed Management Specialists can provide information about weed management BMPs.

8.5 Restoration Priorities

It is important to note that while certain land uses and human activities are identified as sources and causes of water quality impairment, the management of these activities is of more concern than the activities themselves. This plan does not advocate for the removal of land uses or human activities to achieve water quality restoration objectives. It does however advocate for improving water quality and preventing degradation of water quality as a result of current or future land use management practices and human activities. As listed in **Tables 2-1** and **2-2**, management improvements have already been implemented by private landowners, USFS, and FWP in recent years in many parts of the watershed.

This document contains general restoration priorities; site-specific priorities will be determined by local landowners and stakeholders. A list of restoration priorities as identified by the SVWG is contained in **Appendix H** and will be used in conjunction with this document to guide restoration efforts by private landowners. As specific restoration sites are assessed, it is important to determine the underlying causes of problem areas and to address those during restoration implementation as well. Otherwise, time and resources may be spent to restore sediment source areas that will continue to be problem areas.

As discussed in **Section 5.3**, the effect of different sources can change seasonally and be dependent on the magnitude of storm/high flow events. Therefore, restoration activities within the Shields River Watershed should focus on all major sources – upland erosion, streambank erosion, and unpaved roads. For each major source, BMPs will be most effective as part of a management strategy that focuses on critical areas within the watershed, which are those areas contributing the largest pollutant loads or are especially susceptible to disturbance.

Although it is important to apply BMPs to all land management activities, the most critical area for hillslope erosion is within 350 feet of a water body (**Appendix E**). Therefore, activities that increase the health of riparian areas and reduce bank erosion, such as grazing BMPs and maintenance of riparian buffers or vegetative filter strips, can also substantially decrease sediment loading from hillslope erosion. This makes riparian and bank erosion protection BMPs the most effective method of reducing sediment loading throughout the majority of the Shields watershed.

For roads, the results of the source assessment (**Appendix D**) are a good starting point for locating the greatest sources of road erosion, but because of the amount of extrapolation in the model, a survey should be conducted to prioritize which roads (and culverts) should be improved. The field work conducted for the road assessment revealed numerous roads with long segments contributing sediment to water bodies. The most effective way to reduce sediment erosion from roads will be to focus on the longest road segments and the biggest problem areas.

8.6 Adaptive Management Approach

An adaptive management approach is recommended to manage costs as well as achieve success in meeting the water quality standards and supporting all beneficial uses. This approach works in cooperation with the monitoring strategy and allows for adjustments to the restoration goals (**Section 8.1**) or pollutant targets, TMDLs, and/or LAs, as necessary. These adjustments would take into account new information as it arises.

The adaptive management approach is outlined below:

- TMDLs and Allocations: The analysis presented in this document assumes that the load reductions proposed for each of the listed streams will enable the streams to meet target conditions and further assumes that meeting target conditions will ensure full support of all beneficial uses. Much of the monitoring proposed in this section of the document is intended to validate this assumption. If it looks like greater reductions in loading or improved performance is necessary to meet targets, then updated TMDL and/or allocations will be developed based on achievable reductions via application of reasonable land, soil, and water conservations practices.
- Water Quality Status: As restoration activities are conducted in the Shields River TPA and target and supplemental indicator variables move towards reference conditions, the impairment status of the 303(d) listed waterbodies is expected to change. An assessment of the impairment status will occur after significant restoration occurs in the watershed.

8.7 Monitoring Strategy

The monitoring plan discussed in this section and is an important component of watershed restoration, a requirement of TMDL development under Montana’s TMDL law, and the foundation of the adaptive management approach. While targets and LAs are calculated using the best available data, the data are only an estimate of a complex ecological system. The MOS is put in place to reflect some of this uncertainty, but other issues only become apparent when restoration strategies are underway. Having a monitoring plan in place allows for feedback on the effectiveness of restoration activities (whether TMDL targets are being met), if all significant sources have been identified, and whether attainment of TMDL targets is feasible. Data from long term monitoring programs also provide technical justifications to modify restoration strategies, targets, or LA where appropriate. Some field procedures have been revised since data collection for TMDL development; all future monitoring should adhere to standard DEQ protocols.

The monitoring strategy presented in this section is meant to provide a starting point for the development of more detailed and specific planning efforts regarding monitoring needs; it does not assign monitoring responsibility. It is expected that monitoring recommendations provided will assist local land managers, stakeholder groups, and federal and state agencies in developing appropriate monitoring plans to meet aforementioned goals.

8.7.1 Follow-up Monitoring

The primary focus of this section is to identify weak links in the existing source assessments. Since data collection for the source assessment, DEQ has modified several aspects of the procedure, including incorporating riparian buffer health into the hillslope model and better quantifying the contribution from bank erosion sources within the BEHI assessment. These modifications, as well as others identified by DEQ when follow-up monitoring commences, should be included if possible during follow-up monitoring. Strengthening source assessments should also include assessment of future sources as they arise. For example, CBM development is a concern for some stakeholders within the Shields River TPA, and there may be a future need for additional monitoring sites and targets to track CBM-associated changes to water quality. The extent of monitoring should be consistent with the extent of potential impacts, and can vary from basic BMP compliance inspections to establishing baseline conditions and measuring target parameters below the project area before the project and after completion of the project. Suggested monitoring parameters include sulfate, electrical conductivity, sodium adsorption ratio, and total dissolved solids. Cumulative impacts from multiple projects must also be considered. This approach will help track the recovery of the system and the impacts, or lack of impacts, from ongoing management activities in the watershed. Under these circumstances, additional targets and other types of water quality goals may need to be developed to address new stressors to the system, depending on the nature of the activity. If these new sources occur, new data should be used to update TMDL allocations.

Additional monitoring is recommended to gain a better understanding of natural sediment loading from mass wasting and streambank retreat rates. Particularly in the upper Shields Watershed, there are several very steep areas where mass wasting events have occurred. To better understand the link between sediment loading and in-stream conditions, it would be helpful to gain a better understanding of natural loading from mass wasting events. Streambank retreat rates are part of the equation for calculating sediment loading from near-stream sediment sources for sediment TMDLs and allocation. The current sediment TMDLs are calculated using literature values for streambank retreat rates. Measuring streambank retreat rates on water bodies within the Shields River TPA would be useful to verify or revise the current TMDLs and would also be useful for completing or revising sediment TMDLs in other watersheds throughout Montana in similar settings. Bank retreat rates can be determined by installing a series of bank pins at different positions on the streambank at several transects in sites placed in a range of landscape settings and stability ratings. Bank erosion is documented after high flows and throughout the year for several years to capture retreat rates under a range of flow conditions. Aerial photos may also be available to assist with tracking bank retreat rates (SVWG pers. comm. 2008).

The irrigation efficiency studies (Compston 2002; DNRC 2005) could be expanded upon to examine the effects of irrigation improvements, such as converting to sprinkler irrigation and installing ditch lining on surface and ground water. Additionally a feasibility study is needed to determine if the irrigation infrastructure can be modified to reduce irrigation returns and retain more instream flow. Because improving efficiency could diminish surface and groundwater return flows and possibly exacerbate dewatering issues in the watershed (DNRC 2005), caution should be used when implementing irrigation improvements. Therefore, once feasible irrigation improvements are identified and planned, additional monitoring should be conducted to quantify irrigation effects to ground water conditions and ultimately surface water before project implementation. Monitoring should be conducted before, during, and after water use periods for several years. As irrigation efficiency projects are implemented, effectiveness monitoring should occur to see how much water is saved by each project. An economic analysis of each irrigation efficiency project should also occur to determine the cost of the saved water. This effort would need local initiation and funding would likely come from both local match and also Federal and State sources.

Flow monitoring is also recommended for water bodies with chronic flow problems to determine minimum flows needed to support fish and other aquatic life. At a minimum, this is recommended for the Shields River, Cottonwood Creek, and Rock Creek, but should also be extended to other water bodies with low flow problems. Montana FWP can provide guidance and technical assistance for developing minimum flow requirements. The establishment of minimum flow requirements does not obligate landowners or infringe on water rights, but can be used as a tool to guide water management decisions during implementation of irrigation and water conservation BMPs.

In addition to affecting sediment transport, low flows can contribute to elevated water temperatures, which can diminish the ability of a water body to support fish and other aquatic life. Montana FWP has several years of temperature data throughout the watershed (Endicott, pers. comm.., 2008); DEQ should coordinate with FWP to incorporate temperature data into future 303(d) water quality assessments within the Shields TPA.

A study is also recommended on Potter Creek to examine alternatives for reducing bank erosion from outflows from Cottonwood Reservoir. Most problems on Potter Creek are downstream of the reservoir and without modifications to the timing and magnitude of reservoir releases, bank stabilization and riparian BMPs downstream of the reservoir will have limited effectiveness.

8.7.2 Implementation and Restoration Effectiveness

As defined by Montana State Law (75-5-703(9)), DEQ is required to evaluate progress towards meeting TMDL goals and water quality standards after implementation of reasonable land, soil, and water conservation practices. If this evaluation demonstrates that water quality standards and beneficial use support have not been achieved within five years, DEQ is required to conduct a formal evaluation of progress in restoring water quality and the status of reasonable land, soil, and water conservations practice implementation to determine if:

- The implementation of a new or improved phase of voluntary reasonable land, soil, and water conservation practices is necessary.
- Water quality is improving, but more time is needed for compliance with water quality standards.
- Revisions to the TMDL are necessary to achieve applicable water quality standards and full support of beneficial uses.

Although DEQ is responsible for TMDL-related monitoring, it is envisioned that much of it could occur under coordination with land managers and local interests. Implementation and restoration monitoring may include summaries of such items as the length of road upgraded to BMP standards, length of decommissioned roads, fish passage barriers corrected, or tracking riparian shade disturbances, as well as the estimated impact of these actions in terms of decreased pollutant loading or improved habitat. Restoration projects should be tracked by the coordinating agency and/or stakeholders. Recommendations for varying road and agricultural BMPs discussed in **Section 8.4** are provided below (**Table 8-2 and Table 8-3,** respectively). The recommendations provided are not an exhaustive list, and specific details of the implementation and restoration monitoring will be coordinated with local stakeholders and DEQ before future restoration activities occur. To ensure that TMDL implementation is effective in achieving full support of beneficial uses, this monitoring should be closely tied to target and supplemental indicator trend monitoring.

8.7.2.1 Road BMPs

Monitoring road sediment delivery is necessary to determine if BMPs are effective, to determine which are most effective, and to determine which practices or sites require modification to achieve water quality goals. Effectiveness monitoring should be initiated prior to implementing BMPs at treatment sites.

Monitoring actual sediment routing is difficult or prohibitively expensive. It is likely that budget constraints will influence the number of monitored sites. A detailed monitoring study design should be developed once specific restoration projects are identified. Monitoring at specific locations should continue for a period of 2-3 years after BMPs are initiated to overcome environmental variances.

Table 8-2. Monitoring Recommendations for Road BMPs

General Restoration Technique	Monitoring Recommendation	Recommended Methodology
Ditch Relief Culverts or Ditch Relief at Stream Crossings	• Place silt trap directly upslope of tributary crossing to determine mass of sediment routed to that point • Rapid inventory to document improvements and condition	• Sediment yield monitoring based on existing literature/USFS methods • Revised Washington Forest Practices Board methodology
Culvert upgrades	• Repeat road crossing inventory after implementation • Fish passage and culvert condition inventory	• Revised Washington Forest Practices Board methodology • Montana State (DNRC) culvert inventory methods
Improved Road Maintenance	• Repeat road inventory after implementation • Monitor streambed fine sediment (grid or McNeil core) and sediment routing to stream (silt traps) below specific problem areas	• Revised Washington Forest Practices Board methodology • Standard sediment monitoring methods in literature

8.7.2.2 Agricultural BMPs

Management improvements related to grazing, irrigation, and crop production have been implemented in many areas throughout the Shields River TPA. These projects often include monitoring specific to those projects. Additional monitoring is recommended below for future improvements and projects.

Grazing BMPs function to reduce grazing pressure along streambanks and riparian areas. Recovery resulting from implementing BMPs may be reflected in improved water quality, channel narrowing, cleaner substrates, and recovery of vegetation along streambanks and riparian areas. Effectiveness monitoring for grazing BMPs should be conducted over several years, making sure to start monitoring prior to BMP implementation. If possible, monitoring reaches should be established in pastures keeping the same management as well as in those that have changed. Where grazing management includes moving livestock according to riparian use level guidelines, it is important to monitor changes within the growing season as well as over several years. Monitoring recommendations to determine seasonal and longer-term changes resulting from implementing grazing BMPs are outlined below in **Table 8-3**.

Table 8-3. Effectiveness Monitoring Recommendations for Grazing BMPs by Restoration Concern.

Recovery Concern	Monitoring Recommendations	Methodology or Source
Seasonal impacts on riparian area and streambanks	Seasonal monitoring during grazing season using riparian grazing use indicators • Streambank alteration • Riparian browse • Riparian stubble height at bank and "key area"	BDNF/BLM riparian standards (Bengeyfield and Svoboda, 1998)
Long-term riparian area recovery	• Photo points • PFC/NRCS Riparian Assessment (every 5-10 yrs) • Vegetation Survey (transects perpendicular to stream and spanning immediate floodplain) every 5-10 years o Strip transects- Daubenmire 20cm x 50cm grid or point line transects	Harrelson et al., 1994; Bauer and Burton, 1993; NRCS, 2001 Stream Assessment Protocols
Streambank stability	Greenline (i.e. near bank vegetation) including bare ground, bank stability, woody species regeneration (every 3-5 years)	Modified from Winward, 2000
Channel stability	Cross-sectional area, with % fines/ embeddedness • Channel cross-section survey • Wolman pebble count • Grid or McNeil core sample	Rosgen, 1996; Harrelson et al., 1994
Aquatic habitat condition	• Aquatic macroinvertebrate sampling • Pool quality • R1/R4 aquatic habitat survey	DEQ biomonitoring protocols; Hankin and Reeves, 1988; USFS 1997 R1R4 protocols
General stream corridor condition	EMAP/Riparian Assessment (every 5-10 yrs)	NRCS 2001 Stream Assessment Protocols; U.S. EPA 2003.

8.7.3 Standards Attainment and Watershed Trends

This type of monitoring provides a broader perspective and addresses whether water quality standards are being met or if progress is being made towards achieving the standards. Because Montana's water quality standards for sediment are narrative and targets and supplemental indicators are used to translate the standards, targets and supplemental indicators must be assessed to determine if water quality standards are being attained. DEQ will be the lead agency for developing and conducting impairment status monitoring. Other agencies or entities may work closely with DEQ to provide compatible data if interest arises. Impairment determinations are conducted by the State of Montana, but can use data from other collection sources. As mentioned above, this monitoring should be closely tied to restoration effectiveness monitoring.

8.7.3.1 Targets and Supplemental Indicators

Specific water quality targets and supplemental indicators are detailed in **Section 5.0** and **Appendix C**. These targets are intended to reflect conditions that need to be satisfied to ensure protection and/or recovery of beneficial uses. Attainment of water quality targets represent a water quality condition unimpaired for sediment, and is based on the best available data and information regarding what constitutes attainment of sediment water quality standards in the Shields River TPA. Target indicators and values have been developed through evaluation of appropriate reference conditions, and their linkage to Montana's surface water quality standards for sediment (see **Section 4.0**). Evaluation of water quality target attainment consists of two components:

1. Evaluation of the appropriateness of established water quality targets through additional monitoring of reference conditions
2. Evaluation of target attainment

As primary water quality targets (percent surface fines, macroinvertebrates, and width-to-depth ratio) are based primarily on reference conditions thought to be appropriate for streams in the Shields River TPA, further monitoring of the target/indicator parameters in reference streams is needed to help increase confidence that the TMDL targets and supplemental indicator values best represent a translation of the narrative water quality standards for sediment (**Section 4.0**). The methods for determining reference conditions are described in **Appendix B**. As identified in Goal 3 of **Appendix H**, the SVWG would like to establish reference sites within the Shields River Watershed; DEQ will provide technical assistance.

In addition to further reference data collection for validation of established water quality targets, collection of water quality target parameter data will assist in evaluation of target attainment and impairment status. Sediment impairment determinations are based on a limited data set. Collection of primary target parameters (percent surface fines, macroinvertebrates, and width-to-depth ratio) at various locations throughout the Shields River and Potter Creek watersheds will allow a larger data set to be developed and may clarify the relationship between targets and impairment of beneficial uses. DEQ recommends that primary target parameters be collected annually at several established monitoring sites in order to evaluate attainment of water quality targets over time. The reduction of all preventable and significant anthropogenic sediment sources is a primary goal of this document. Accordingly, the TMDL implementation team will conduct 5-year inventories of these sources and will track progress towards meeting this goal.

Other parameters that may be measured for TMDL-related monitoring or impairment status monitoring include the frequency of pools and LWD, sinuosity, proper function condition assessments (PFC), algal bioassessments, and fish population dynamics (particularly for Yellowstone cutthroat trout). The siltation index is currently being revised by DEQ, but may be a good parameter to measure in the future as it is directly related to aquatic life support. Subsurface sediment may also be collected as most literature values regarding fisheries survival and fine sediment are for subsurface sediment collected with a McNeil core sampler, and existing sediment data within the Shields River TPA are for surface sediment. Although there is a relationship between the percentage of subsurface sediment and surface sediment (Platts et al. 1989), the relationship varies and DEQ is currently conducting method comparisons to determine how variable the relationship is within Montana.

8.7.3.2 Watershed Trends

Monitoring should be conducted at a watershed scale over several years to determine if restoration activities are improving water quality, instream flow, and aquatic habitat and communities. Because whirling disease is a growing concern for YCT and its severity is associated with sediment and organic enrichment, it may be useful to compare effectiveness monitoring results in areas of BMP implementation to trends in whirling disease occurrence and severity within the watershed. It is important to remember that degradation of aquatic resources happens over many decades and that restoration is also a long-term process. Long-term monitoring should be an understood component of any restoration effort.

Trends in water quality are difficult to define, and even more difficult to relate directly to restoration or other changes in management, due to the natural high variability in water quality conditions. Improvements in water quality or aquatic habitat resulting from restoration activities on listed streams are most likely to be evident in increases in instream flow, changes in communities and distribution of fish and other bioindicators, improvements in bank stability and riparian habitat, changes in channel cumulative width/depths, fine sediment deposition, and channel substrate embeddedness. Because targets may be adjusted in the future as the relationship between targets and beneficial use impairment is refined, values that are currently well below the target, such as fine sediment in riffles, should be included in trend monitoring. Specific monitoring methods, priorities, and locations will depend heavily on the type of restoration projects implemented, landscape or other natural setting, the land use influences specific to potential monitoring sites, and budgetary and time constraints. Three priority watershed scale monitoring sites should be located within the Shields River Watershed (**Table 8-4**); these are existing DEQ sites located in the upper, middle, and lower part of the watershed.

Table 8-4. Sampling Locations to Monitor Watershed Trends

Site location	Latitude	Longitude
Shields River below Hill Rd bridge	46.16608	-110.569
Shields River below Indian Creek Rd bridge	45.95583	-110.634
Shields River near mouth and Livingston	45.72639	-110.464

SECTION 9.0
STAKEHOLDER AND PUBLIC COMMENTS

Stakeholder and public involvement is a component of TMDL planning efforts supported by EPA guidelines and Montana State Law. Public comment on the Shields River Watershed TMDL involved two components. First, stakeholders (including private landowners, conservation groups, and agency representatives) were kept abreast of the TMDL process through periodic meetings, and were provided opportunities to review and comment on technical documents, including a stakeholder draft. In addition, presentation of the key components of the TMDL plan at a meeting for the Upper Shields Watershed Group in Wilsall, Montana, on January 21, 2008, provided an additional forum for disseminating information on the TMDL to those living and working in the watershed. Stakeholder comments and concerns were incorporated into the next draft, the public review draft.

The second component of public involvement was the 30-day public comment period. This public review period was initiated on June 2, 2008 and extended to July 2, 2008. A public meeting on June 12, 2008 in Clyde Park, Montana provided an overview of the Shields River Watershed Water Quality Planning Framework and Sediment TMDLs and an opportunity to solicit public input and comments on the plan. This meeting and the opportunity to provide public comment on the draft document were advertised via a press release by DEQ and was included in a number of local newspapers. Copies of the main document were available at the Park County Conservation District, Livingston-Park County Public Library, and via the internet on DEQ's web page or via direct communication with the DEQ project manager.

Appendix J includes a summary of the public comments received and the DEQ response to these comments. The original comment letters are located in the project files at DEQ and may be reviewed upon request.

DEQ also provides an opportunity for public comment during the biennial review of the Montana's Integrated Water Quality Report that includes the 303(d) List. This includes public meetings and opportunities to submit comments either electronically or through traditional mail. DEQ announces the public comment opportunities through several media including press releases and the Internet.

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ACRONYMS

Acronym	Meaning
AGNPS	Agricultural Nonpoint Source Model
ANSWERS	Areal Nonpoint Source Watershed Environment Response Simulation Model
ARM	Administrative Rules of Montana
BDNF	Beaverhead-Deerlodge National Forest
BEHI	Bank Erodibility Hazard Index
BER	Board of Environmental Review
BLM	Bureau of Land Management, United States
BMP	Best Management Practice
CBM	Coal bed methane
CD	Conservation District
CFR	Code of Federal Regulations
cfs	Cubic Feet Per Second
CWA	Clean Water Act
CWMA	Cooperative Weed Management Area
DEM	Digital Elevation Models
DEQ	Department of Environmental Quality, Montana
DEQ-7	Circular DEQ-7, Montana Water Quality Standards
DNRC	Department of Natural Resources and Conservation
DOQQ	USGS Digital Orthophoto Quarter Quad
EPIC	Erosion Productivity Impact Calculator
EPA	Environmental Protection Agency
FWP	Fish Wildlife and Parks, Montana Department of
GIS	Geographic Information Systems
GNF	Gallatin National Forest
GWLF	Generalized Watershed Loading Functions
HUC	Hydrologic Unit Code
LA	Load Allocation
LS	length and slope
LWD	Large Woody Debris
MAES	Montana Agricultural Extension Service
MCA	Montana Code Annotated
MDEQ	Montana Department of Environmental Quality
MMI	Multi-Metric Index
MOS	Margin of Safety
MPDES	Montana Pollutant Discharge Elimination System
MSU	Montana State University
NAIP	National Agriculture Imagery Program
NBS	Near Bank Stress
NF	National Forest
NHD	National Hydrography Dataset
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPS	Nonpoint Source Pollution

NRCS .... Natural Resource Conservation Service
NRIS .... Natural Resource Information Services
O/E .... Observed/Expected
PFC .... Proper Functioning Condition (Riparian)
PRISM .... Parameter-elevation Regressions on Independent Slopes Model
RIVPACS .... River Invertebrate Prediction and Classification System
SCAS .... Spatial Climate Analysis Service
SCD .... Sufficient Credible Data
SCS .... Soil Conservation Service
SDR .... Sediment Delivery Ratio
SMZ .... Streamside Management Zones
SNOTEL .... Snowpack Telemetry
STATSGO .... State Soil Geographic Database
SSURGO .... Soil Survey Geographic Database
SVWG .... Shields Valley Watershed Group
SWAT .... Soil Water Assessment Tool
TIGER .... Topologically Integrated Geographic Encoding and Referencing
TM .... Thematic Mapper
TMDL .... Total Maximum Daily Loads
TPA .... TMDL Planning Area
TSS .... Total Suspended Solids
UAA .... Use Attainability Assessment
USDA .... United State Department of Agriculture
USFS .... United States Forest Service
USGS .... United States Geological Survey
USLE .... Universal Soil Loss Equation
VFS .... Vegetated Filter Strips
VM .... Vegetation Management
W/D Ratio .... Width to Depth Ratio
WARSEM .... Washington Road Surface Erosion Model
WQA .... Water Quality Act
WLA .... Waste Load Allocation
WQB-7 .... Circular DEQ-7, Montana Water Quality Standards
WQPB .... Water Quality Planning Bureau
WQS .... Water Quality Standards
WRP .... Watershed Restoration Plans
YCT .... Yellowstone cutthroat trout