APPENDIX D - LITTLE BLACKFOOT RIVER WATERSHED SEDIMENT AND NUTRIENT ASSESSMENT

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ACRONYMS

Acronym	Definition
AFO	Animal Feeding Operation
AMSL	Above Mean Sea Level
ArcSWAT	ArcView (GIS) Extension of SWAT
ARS	Agricultural Research Service
BMP	Best Management Practice
cfs	cubic feet per second (a unit of flow)
cms	cubic meters per second (a unit of flow)
DEQ	Department of Environmental Quality (Montana)
DNRC	Department of Natural Resources & Conservation
EPA	Environmental Protection Agency (US)
GIS	Geographical Information System
ha	Hectares (a unit of area)
HNF	Helena National Forest
HUC	Hydrologic Unit Code
MDOT	Montana Department of Transportation
MUSLE	Modified Universal Soil Loss Equation
NCDC	National Climatic Data Center
NED	National Elevation Dataset
NHD	National Hydrography Dataset
NLCD	National Land Cover Dataset
NO3	Nitrate/Nitrite
NRCS	Natural Resources Conservation Service
NSE	Nash-Sutcliffe Coefficient of Efficiency
QUAL2E	River and Stream Water Quality Model
RE	Relative Error
SCS	Soil Conservation Service
SNOTEL	NRCS Snowpack Telemetry
STATSGO	State Soil Geographic Database
SWAT	Soil and Water Assessment Tool (model)
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TPA	TMDL Planning Area
TSWQC	Tri-State Water Quality Council
UM	University of Montana
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
USLE C	Universal Soil Loss Equation Cover Factor
WWTP	Wastewater Treatment Plant

D1.0 INTRODUCTION

The Little Blackfoot River watershed is located in western Montana within the Clark Fork River watershed (**Figure D1-1**). The Little Blackfoot River and eight tributaries are characterized as "water quality-limited" from sediment or nutrient impairment (**Table D1-1**). To satisfy Federal Clean Water Act requirements, Total Maximum Daily Loads (TMDLs) must be developed for these waterbodies such that they support beneficial uses. The Montana Department of Environmental Quality (DEQ) has determined that a modeling approach will be the most effective way to identify existing nonpoint source loads in the watershed, and complete equitable allocations between those sources as part of the TMDL. As such, a Soil and Water Assessment Tool (SWAT) watershed model has been prepared to account for watershed-scale loadings of sediment and nutrients, and to calculate associated fate and transport in the channel network.

The tool will be used for a number of TMDL planning purposes including (1) evaluating baseline conditions in the watershed, (2) partitioning between nonpoint sources, (3) allocating sediment and nutrients for TMDL development, (4) formulating water quality restoration plans, and (5) prescribing management and land use scenario changes within the Little Blackfoot River watershed to meet TMDL objectives.

A list of the reaches evaluated as part of this project is provided in **Table D1-1**, and these reaches are shown in **Figure D1-2**.

Table D1-1. Water quality limited segments in the Little Blackfoot River watershed

Waterbody Name	Reach Segment	TMDL Developed*
Carpenter Creek	MT76G004_092	TP
Dog Creek (upper)	MT76G004_071	Sediment
Dog Creek (lower)	MT76G004_072	Sediment/TP
Elliston Creek	MT76G004_040	Sediment
Little Blackfoot River (upper)	MT76G004_020	Sediment
Little Blackfoot River (lower)	MT76G004_010	Sediment/TP
Snowshoe Creek	MT76G004_080	Sediment/NO3-NO2
Spotted Dog Creek (lower)	MT76G004_032	Sediment/TP
Telegraph Creek (upper)	MT76G004_051	Sediment
Threemile Creek	MT76G004_112	Sediment/TN/TP
Trout Creek	MT76G004_120	Sediment

*TN: Total Nitrogen, TP: Total Phosphorus, NO3-NO2: Nitrate plus Nitrite

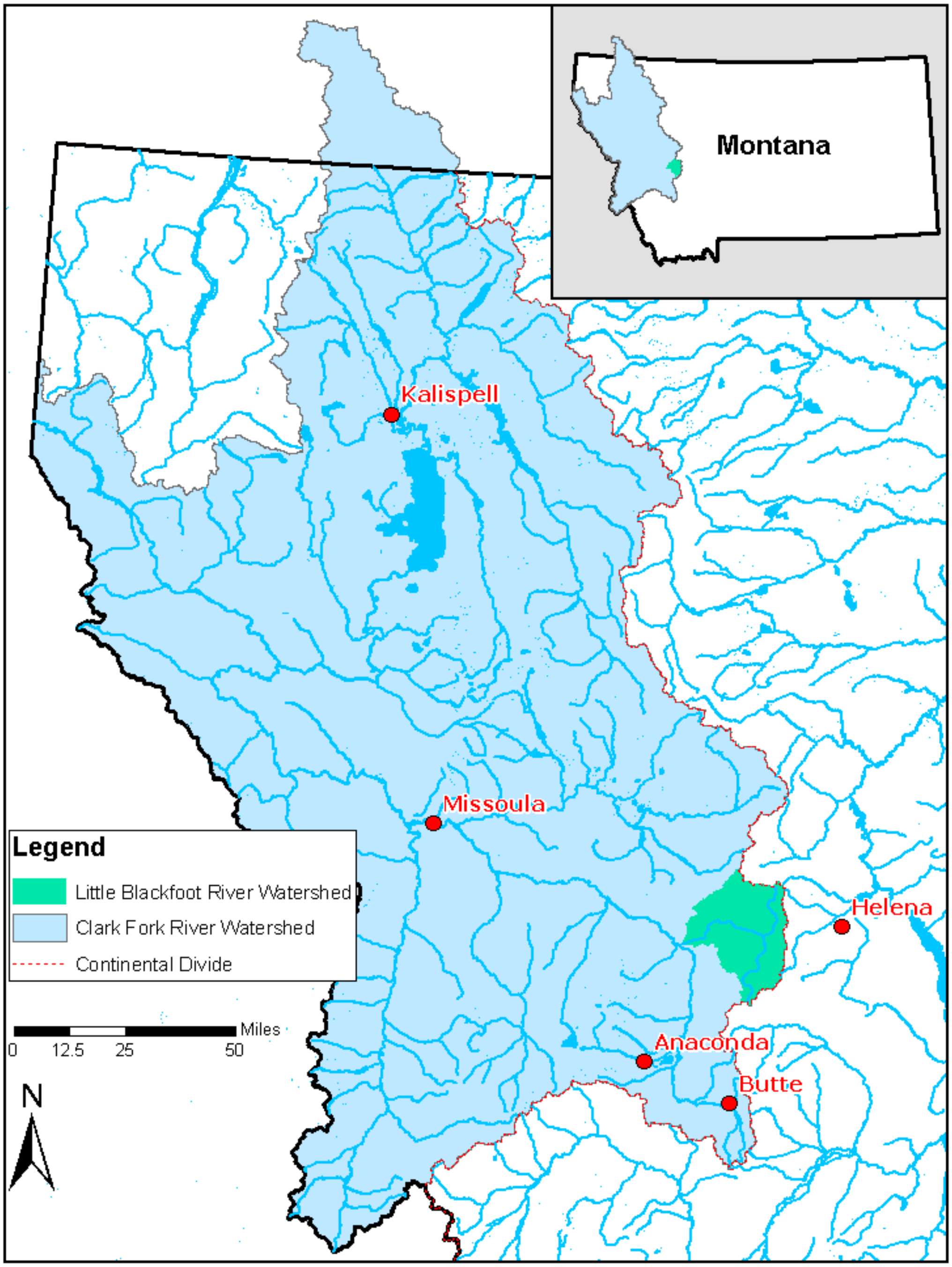


Figure D1-1. The location of the Little Blackfoot River watershed within Montana

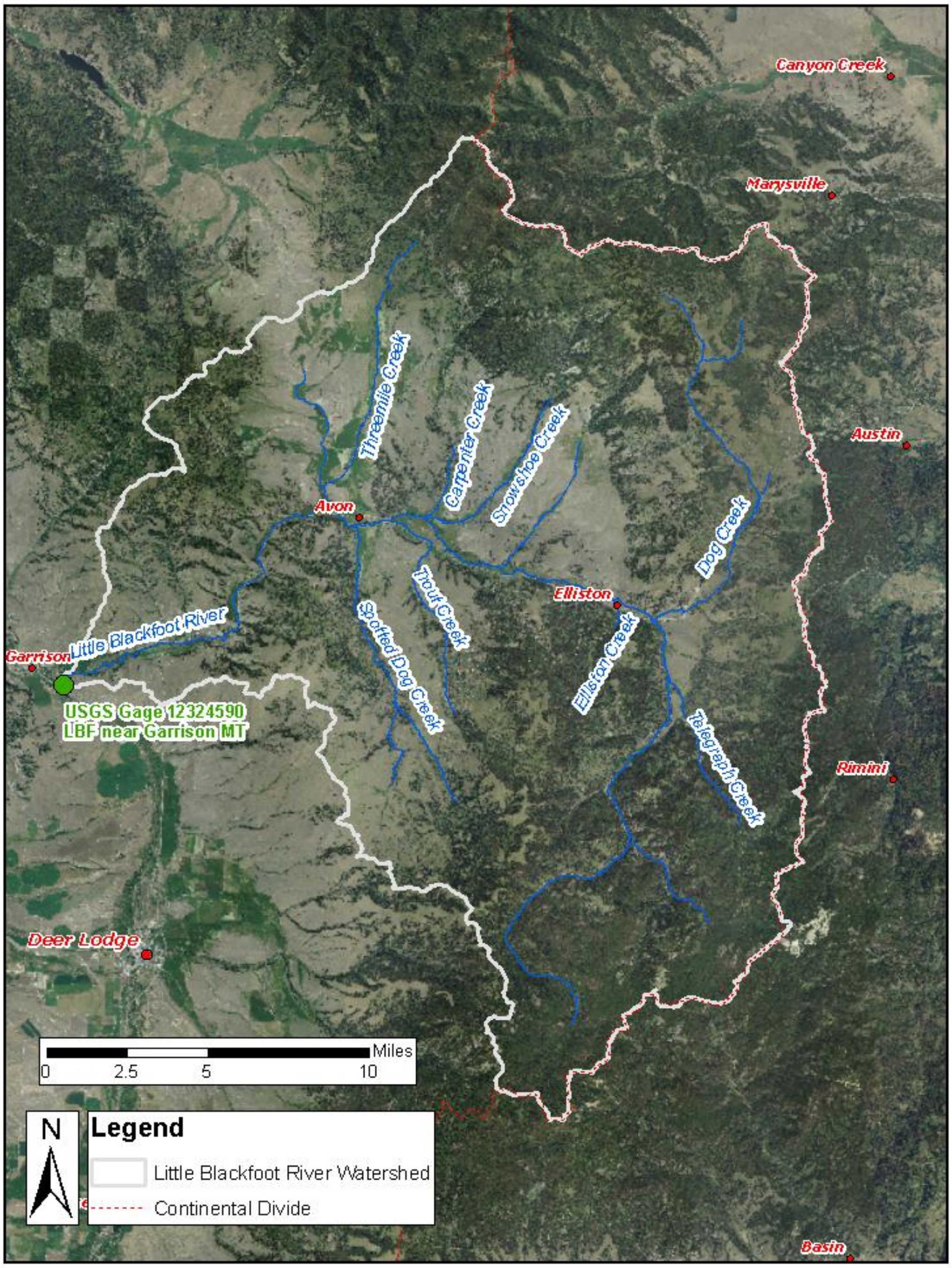


Figure D1-2. The Little Blackfoot River watershed with 303(d) listed streams identified

D1.1 Prior Studies

There have been several prior studies specific to the Little Blackfoot River watershed, all of which were reviewed for development of this model. These include:

- Flow Study on the Lower Little Blackfoot River (Barnes, 2008)
- Hydrogeochemistry of a Natural Wetland Receiving Acid Mine Drainage (Milodragovich, 2003a)
- Little Blackfoot River Groundwater/Surface Water Interaction Study (PBS&J, 2009)
- Plant-Metal Interactions in a Natural and Remediated High Elevation Metal-Contaminated Wetland (Olsen, 2004a).
- Road Sediment Assessment & Modeling Little Blackfoot River TPA (Water & Environmental Technologies, 2010)
- Sediment and Habitat Data and Bank Erosion Assessment (PBS&J, 2010)

D1.2 REPORT UNITS

Units used by SWAT (and reported here) are in the metric system. All units are clearly labeled in the report, but useful conversions are listed below. Many of the units were converted to English units in the actual TMDL report.

1 cubic meter per second (cms) = 35.3 cubic feet per second (cfs)
1,234.0 cubic meters = 1 acre-foot
1 degree Celsius (C) = 1.8 degrees Fahrenheit (F)
1 hectare (ha) = 2.47 acres (ac)
1 kilogram (kg) = 2.205 pounds (lbs)
1 metric ton (mT) = 1.102 short tons (tons)
25.4 millimeters (mm) = 1 inch (in)
2.59 square kilometers (sqkm) = 1 square mile (sqmi)

D2.0 DATA COMPILATION AND ASSESSMENT

A variety of different climatic, flow, water quality, and spatial geographic information system (GIS) data were reviewed and evaluated for use in SWAT model development. These details are briefly overviewed below.

D2.1 WATERSHED DESCRIPTION

The Little Blackfoot River is located in western Montana and flows west from the continental divide near Helena, Montana to Garrison, Montana, where it joins the Clark Fork River (**Figure D1-2**). The watershed is approximately 265,000 acres (107,000 hectares) in size, with 48 miles of mainstem river originating in the Boulder Mountains in the southeast. The continental divide runs along the southern, eastern, and northern borders of this watershed. Elevations in the watershed range from approximately 4,300 to 5,500 feet above mean sea level (AMSL) in the valley to mountain peaks over 8,500 feet AMSL. The average annual precipitation ranges from 10 to 20 inches in the valleys to approximately 30 to 50 inches in the mountains.

D2.2 CLIMATE

Climate in the Little Blackfoot River watershed is inter-montane with distinct seasonality. Valleys tend to be moderately arid while mountainous regions are moderately wet. Annual average precipitation is estimated to be 22 inches basin-wide, with significant spatial variability. Snowfall in the surrounding mountains is moderate, with snowpacks rarely exceeding 72 inches (six feet), although this varies significantly from year to year.

Climate data was obtained from seven weather stations in close proximity to the watershed (**Figure D2-1**). Daily precipitation, temperature, wind speed, solar radiation, and relative humidity were obtained from the Deer Lodge AgriMET Site (Coop ID DLRM), while daily precipitation and temperature were acquired from five of the remaining National Climatic Data Center (NCDC) and NRCS Snow Telemetry (SNOTEL) stations (**Table D2-1**). The MDOT Garrison weather station did not collect precipitation, and thus was used for temperature data only. Only one of the climate stations was located within the watershed (Elliston), with the rest being located in the surrounding area. Although there are other nearby stations, only these had a complete (or nearly complete) data set for the time frame included in the model. The modeling period (1999 through 2008) was chosen because it had the most climatic, hydrologic, and water-quality data available.

Table D2-1. Weather stations used in the Little Blackfoot River watershed model

Location	Station Type	Average Annual Precipitation (in)	Avg Annual Max Temp (F)	Avg Annual Min Temp (F)	Elevation (ft AMSL)	Avg. Max Snow Pack (in)
Austin	NCDC	16.2	52.7	30.0	4,999	-
Deer Lodge	NCDC	11.2	55.3	28.1	4,848	-
Elliston	NCDC	16.7	54.9	26.7	5,075	-
Frohner	SNOTEL	23.7	48.9	29.0	6,479	34.2
Nevada	SNOTEL	28.0	46.1	30.0	7,020	54.2
Rocker	SNOTEL	29.9	43.9	26.8	7,998	59.3
Garrison	MDOT	-	57.6	30.4	4,327	-

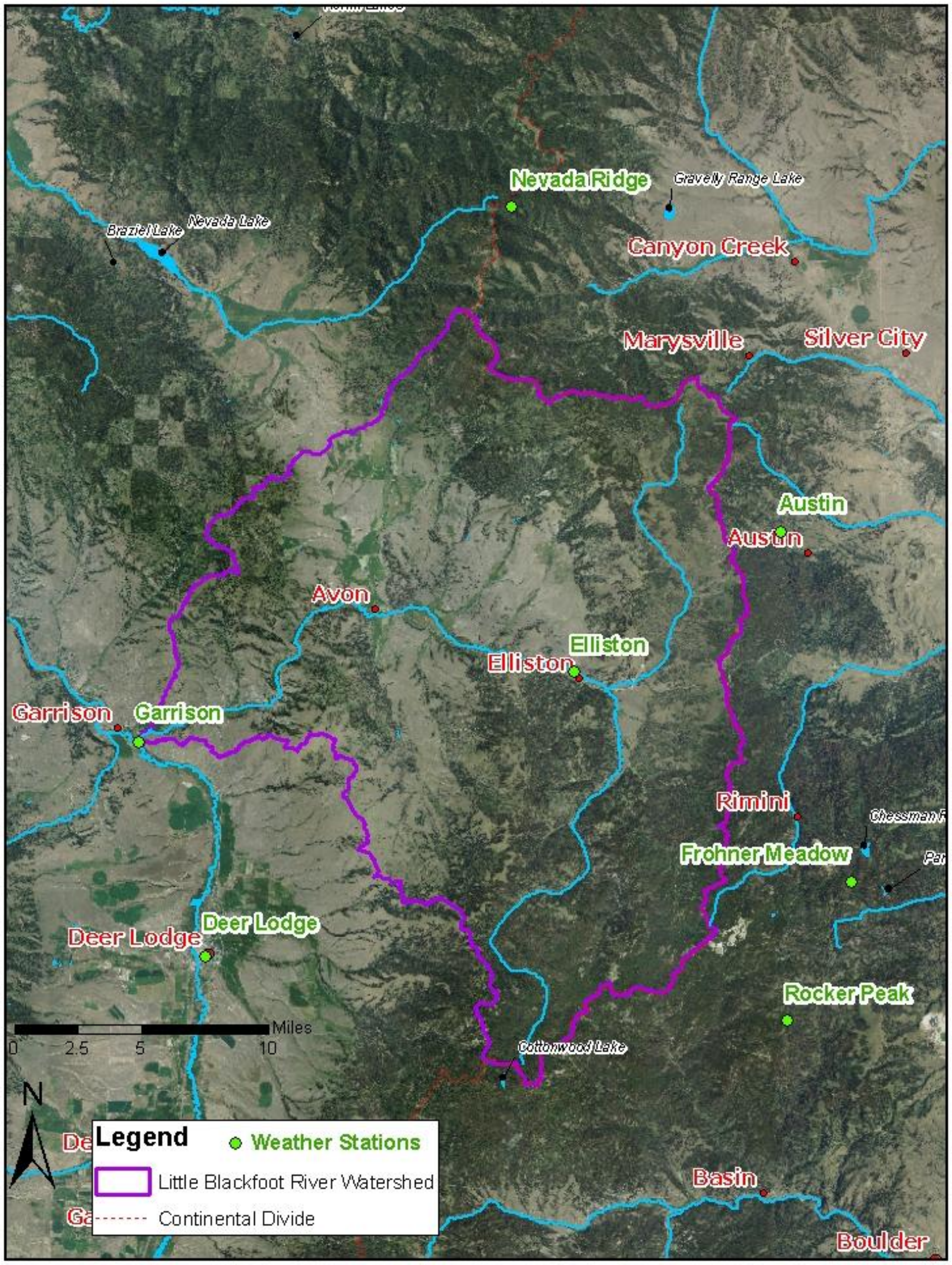


Figure D2-1. Location of weather stations used in the Little Blackfoot River watershed model

D2.3 Streamflow Hydrology

The hydrology of the Little Blackfoot River is a complex interconnection of tributaries from the surrounding mountains, groundwater recharge and discharge, wetlands, irrigation diversions, and other human withdrawals and discharges. Streamflow is monitored by the United States Geological Survey (USGS) at a single location at the outlet of the Little Blackfoot River (USGS #12324590 Little Blackfoot River near Garrison, MT). Based on nearly 40 years of available streamflow records for this gage (1972-2011), the average annual discharge for the river is approximately 155 cubic feet per second (cfs), ranging from a low of 6.5 cfs (8/23/1977) to a high of 6,280 cfs (5/22/1981). The onset of runoff routinely begins in early April, reaching peak approximately the last week of May, and is typically back to baseflow conditions by August 1st (**Figure D2-2**).

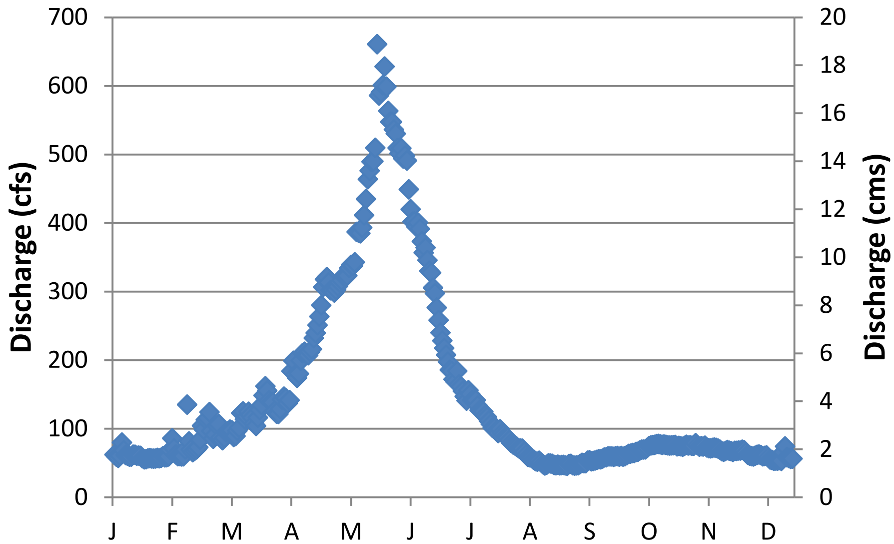


Figure D2-2. Average annual hydrograph (1979-2009), Little Blackfoot River (USGS gage #12324590)

There are approximately 1,500 – 2,000 active water rights within the Little Blackfoot River watershed, of which about half are for surface water (Montana Department of Natural Resources and Conservation, 2011). Numerous irrigation diversions are present and range from small one-field diversions on tributaries to larger mainstem diversions. The exact amount of water diverted from the Little Blackfoot River is difficult to determine because individual records are not kept, although if all water rights in the watershed were exercised to their fullest, they would exceed the typical summer flows in the Little Blackfoot River.

There are three reservoirs in the Little Blackfoot River watershed. These reservoirs are used primarily for irrigation. One reservoir is located on Snowshoe Creek, one is located on Spotted Dog Creek, and a third smaller one is located on Threemile Creek (Quigley Reservoir). Inflow to each reservoir depends on the amount of water accumulated in the mountain snowpack, temperatures during snowmelt, and spring precipitation. Reservoir releases are primarily based on satisfying downstream irrigation uses. These reservoirs are discussed further in **Section D3**.

D2.3.1 Available Data

Streamflow and water quality data are required components for sediment and nutrient model calibration. Those available to DEQ in 2010 were used in the modeling process. Data were reviewed with particular focus on recent data (1990 through 2009) for model construction and development. This data is considered most relevant as it is coincident with the landcover that will be used for the model (the 2001 National Land Cover Data [NLCD]). Key data included the following:

- Flow
- Sediment
- Nutrients
    - Total phosphorus (TP)
    - Soluble phosphorus or orthophosphate (OP)
    - Total nitrogen (TN)

- Nitrate/nitrite (NO_3/NO_2)

Data was acquired from several agencies including the USGS, United States Forest Service (USFS), Tri-State Water Quality Council (TSWQC), the University of Montana (UM), and the DEQ. Water quality data were collected by the USGS at the USGS station described in **Section D2.3**. A majority of the non-USGS data is for the period 1998 through 2005. USGS data collection ranges from the 1970s through the current period. All sampling was generally sporadic throughout the period.

Available data for calibration and validation of the Little Blackfoot SWAT model are identified in **Table D2-2.** This includes the location, overall period of record, and frequency of sampling for each data type (flow, sediment, and nutrients).

Table D2-2. Available data for calibration and validation of SWAT in the Little Blackfoot River

Location	Period of Record		Frequency of Sampling	
USGS 12324590 Little Blackfoot River near Garrison, MT	Flow Sediment Nutrients	1972-current 1978-2010 1978-2010	Flow Sediment Nutrients	Daily Intermittent Intermittent
Mouth of Little Blackfoot River	Sediment Nutrients	1990s-present 1990s-present	Sediment Nutrients	Intermittent Intermittent
Little Blackfoot River nr Telegraph Creek	Flow	2009-2010	Flow	Daily

Comparing the water quality sample dates with the flow data is valuable for assessing whether or not the water quality sampling was largely completed during low flow periods, or whether the data represent a range of flows from high to low. Flow data for the sediment and nutrient data used to calibrate the model are plotted by month (**Figure D2-3**). Sample data are spread out across the year, although a majority of the data are from the spring and summer. Data from the USGS gage and the mouth of the river are lumped together here (and throughout the document), as they are only a few hundred meters apart and have no known inflows between them.

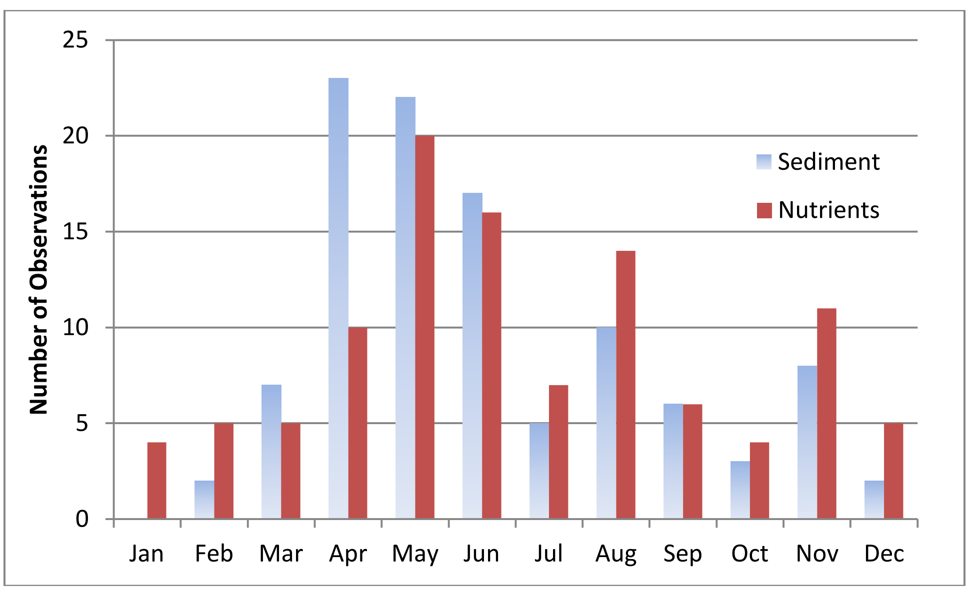


Figure D2-3. Observed sediment and nutrient values used in calibration of model

D2.4 LAND USE

Land uses in the model were based on the NLCD 2001 data set (**Table D2-3**). Nearly 95% of the watershed is categorized as either forest or rangeland. Land use activities in the Little Blackfoot River watershed consist primarily of activities associated with cattle production. Logging and associated activities such as road construction did occur in the 1970s and 1980s, and may occur again due to the recent pine-bark beetle epidemic; however, for the period of time during the model run (1998-2008), little known logging occurred (USFS, personal communication). Agriculture in the watershed consists primarily of irrigated hay. The NLCD labels about 300 acres of the watershed as “row crops”, although field reconnaissance and personal communications with landowners suggest that there are almost no row crops grown in the Little Blackfoot River watershed. Therefore, in the model analysis, agricultural land was assumed to be pasture (and parameterized as such), and no further separation of the two was made. Stock owners often pasture their livestock on USFS Helena National Forest (HNF) range during the summer months and in irrigated hay fields during the winter. Urban residential development occurs in the communities of Elliston and Avon, as well as some other locations in the watershed, but overall only accounts for about 0.5% of the watershed. On-site septic systems in the watershed number approximately 301. There are no permitted wastewater treatment plant (WWTP) point source discharges in the watershed.

Table D2-3. Land uses within the Little Blackfoot River watershed

Land Use	SWAT Code	Area (hectares)	Area (acres)	Watershed Area (%)
Agricultural Land-Row Crops	AGRR	129.9	321.0	0.12%
Forest	FRSE	59,151.8	146,167.0	55.42%
Pasture	PAST	4,744.2	11,723.2	4.45%
Range	RNGB	41,556.5	102,688.2	38.94%
Urban-Residential	URBN	582.4	1,439.1	0.55%
Arid Range	SWRN	9.4	23.3	0.01%
Water	WATR	22.1	54.6	0.02%
Wetlands	WETF	535.2	1,322.6	0.50%
Totals	**-**	**106,732**	**263,739**	**100.0%**

D2.5 SOILS

Soils in the Little Blackfoot Watershed exhibit considerable spatial variability. A total of 17 soil associations occur in the watershed, as defined by the State Soil Geographic Database (STATSGO). Most soils on the bottom lands of the Little Blackfoot River are very shallow to barely moderately deep over loose sands and gravels. They consist of silt loams, loamy fine sands, and fine sandy loams. Deeper soils occur in the higher portions of the watershed. These soils are typically silt loams, loams, and cobbly loams.

D2.6 IRRIGATION

Approximately 4,900 hectares in this watershed are used to grow hay for cattle production. Streamflow on the Little Blackfoot River is heavily influenced by irrigation withdrawals for hay production in the late spring and summer. There are also three small reservoirs within the Little Blackfoot River watershed that are used for irrigation. Irrigation practices and reservoir management are discussed in more detail in **Section D3**.

D3.0 Model Development

D3.1 SWAT Model Description

The Montana DEQ selected the SWAT model for modeling the Little Blackfoot River watershed. The SWAT model and its ArcView Extension (ArcSWAT) were developed and are actively supported by the U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS). SWAT is a public domain watershed-scale hydrologic and water quality model developed to quantify the impact of land management practices in large, complex watersheds. It is a deterministic, distributed parameter continuous simulation basin-scale model. SWAT partitions a watershed into a number of subwatersheds that are homogeneous in terms of climate and topography, but are distributed in the context that they are linked with other subwatersheds through the channel network. Each subwatershed is further partitioned (i.e., discretized) into hydrologic response units (HRUs) that are lumped into unique soil, landcover, and slope combinations having no spatial context. These HRUs form the fundamental computational unit of the model.

The advantages of SWAT include:

- It is physically based and uses readily available inputs.
- It is computationally efficient in that modern computers are able to complete the simulation calculations within a reasonable amount of time.
- It incorporates comprehensive processes by using mathematical equations to represent flow, fate, and transport and other physical, chemical, and biological interactions.
- It can be used to study long-term affects and to simulate management scenarios.
- It has globally-validated model code, as both the model and its code are publicly available for free and widely used.

Pollutant yields, water balance, surface runoff, sediment yield, and management practices are computed at the HRU level, and then are aggregated for subsequent routing through the channel system. SWAT simulates both streamflow and sedimentation, and six general compartments are incorporated into the model to describe the flux of water through the landscape. These include: (1) snow accumulation and melt, (2) surface runoff, (3) unsaturated zone processes/evapotranspiration, (4) lateral flow, (5) shallow groundwater flow, and (6) deep aquifer flow. Hydrologic computations are completed using a modified version of the curve number (CN) (United States Department of Agriculture, 1986) where daily CN is adjusted according to the previous day's soil water content (Arnold, et al., 2011; Neitsch, et al., 2011). Sediment yield in SWAT is simulated using the Modified Universal Soil Loss Equation (MUSLE) (Williams and Berndt, 1977), where erosion and delivery are calculated as a function of peak runoff rate and volume, soil erodibility, slope steepness and length, cover factor, and supporting practice factor. In particular, the slope steepness and length (USLE LS factor), and the cover management factor (USLE C factor) are important because they are largely based on specific field-level conditions, and therefore the model has a harder time parameterizing them without user input. Channel sediment routing is based on the unique sediment transport characteristics of the individual routing reach and the upstream continuum of sediment from other subbasins and channel reaches. Sediment is routed through the stream channel considering deposition and degradation processes and using a simplified equation based on stream power as defined by Bagnold (1977). For each reach on each day, either deposition or degradation (e.g. bank erosion) occurs.

SWAT comprehensively models transfers and internal cycling of the major forms of nitrogen and phosphorus. The model monitors two pools of inorganic and three pools of organic forms of nitrogen. SWAT also monitors three pools of inorganic and three pools of organic forms of phosphorus. SWAT incorporates in-stream nutrient dynamics using kinetic routines from the in-stream water quality model referred to as QUAL2E (Brown and Barnwell, Jr., 1987). Other in-stream variables that may be simulated include temperature, dissolved oxygen, bacteria, and pesticides. Details regarding model development are described by Arnold et al. (1993). SWAT documentation consists of theoretical documentation, input and output documentation, and user's manual (Arnold, et al., 2011; Neitsch, et al., 2011; Winchell, et al.,2010).

D3.2 Model Input

ArcSWAT and SWAT Editor (both Version 2009.93.5) were used in this modeling effort. This is not the most current version of SWAT but it was the most recent version at the onset of the project, and compatibility problems did not allow the updating of the model version without significant structural modification. Fundamental input data for SWAT are topography, land use, soils, and climatic data. ArcSWAT (with its GIS interface) was used to perform the pre-processing, initial model setup and parameterization. Geographic data sources used for model setup are shown below:

- National Elevation Dataset (NED) – The USGS NED is a 1:24,000 scale high-resolution compilation of elevation data used for watershed delineation, flow accumulation processing, and slope determination (U.S. Geological Survey, 2010a).
- National Hydrography Dataset (NHD) – NHD is a 1:24,000 scale vector coverage of stream topology (U.S. Geological Survey, 2010b). It was used in definition of the stream and channel network.
- National Land Cover Dataset (NLCD) – The 2001 NLCD is a 21-category land cover classification (30-m grid) available for the conterminous U.S. Eight categories of land-use were used in this model (**Table D2-3**).
- STATSGO Soils – The STATSGO soil map (United States Department of Agriculture, Natural Resources Conservation Service, Soil Survey, 1994) is a 1:250,000 scale generalization of detailed soil survey data that was used to develop soil properties of landcover classes.

ArcSWAT was used as the initial model pre-processor. The raster based processing consists of a modular structure that contains a tool for optimizing the definition and segmentation of a watershed and network based on topography. It also consists of a tool for defining the HRUs over the watershed and an integrated user-friendly interface. The GIS interface not only allows users to segment a watershed, but to import and format the supporting data necessary for the specific application and calibration of the model.

D3.3 Simulation Period

The model simulation period was chosen to be coincident with the most recent landcover, available calibration data for flow, sediment, and nutrients, and climatic data sets with few or no missing values. The period of 1999 through 2008 was chosen to best meet these requirements. The dataset was partitioned into three subsets – 1999-2001 for a "warm-up" period, 2002-2005 for calibration, and 2006-2008 for validation. Land use did not change substantially in the watershed within this time period, so 2001 NLCD land-use data should adequately reflect the actual land use within the watershed.

This time period was generally within a drought period (i.e., low flows in the watershed). Low flow periods are generally more reactive to sediment and nutrient stresses than high flow periods. Since TMDLs must consider seasonality and the most critical time period for each pollutant, it is preferable for the model period to have low flows overall instead of high flows. This is further discussed in **Section D4.2**.

D3.4 WATERSHED DELINEATION

Subwatershed discretization was performed to capture 6th code hydrologic unit code (HUC) boundaries for the watershed, and also to capture specific 303(d) listed sub-watersheds within the model, all while keeping the model as simple as possible. This resulted in a delineation of 37 total subwatersheds (also referred to as sub-basins) for the Little Blackfoot River (**Figure D3-1**). Sub-basin sizes ranged from 56 hectares to almost 7,500 hectares (**Table D3-1**). Elevations within sub-basins also varied greatly, with well over 1,000 m (3,280 feet) of elevation differences between the headwaters and the watershed outlet (**Figure D3-2**).

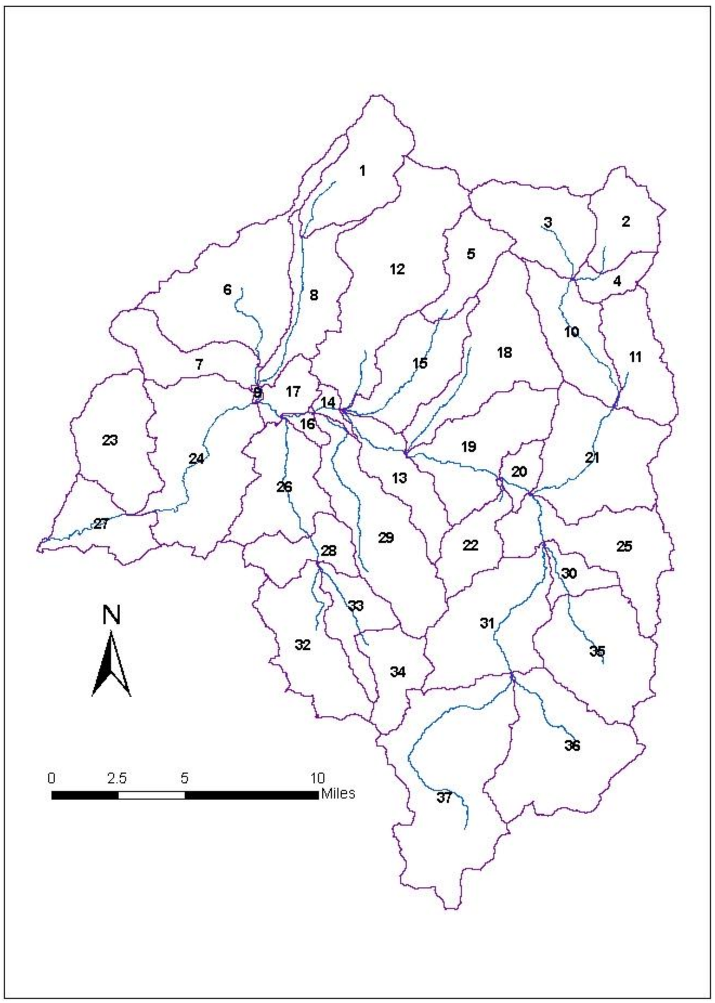


Figure D3-1. Sub-basins within the Little Blackfoot River watershed

Table D3-1. Sub-basin summary, Little Blackfoot River watershed

Sub-Basin	Area (square kilometers)	Area (hectares)	Area (acres)	% Watershed Area	Comment
1	30.2	3,021	7,464	2.8%	HW, Quigley Reservoir
2	18.9	1,892	4,674	1.8%	HW
3	29.2	2,915	7,203	2.7%	HW
4	8.2	823	2,032	0.8%	-
5	17.2	1,719	4,247	1.6%	HW, Snowshoe Reservoir
6	54.5	5,452	13,473	5.1%	HW
7	21.3	2,130	5,263	2.0%	
8	26.2	2,618	6,470	2.5%	
9	0.6	56	139	0.1%	
10	25.8	2,579	6,372	2.4%	
11	24.3	2,428	6,001	2.3%	HW
12	67.2	6,724	16,614	6.3%	HW
13	20.7	2,071	5,118	1.9%	LBR
14	3.2	316	780	0.3%	LBR
15	29.7	2,970	7,339	2.8%	
16	2.9	294	727	0.3%	LBR
17	9.5	954	2,358	0.9%	LBR
18	43.1	4,307	10,643	4.0%	HW
19	37.2	3,719	9,191	3.5%	LBR
20	7.0	704	1,739	0.7%	LBR
21	45.1	4,506	11,134	4.2%	
22	15.8	1,581	3,908	1.5%	HW
23	31.7	3,169	7,830	3.0%	
24	58.4	5,837	14,423	5.5%	LBR
25	38.0	3,804	9,401	3.6%	LBR
26	30.3	3,033	7,495	2.8%	
27	20.4	2,039	5,039	1.9%	Outlet, LBR
28	16.5	1,646	4,068	1.5%	Spotted Dog Reservoir
29	45.2	4,520	11,170	4.2%	HW
30	8.6	859	2,123	0.8%	
31	44.1	4,413	10,905	4.1%	LBR
32	33.7	3,374	8,336	3.2%	HW
33	17.1	1,706	4,216	1.6%	
34	17.4	1,741	4,302	1.6%	HW
35	41.7	4,168	10,298	3.9%	HW
36	51.5	5,150	12,727	4.8%	HW
37	74.9	7,493	18,515	7.0%	HW, LBR
Totals	**1,067.3**	**106,732**	**263,734**	**100.0%**	

HW: Headwaters sub-basin (no inflows), LBR: Little Blackfoot River sub-basin.

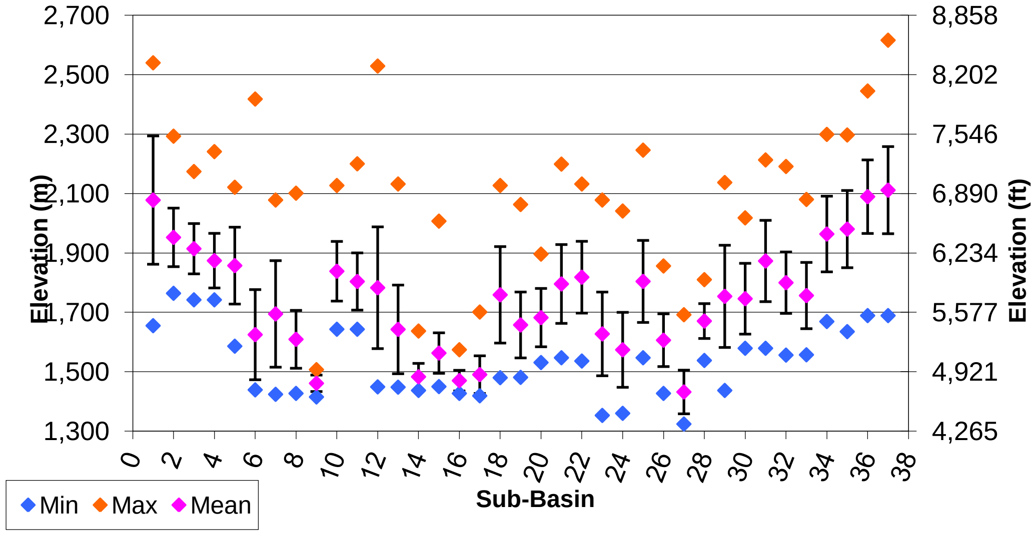


Figure D3-2. Elevation distribution by sub-basin within the Little Blackfoot River watershed

D3.5 Hydrologic Response Units

Subwatersheds were further subdivided into homogeneous landscape units, HRUs,having unique soil, land cover, and slope combinations. A minimum threshold percentage of two percent was specified, meaning that soil, land use, or slope categories totaling less than 2% of the sub-watershed would be excluded from the HRU definition process. This reduces the number of HRUs in the model and greatly reduces computational time without sacrificing accuracy. This process resulted in 1,387 HRUs delineated within the watershed. Management files for each HRU were written based on an understanding of activities that were occurring within the watershed which included: (1) cattle grazing on pasture, rangeland, and forests, (2) agricultural hay production, and (3) BMP implementations for future scenarios. Model runoff parameters were adjusted to calibrate water yield, and vegetation changes were simulated by modifying the minimum cover factor (USLE C) used in the sediment calculations. Riparian areas were simulated with filter strips.

USLE C factors are calculated by SWAT on a daily basis by modifying a user-specified minimum USLE C factor. Therefore, the USLE C factor is constantly changing from day to day based on plant growth, harvest, etc. However, average USLE C factors can be estimated based on the minimum USLE C factor. These average values are listed in **Table D3-2**. USLE C minimum factors were determined based on typical literature ranges for land use types, and were then adjusted based on the perceived condition (field visits, vegetation surveys, etc.) of these land uses within the watershed.

Table D3-2. Average USLE C factors

Land Use	USLE C factor
Forest	0.005
Pasture	0.013
Range	0.031
Arid Range	0.310
Urban	0.022
Wetland	0.008
Improved Pasture	0.008
Improved Range	0.028

D3.6 Climatic Patterns

Climate data was obtained from a total of seven weather stations in close proximity to the watershed, as described in **Section D2.2**. Stations were assigned to representative subwatersheds in SWAT, based on proximity. Because precipitation and air temperature vary with elevation, especially in areas of large topographic relief, elevation bands were used in each subbasin to better describe orographic effects. Bands were generated from the SWAT topographic report and climatic information from the most proximal meteorological station was lapsed according to the elevation of the assigned climate station and each band. Lapse rates were determined based on the seven climate stations (**Figure D3-3** and **Figure D3-4**). Precipitation and temperature lapse rates were determined to be approximately 460 mm/km (r2=0.93) and -4.7 ˚C/km (r2=0.96) respectively, which is similar to that reported by Flynn and Van Liew (2010) in other watersheds in Montana. In order to define which precipitation station is assigned to a particular sub-basin, SWAT identifies the closest defined meteorological station by its proximity to the centroid of the sub-basin. Both temperature and precipitation information are then read from this station, and elevation bands are incorporated into the model to account for the orographic effects due to the large topographic variations in the watershed. These lapse rates were applied basin-wide.

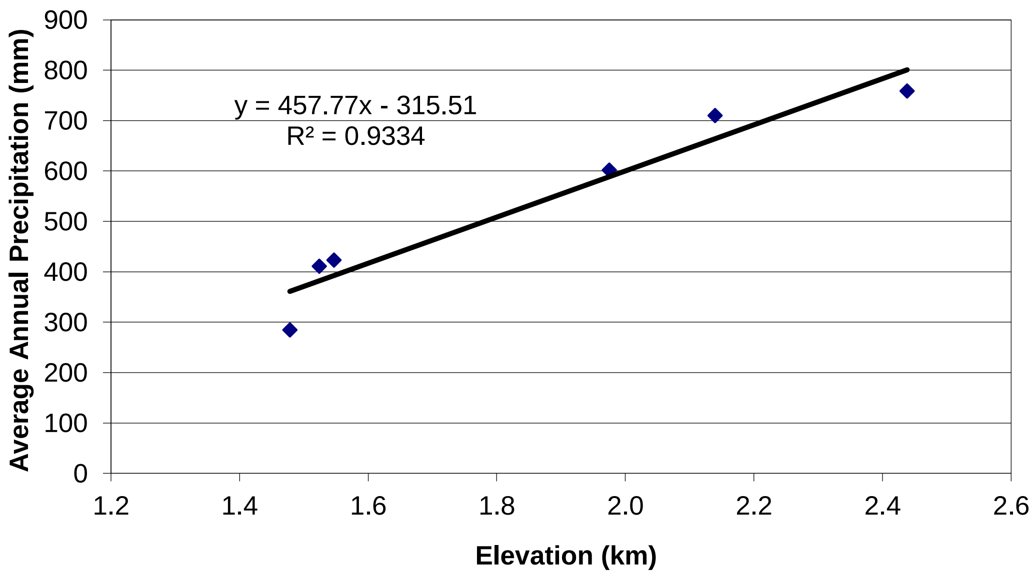


Figure D3-3. Precipitation lapse rate used in the Little Blackfoot River watershed model

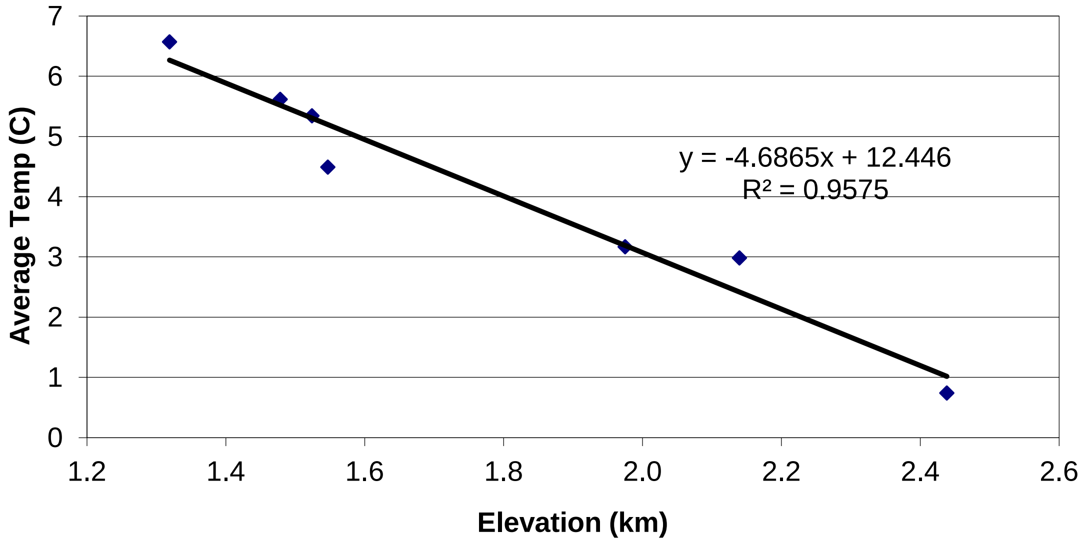


Figure D3-4. Temperature lapse rate used in the Little Blackfoot River watershed model

D3.7 Routing Geometry

The SWAT model automatically calculates channel dimensions for the main channel and tributaries based on drainage area regression statistics. Flynn and Van Liew (2010) have shown that the SWAT regression is not valid for mountainous regions. Field channel measurements were taken by the DEQ for several reaches within the watershed (PBS&J, 2010), and when available these values were used to define the channel geometry. If these were not available, a USGS channel geometry-drainage area regression for western Montana (Lawlor, 2004) was used. Comparing the USGS regression and SWAT method with actual field data or aerial photos shows that SWAT consistently over-predicted the bankfull channel width and generally under-predicted the width-to-depth ratio.

The default main and tributary channel Manning's n values were low, and more representative of smooth channels or fallow agricultural lands. A Manning's n value more typical of natural stream systems was used. A slightly higher value was used for the tributaries than for the main channels. All routing coefficients can be found in **Appendix DC** (Model Input).

D3.8 Evapotranspiration

Evapotranspiration (ET) is the combined loss of water from ground surface evaporation and by transpiration from plants, while the potential evapotranspiration rate (PET) describes how fast water vapor would be lost from a densely vegetated plant-soil system if soil water content was continuously maintained at an optimal level. In SWAT, three options exist for estimating PET and subsequently ET: the Penman-Monteith method (Monteith, 1965), the Priestly-Taylor method (Priestly and Taylor, 1972), and the Hargreaves method (Hargreaves and Samani, 1985). Measured PET values can also be used if measurements are available. **Table D3-3** shows the data requirements of the three PET methods listed from the method requiring the most to least data for the calculation. The Penman-Monteith method was used in this model.

Table D3-3. Data requirements for SWAT-available PET methods

Method	Air Temperature	Wind Speed	Relative Humidity	Solar Radiation
Penman-Monteith	Input	Input	Input	Input
Priestly-Taylor	Input	not used	Input	Input
Hargreaves	Input	not used	not used	not used

D3.9 IRRIGATION

Streamflow on the Little Blackfoot River is heavily influenced by hay irrigation in the late spring and summer. There are also three small reservoirs within the Little Blackfoot River watershed that are used for irrigation. These include the Spotted Dog Reservoir, the Snowshoe Reservoir, and the Quigley Reservoir along Threemile Creek. These are discussed further in the next section. Hay in this watershed is grown for a single cutting in early August. Fields are irrigated after hay cutting to grow a smaller second crop for fall grazing.

Because the location of irrigation diversions cannot be depicted in SWAT, it was assumed in this study that water is diverted from river reaches that are nearest to the subbasin where irrigation occurs. If irrigated land was in a sub-basin that included a reservoir, the irrigation was assumed to come directly from the reservoir. Water applied to an HRU is used to fill the soil layers up to field capacity beginning with the soil surface layer and working downward until all the water applied is used up or the bottom of the profile is reached. If the amount of water specified in an irrigation operation exceeds the amount needed to fill the soil layers up to field capacity water content, the excess water is returned to the source. For pasture, irrigation was assumed to occur at a rate of three inches every two weeks, beginning in early June and ending in mid September. This value is similar to values used in models for other watersheds in western Montana (Montana Department of Environmental Quality, 2011).

D3.10 RESERVOIRS

SWAT models four different types of waterbodies: ponds, wetlands, depressions/potholes, and reservoirs. Reservoirs are located on the main channel network and receive water from all sub-basins upstream of the waterbody. As simulated in SWAT, no distinction is made between naturally-occurring and man-made structures. Daily calculations of surface area, precipitation, evaporation, and seepage are completed in SWAT based on user-provided information on the reservoir outflow or storage-operational curves. No ponds, wetlands, or depressions/potholes were modeled in the Little Blackfoot River watershed, but three reservoirs were modeled.

The three reservoirs include the Spotted Dog Reservoir, the Snowshoe Reservoir, and the Quigley Reservoir along Threemile Creek (at the outlets of sub-basins 1, 5, and 28 in **Figure D3-1**). All three reservoirs are believed to be used primarily for irrigation. There are no operation records or other statistics available for these reservoirs, so all reservoir data was estimated from GIS. The drainage areas above Quigley Reservoir, Snowshoe Reservoir, and Spotted Dog Reservoir are 3,021 ha, 1,719 ha, and 8,467 ha, respectively. Inflow to each reservoir depends on the amount of water accumulated in the mountain snowpack, temperatures during snowmelt, and spring precipitation. All three of these reservoirs are on tributaries rather than the mainstem, and do not have a great influence on the overall flows in the watershed.

Four different outflow options exist for modeling reservoirs within SWAT. These are: (1) measured daily outflow (from a USGS gage or other continuous streamflow source), (2) measured monthly outflow, (3) average annual release rate for uncontrolled reservoir, and (4) target release for controlled reservoir. The operation of these facilities is uncertain, but the dam control structures are likely set to fill up near the end of the spring runoff season so as to have a full capacity for the summer irrigation season. In this model, the average annual release method was used. This means that an average daily (or monthly) release was specified, and any water after that was used to fill the reservoir. Once the reservoir is at capacity, then inflow is set equal to outflow. This is the most general reservoir management setting, and is appropriate when little or no management data is available. There was no data to set the average daily release to, so these values were determined through an iterative process. A value was chosen, and the modeled hydrology of the reservoir was observed. Then the average daily release was adjusted up or down until the reservoirs followed the known hydrology (e.g., reached full capacity near the end of the spring season).

D3.11 Wastewater Point Sources

There are no permitted wastewater treatment plants or industrial sources within the Little Blackfoot River watershed. There are approximately 301 on-site septic systems located within the watershed (Regensburger, unpublished 2010). These on-site septic systems were treated as point sources in the model.

On-site septic systems were located based on residential land parcels within the Little Blackfoot River watershed as determined from the state's cadastral database. They were assigned to residential land parcels at the centroid of the parcel. Thus, each septic system was spatially located, and was then assigned to the appropriate sub-basin.

Nutrient loading estimates for each septic system were completed by estimating soil types (using GIS) at each drainfield and the nearby streams, and the distance of each drainfield to the nearest stream. Other parameters that were estimated were assumed to be of an "average" type (calcium carbonate concentrations in soil, nitrate and phosphorus reductions, etc.). Average reductions in the soil column were determined to be 52.5% for nitrate and 80.7% for phosphorus. Average annual loading rates for a single family home are 30.5 lbs/year of nitrate, and 6.44 lbs/year of phosphorus; with the estimated reductions of nitrate and phosphorus, the average loading to surface water is 14.5 lbs/year of nitrate and 1.24 lbs/year of phosphorus per single family septic system. Septic loading estimates for nutrients in the Little Blackfoot River watershed assumed that all septic systems are operating properly. The rationale for this assumption is discussed below.

The most likely type of failure to create a direct connection of untreated wastewater into an adjacent surface water is a septic system that is creating a surface expression of wastewater. This type of failure will commonly be repaired quickly (days or weeks at the most) by an owner as it is an obvious hazard and aesthetically unpleasant to anyone nearby. In addition, unless the failing systems is a short distance to a surface water the wastewater will likely seep into the ground prior to any direct surface water discharge. Short duration failures such as this do not provide significant additional loading of nutrients at the scale of time associated with the TMDL development, and therefore the accuracy of the model is not diminished by ignoring these types of failures. Other common types of failures are a septic tank with decreased volume due to excess sludge accumulation, and a reduction of the unsaturated zone beneath the drainfield due to groundwater mounding. To discuss these failures the treatment capabilities of conventional septic systems (septic tank and subsurface drainfield) must be reviewed first. A properly operating conventional septic system is not designed to remove significant amounts of nitrogen or phosphorus from the raw wastewater - its primary purpose is to remove solids and pathogens.

Therefore, a system that is failing through reduced septic tank settling or reduced unsaturated soil is not going to discharge a significantly larger load of either nitrogen or phosphorus to the environment. The septic loading analysis assumed that this small variation of nitrogen and phosphorus loading due to failing systems was well within the margin of error associated with septic systems that are documented (Environmental Research Laboratory-Duluth, 2002) to have a large range of flow rates (54 to 67 gallons per day per person), nitrogen concentrations (26-75 mg/L), and phosphorus concentrations (6-12 mg/L). Therefore, estimation of failure loading rates without any site specific data was deemed less accurate than the simpler assumption that all septic systems were operating properly.

An analysis of aerial photos indicated that there may be a livestock confinement on Threemile Creek, but field visits to this area did not verify that it should be modeled as such. Therefore, this was simply modeled as a grazed pasture. Future studies may want to re-consider this based on the best available data. The potential effect of livestock confinements on nutrient and sediment loading is significant. These facilities act as point sources discharging directly to streams, and can greatly contribute to nutrient and sediment loading. SWAT does not model direct excrement from cattle other than by using a user-specified point source. SWAT loads cattle manure into grazed fields, which then breaks down (or is carried into streams by runoff). Cattle manure and grazing are discussed further in the following section.

D3.12 GRAZING

The Little Blackfoot River watershed is heavily managed for cattle production. This includes agricultural growth of hay in the summer, and grazing on pasture, range, and forested lands in the winter and summer.

Irrigated hay fields are grazed throughout the fall, winter, and spring, and are then managed for hay production in the summer. During the summer, they are heavily irrigated, and area also fertilized on an infrequent basis. Much of the fertilization comes from cattle manure, although some ranches in the watershed do fertilize with chemical fertilizer on an annual basis. Hay is harvested in early August.

To estimate the effects of cattle production on the Little Blackfoot River watershed, the first step was to estimate the total number of cattle in the watershed throughout the year. This was done using two different methods. The first method was counting heads. During the winter months, several “windshield surveys” were done when cattle should be congregated in the pastures along the Little Blackfoot River. The cattle were simply counted, driving from Helena to Garrison, and then from Avon up to Nevada Creek. Both times, over 1,000 head of cattle were counted. While not scientific, this does set a lower bound (there are *at least* this many cattle in the watershed). The second method was the USFS Helena National Forest (HNF) grazing allotment data. The USFS has 12 active grazing allotments that overlap into the Little Blackfoot River watershed. These grazing allotments have a total area of approximately 36,800 hectares and 1,978 permitted cow-calf pairs. The spatial portion of each allotment within the watershed was prorated to determine the number of cattle in each watershed allotment. All allotments were assumed at 100% capacity every year. This is conservative, as several of the allotments are known to be less than full certain years. When the portions outside of the watershed are excluded, this leaves a proportionate area of approximately 25,700 hectares and about 1,431 cow-calf pairs. Although it is possible, or even likely, that some landowners summer their cattle on their own land, for this analysis we assumed that the watershed held approximately 1,431 cow-calf pairs. An extra 69 head were added to account for other stock animals, such as bulls, dairy cattle, horses, etc, and to make the estimate a round number which more appropriately reflects the precision (or lack thereof) of the estimate. Each allotment was then overlaid by the sub-basins, and an area-weighted value was calculated for the number of grazed acres and head of cattle within each sub-basin.

The assumptions for the life cycle of cattle in the Little Blackfoot River watershed are as follows. From November to February, the cattle graze in the irrigated hay pasture without calves (the yearlings have been sold to feedlots outside of the watershed). It was assumed that 100% of the pasture in the watershed was grazed during the winter. From March through July, the cows are with calves. Around June 15th (this varied slightly in each grazing allotment), the cow-calf pairs are moved to summer pasture. From August through October, the cows are with grown calves. Around October 1st, the cattle move from summer pasture back down to the winter pasture, and the yearlings are sold (removed from the watershed) soon thereafter.

Each cow-calf pair consumes about 40 pounds of forage (dry weight) per day. A grazing value in kg/ha/day dry weight was obtained for each allotment based on this value. Daily trampling (kg/ha/day) was assumed to be approximately 95% of daily consumption. This is based on prior studies in western Montana, and a discussion with a local rancher who claims they trample “about as much as they eat”. Finally, each cow was assumed to produce about 63 pounds of manure (wet weight) per day, and calves anywhere from 26 lbs to 63 lbs per day depending on their age (Ohio State University, 1993). A cow-calf pair on average then produces approximately 100 lbs of manure per day. Manure is approximately 85% water weight, which means each cow-calf pair produces on average 15 lbs of manure (dry weight) each day. This ratio of daily manure production to daily food consumption is about 37% (15/40), which is similar to values of manure production used in modeling efforts on the Upper Clark Fork River and the Bitterroot River watersheds in western Montana (Montana Department of Environmental Quality, 2011). These assumptions were used to calculate the daily consumption, trampling, and manure production for cattle in the pasture areas and the summer range.

D3.13 Roads

The Little Blackfoot River watershed contains approximately 641 miles of roads, 92% of which are unpaved (PBS&J, 2010). Runoff from unpaved roadways carries excess sediment to the streams. Paved roadways (e.g. highways) are often treated with traction sand in the winter months, and this can also have an effect on sediment loading.

In this model, roadways were grouped by sub-basin and treated as point sources of sediment within that sub-basin based on the road assessment (PBS&J, 2010). The actual point source value for the model was taken from the assessment. Additionally, the assessment provided potential improvements in roadway sediment loading for each sub-basin. The point sources were input as average daily loadings, which means they are not tied to hydrology (i.e., the daily loading for April is the same as the daily loading for October, even though it rains more in April than in October). Overall, the roads were a minor source of sediment loading, and this is not expected to make a significant difference in the model results.

D4.0 Model Calibration

A deterministic modeling approach was employed by the DEQ to evaluate the cause-effect relationship between management activities and sediment and nutrients in the Little Blackfoot River watershed. Evaluation criteria are listed below.

D4.1 Evaluation Criterion

Two model performance statistics were used to assess monthly and daily predictions of the SWAT model. The first is relative error (RE), which is a measure of the average tendency of simulations to be larger or smaller than an observed value. RE is defined as the deviation between observed ($X_{i,obs}$) and simulated ($Y_{i,sim}$) values, where optimal RE is 0.0, and positive and negative values reflect bias toward under- or over-estimation. Van Liew et al. (2005) suggested RE values <±20% are "good", while more strict guidelines have been suggested elsewhere. For the purpose of this project, RE< ±10% was considered to be sufficient for model calibration. RE is calculated as:

$$RE\% = \frac{\sum_{i=1}^{n} (Y_{i,sim} - X_{i,obs})}{\sum_{i=1}^{n} (X_{i,obs})} \times 100 \qquad (1)$$

The second evaluation criterion was Nash-Sutcliffe coefficient of efficiency (NSE) (Nash and Sutcliffe, 1970). NSE expresses the fraction of the measured variance reproduced by the model and is defined as:

$$NSE = 1 - \frac{\sum_{i=1}^{n} (X_{i,obs} - Y_{i,sim})^2}{\sum_{i=1}^{n} (X_{i,obs} - \overline{X}_{i,obs})^2} \qquad (2)$$

By increasing NSE, error in the model is inherently decreased. Simulation results are considered to be good when NSE > 0.70, while NSE values between 0.36 and 0.70 are considered to be satisfactory (Motovilov, et al., 1999). The NSE is widely used and is considered one of the best objective functions for overall hydrograph fit (Moriasi, et al., 2007).

Criteria for seasonal and annual loading for water quality constituents (nitrogen, phosphorus, and sediment) were not established, although graphical comparisons of model performance were deemed suitable where time series plots are generally evaluated visually for agreement between the simulated and observed values.

D4.2 Simulation Period and Boundary Conditions

The simulation was performed for the time period 1999-2008. The 1999-2001 time period was used as a "warm-up" period to allow some of the initialized variables to reach a steady-state. This lowers the reliance on initial values and initial value estimation procedures, as these parameters have several years in which to reach a steady-state. The model was calibrated for the period 2002-2005, and validated for the period 2006-2008. Model calibration refers to the process of adjusting model parameters to obtain a fit to observed data. Once the model does a good job of reproducing observed values, it is then run with another data set (typically from an earlier or later time period) to test the performance of the model.

An overview of streamflow in the Little Blackfoot River shows that the modeled period was characterized by low overall flows (**Figure D4-1**). While it is always ideal to have a representative time period, low flow periods are generally more reactive to sediment and nutrient stresses than high flow periods. Because TMDLs must consider seasonality and the most critical time period for each pollutant, it is acceptable for the model period to have low flows overall instead of high flows.

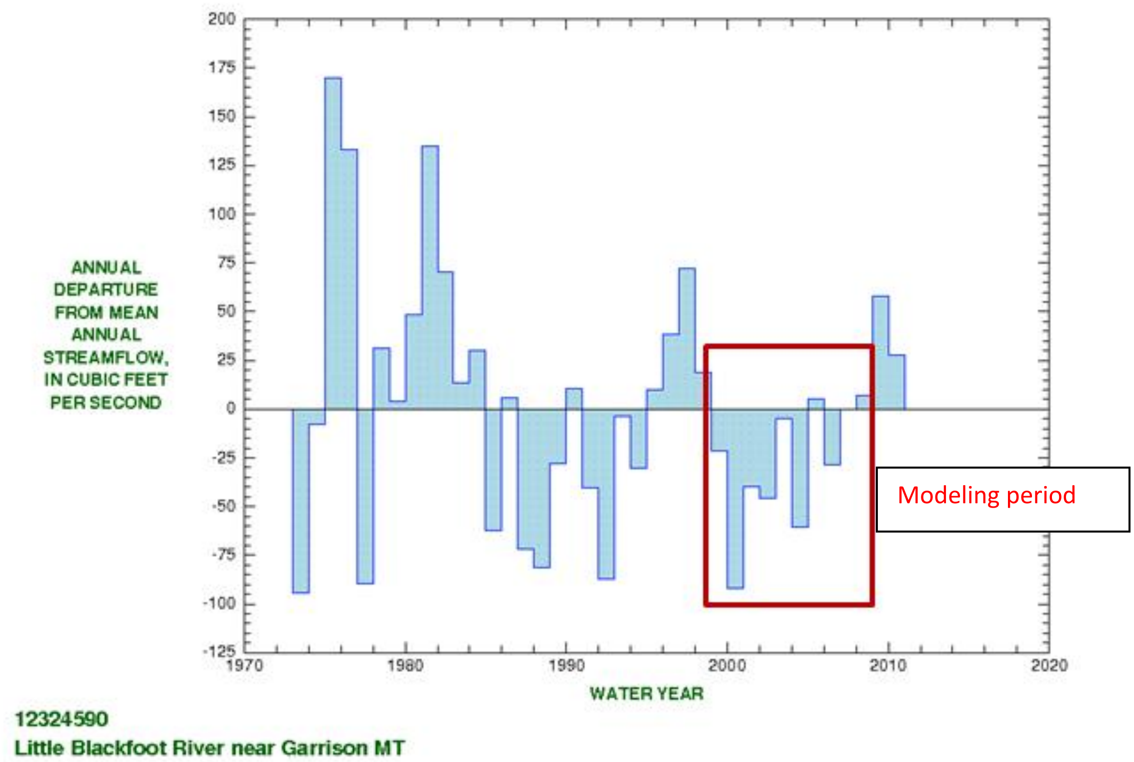


Figure D4-1. Hydrology for model run period

Boundary conditions are entirely geographic for this modeling effort. There are no inflows, as this watershed is one of the headwaters of the Clark Fork River. The only outflow is the mouth of the Little Blackfoot River near Garrison. There are no modeled inter-basin transfers in this watershed. Based on aerial photo interpretation, an inter-basin transfer may be occurring in the headwaters of Sixmile Creek (sub-basin 6), but this could not be verified and thus was not included in the modeling effort.

D4.3 STREAMFLOW CALIBRATION

Calibration of streamflow in SWAT was completed using a combined automated and manual approach. First, a sensitivity analysis was performed on various parameters to identify those that have a strong effect on the model. Then, a best-fit parameter set is first estimated using the automated shuffled complex evolution algorithm (SCE-UA) (Van Griensven and Bauwens, 2003) finally this was adjusted manually based on desired system response and watershed knowledge. Approximately 25 parameters that govern snow accumulation and melt, precipitation runoff, and subsurface flow were optimized, followed by manual calibration (**Table D4-1**).

Table D4-1. Calibrated and adjusted parameters for the Little Blackfoot River SWAT model

Component	Parameter	Description	Calibrated Value	Min	Max	Units
Basin (.bsn)	SFTMP	Snowfall temperature	2.0	-5	5	ºC
Basin (.bsn)	SMTMP	Snow melt base temperature	0.5	-5	5	ºC
Basin (.bsn)	SMFMX	Melt factor for snow on June 21	2.0	0	10	mm $ºC^{-1}$ day^{-1}
Basin (.bsn)	SMFMN	Melt factor for snow on December 21	0.1	0	10	mm $ºC^{-1}$ day^{-1}
Basin (.bsn)	SNOCOVMX	Minimum water that corresponds to 100% snow cover	50	0	500	mm
Basin (.bsn)	SNO50COV	Fraction of snow volume that corresponds to 50% cover	0.55	0	1	dimensionless
Basin (.bsn)	TIMP	Snowpack lag factor	0.1	0	1	dimensionless
Basin (.bsn)	SURLAG	Surface runoff lag time	4.0	1	24	days
Basin (.bsn)	SPCON	Linear parameter for sediment re-entrainment	0.0005	0.0001	0.01	dimensionless
Basin (.bsn)	SPEXP	Exponent parameter for sediment re-entrainment	2.0	1	2	dimensionless
Basin (.bsn)	ESCO	Soil evaporation compensation factor	0.95	0	1	dimensionless
Basin (.bsn)	EPCO	Plant water uptake compensation factor	0.96	0	1	dimensionless
HRU (.hru)	SLOPE	HRU slope steepness	0.0003-0.6	0	1	m/m
HRU (.hru)	SLSUBBSN	Average slope length	9-60	0	90	m
GW (.gw)	GW_DELAY	Delay time for aquifer recharge	205	0	500	days
GW (.gw)	ALPHA_BF	Baseflow recession constant	0.251-0.8	0	1	days
GW (.gw)	GW_REVAP	Revap coefficient	0.122	0.02	0.2	dimensionless
GW (.gw)	REVAPMN	Threshold depth for “revap” to occur	500	0	1000	mm
GW (.gw)	GWQMN	Threshold depth for return flow to occur	100	0	1000	mm
GW (.gw)	RCHRG_DP	Deep aquifer percolation fraction	0.05	0	1	fraction
Reach (.rte)	CH_K(2)	Effective hydraulic conductivity of main channel	171-500	0	1000	mm/hr
Reach (.rte)	CH_EROD	Channel erodibility factor	0.1	0	1	dimensionless
Reach (.rte)	CH_COV	Channel cover factor	0.8	0	1	dimensionless
Adjusted parameters						
Management (.mgt)	CN	Curve Number	Various			dimensionless
Crop (.crop)	USLE_C	cover management factor	See **Table D3-2**			dimensionless

The point of calibration was the USGS gage near Garrison, located approximately 700 meters upstream of the mouth of the Little Blackfoot River. For practical purposes, this was considered equivalent to the model outfall at the actual mouth. The last few hundred meters of the river channel have been channelized and leveed, and receive virtually no overland drainage. There is also a USFS gage that was used in for an ancillary calibration, discussed further below. These gages are shown in **Figure D4-2**.

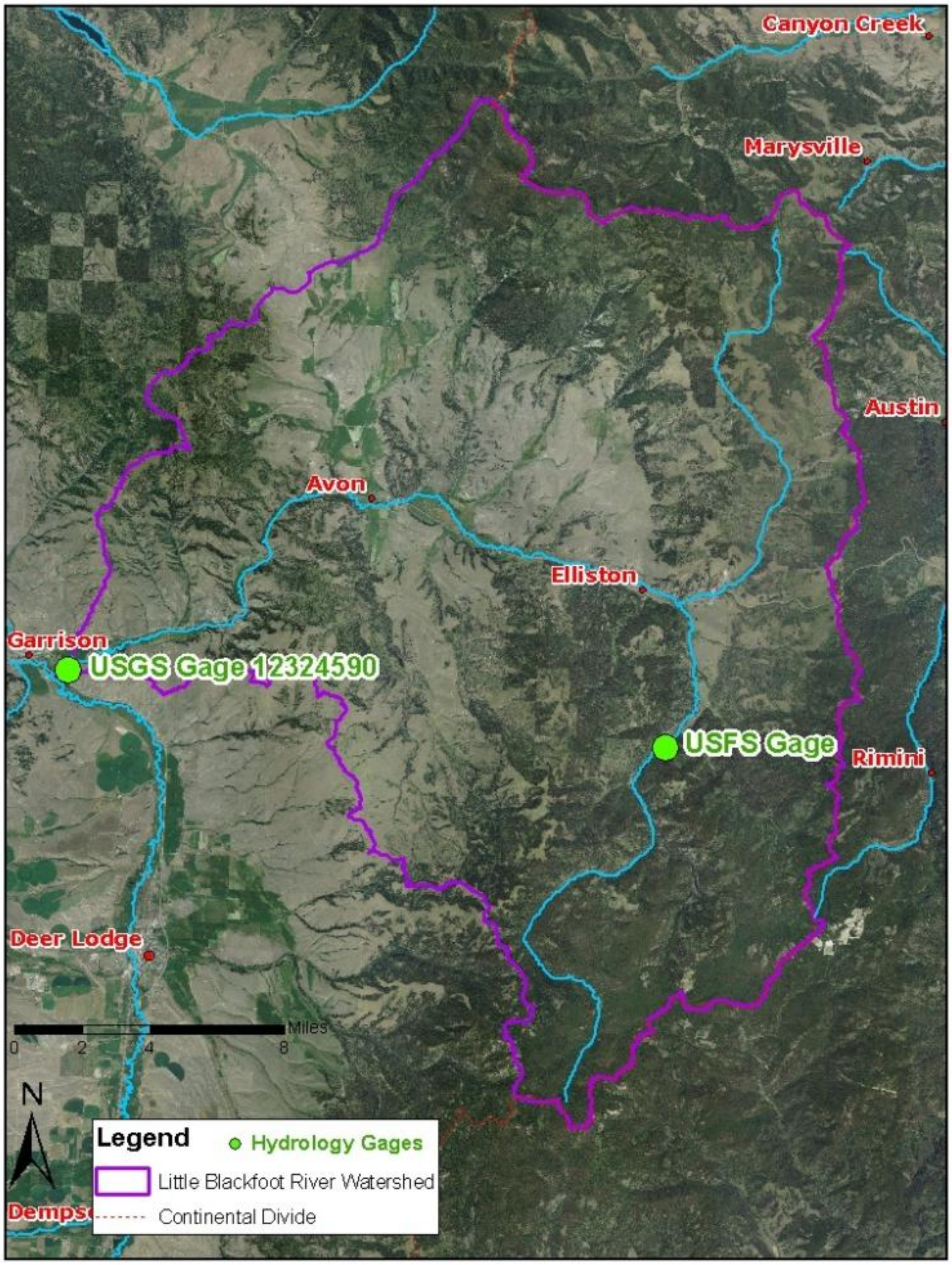


Figure D4-2. Hydrology gage locations in the Little Blackfoot River watershed

The calibrated daily flows from 2002-2005 are compared to the observed flows in **Figure D4-3**. The model does a good job of capturing the peak flows and the low flow periods in the summer. However, there are several peaks in the observed flows that are not seen in the simulated flows. This is typically due to localized precipitation events that the weather gage network does not capture due to large areas of the watershed with no weather stations present (**Figure D2-1**).

Overall water balance was good, with the difference between observed and simulated being less than 1% for the entire simulation period, with approximately 7% difference for the growing seasons (July-

September); the relative errors were -0.3 and 8.6%, respectively (**Table D4-2**). The Nash-Sutcliffe values were 0.71 for the entire simulation period, and 0.53 for the growing season. These values are within the specified bounds of model fit.

Summer growing season values were the most difficult to calibrate. Due to low summer flows, a small difference in simulated versus observed flows can make a large difference in the metrics used to analyze them. In particular, a delay in the spring discharge falling limb by even a week or so around July 1st made a large difference in the summer growing season fit. Additionally, the year to year variability of irrigation practices in the watershed make it a difficult effect to capture. In high runoff years, irrigators use more water, and in low years, they use less. This trend is difficult to capture in the management files because diversion volumes are not recorded by the users. Summer flow calibration involved manipulation of groundwater and lateral flow parameters to get the baseflow to correct conditions.

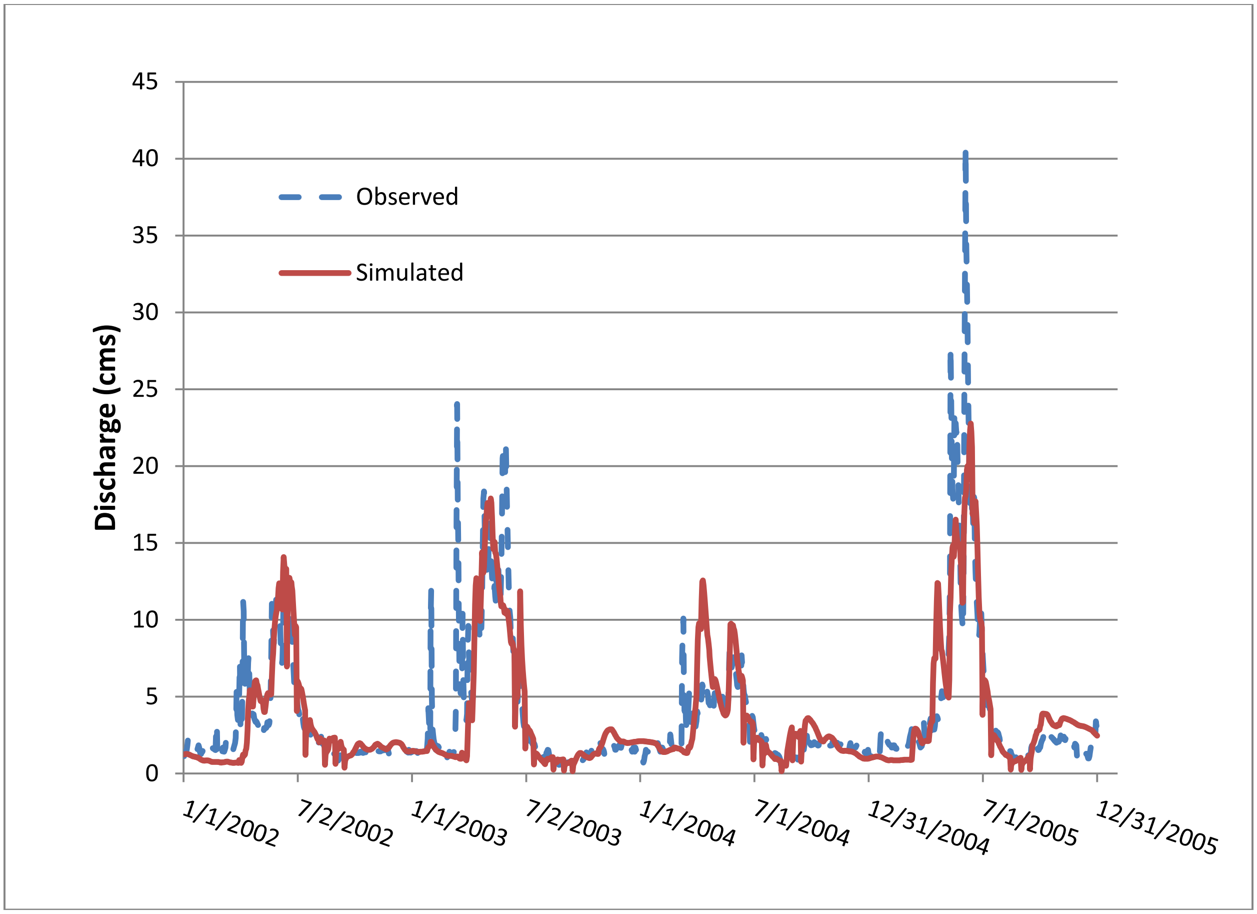


Figure D4-3. Simulated and Observed Daily Hydrology, 2002-2005

Table D4-2. Daily Calibration Metrics

	Observed Total Volume (acre-feet)	Simulated Total Volume (acre-feet)	Difference (%)	Relative Error (%)	Nash-Sutcliffe
Annual	367,857	366,679	-0.3	-0.3	0.71
Summer	44,120	47,213	7.0	8.6	0.53

The model was also analyzed on a monthly basis (**Figure D4-4**). The monthly values parallel the daily values, showing good match on relative error and Nash-Sutcliffe (**Table D4-3**). The Nash-Sutcliffe statistic is based on the fluctuation between values, so the better match on monthly data is a function of the smaller variation between monthly totals versus daily totals.

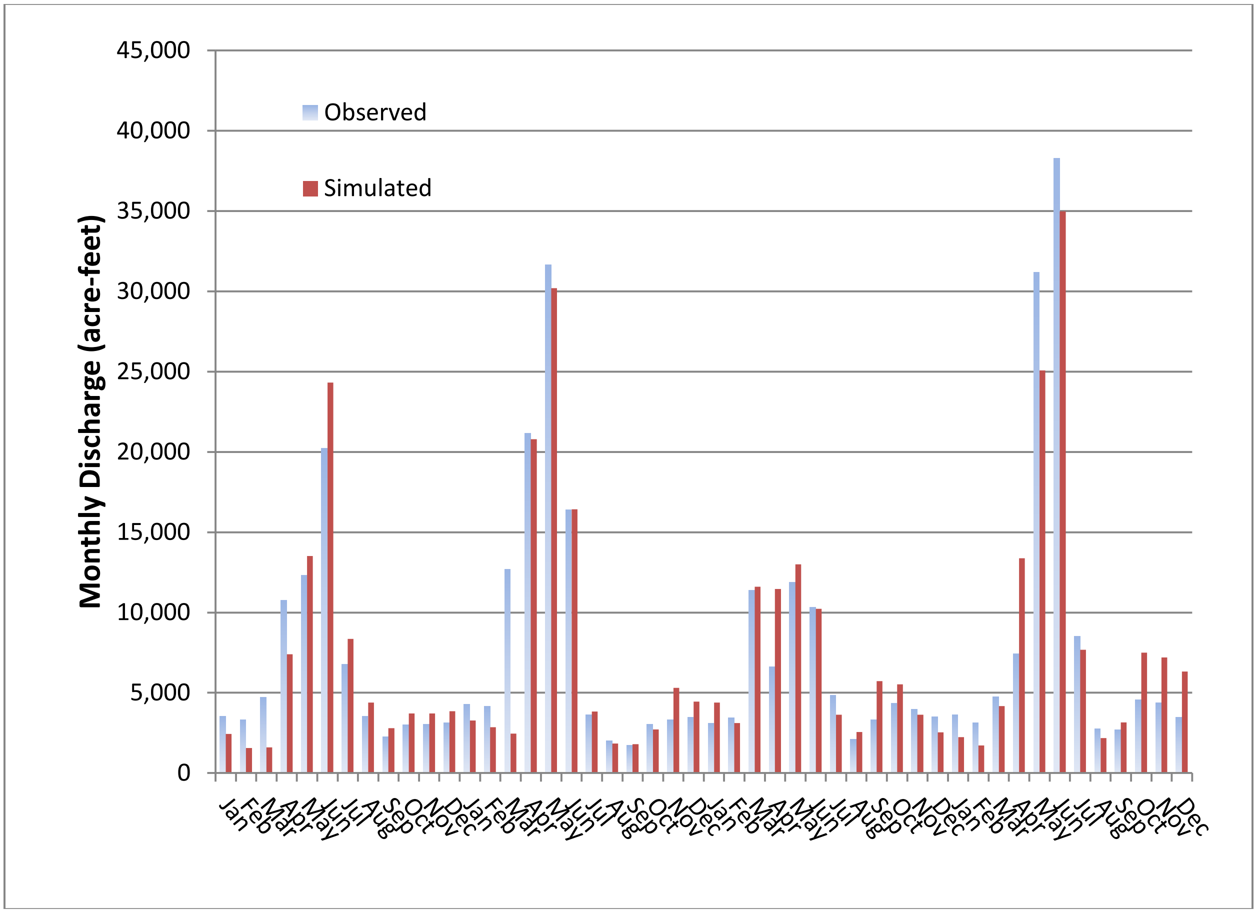


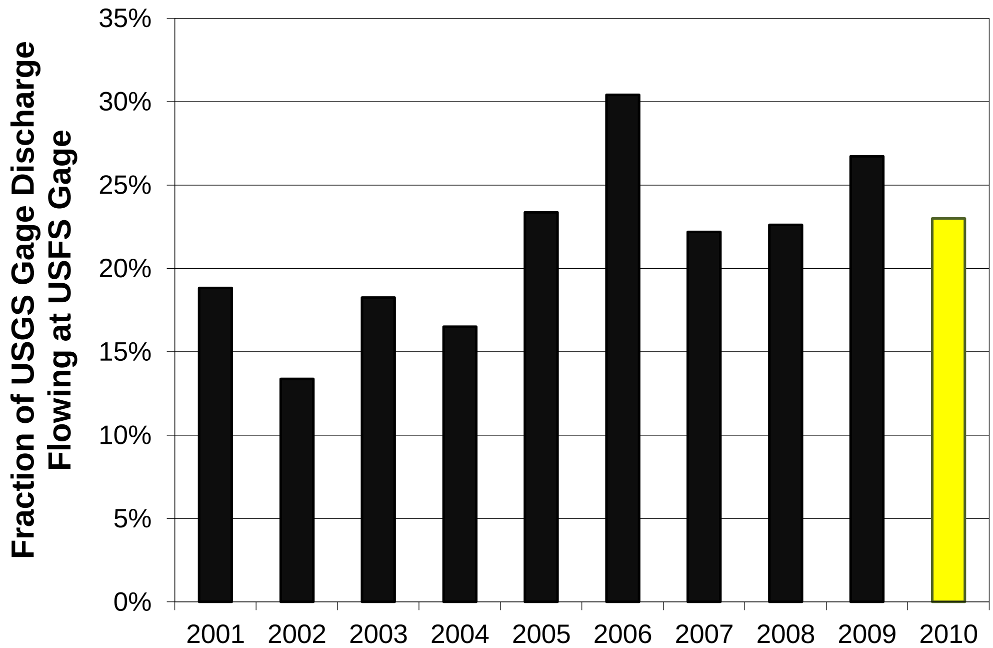
Figure D4-4. Simulated and Observed Monthly Hydrology, 2002-2005

Table D4-3. Monthly Calibration Metrics

	Relative Error (%)	Nash-Sutcliffe
Annual	-0.3%	0.90
Summer	8.7%	0.74

These metrics show that the model calibration resulted in a good fit between simulated and observed data for hydrology at the outlet of the watershed. However, this does not necessarily reflect on how well the model might predict streamflows further upstream. To achieve a better calibration, it is useful to fit the results to more than one location if possible.

Although the USGS maintains no other gages on the watershed, the USFS HNF installed a gage on the upper Little Blackfoot River in 2009 (**Figure D4-2**), and began collecting data in the spring of 2010. Since the model was only run from 1999-2008, it does not overlap with the gage data of 2010, so no direct comparisons can be made between the two. However, the fraction of total flow volume of the Little Blackfoot River (from July through October, the only complete months that the USFS gage had data) that originates above this gage was compared to the simulated fraction to see if the fractions predicted by the model were similar to the observed values from 2010 (**Figure D4-5**). The climate files in the model included data for calendar year 2009, so even though this year was not used for the basic model run, the model was run through 2009 and compared to the observed flow in 2010. The fraction of total river volume compared very favorably near the headwaters, further indicating that the hydrology calibration has resulted in a good fit.



* black values are simulated; the yellow value is observed

Figure D4-5. Fraction of river discharge originating in the Little Blackfoot headwaters during the growing season (July-October, 2001-2010)

Finally, the overall output water budget is shown in **Table D4-4**. This is from the standard output file in SWAT (output.std) and shows the annual average water budget for the modeling period. Although this data is not used for the calibration, it does provide a check on the overall water budget values. The ratio of surface runoff to precipitation and evapotranspiration to precipitation are similar to those observed in other modeling efforts in western Montana (Montana Department of Environmental Quality, 2011) and in other semi-arid climates (Tateishi and Ahn, 1996).

Table D4-4. Average Annual Basin Values (from the SWAT output.std file)

Parameter	Value (mm/year)	Percentage of Precipitation (%)
PRECIPITATION	550.5	-
SNOW FALL	213.69	38.8%
SNOW MELT	168.02	-
SUBLIMATION	37.19	-
SURFACE RUNOFF Q	19.41	3.5%
LATERAL SOIL Q	60.49	11.0%
GROUNDWATER (SHAL AQ) Q	36.71	6.7%
REVAP (SHAL AQ => SOIL/PLANTS)	39.71	-
DEEP AQ RECHARGE	4.43	-
TOTAL AQ RECHARGE	88.66	-
TOTAL WATER YLD	116.04	21.1%

Table D4-4. Average Annual Basin Values (from the SWAT output.std file)

Parameter	Value (mm/year)	Percentage of Precipitation (%)
PERCOLATION OUT OF SOIL	91.59	-
ET	374.5	68.0%
PET	623.2	113.2%
TRANSMISSION LOSSES	0.56	-

D4.4 Sediment Calibration

Sediment is delivered to the river mouth by two separate processes – sediment delivery and sediment routing. Sediment delivery is the process by which sediment is washed off of the land surface and carried into the river channel. This happens during runoff events, and is modeled by SWAT using the modified Universal Soil Loss Equation (MUSLE). Sediment routing within the river channel is a separate process, where sediment can either be deposited on the river channel, or sediment degradation can cause channel and bed erosion and pick up sediment on its way to the river outlet. Both delivery and routing are important to the sediment modeling process.

Calibration of the sediment model was difficult because the existing sediment data was not collected on a frequent or regular basis. There are 108 samples taken by various groups at the USGS gage over the course of approximately 30 years. Additionally, a handful of samples have been taken at various points along the Little Blackfoot River and its tributaries. Therefore, a daily calibration with Nash-Sutcliffe values was not possible. Furthermore, a direct comparison between the modeled data and the observed data (on a day when there is an observed data point) is not practical, as the sediment load is strongly correlated to discharge, and if the discharges were even a bit different, the comparison of sediment concentrations would not provide meaningful results. The model is not detailed enough to attempt a comparison of this nature. An alternative strategy had to be used to compare simulated sediment values to the few observed values.

To accomplish this, the 107 data points observed at the mouth of the Little Blackfoot River (one was discarded as an outlier) were plotted versus the observed daily discharge on the day the sample was taken. The data were then fit with a best-fit polynomial line (**Figure D4-6**). The r^2 value for this line was 0.68. The polynomial line was forced through zero. This polynomial fit was used to correlate observed daily discharges to a total suspended sediment value using the regression equation:

$$SED_{CONC} = 0.1797 \times Q^2 + 1.2077 \times Q \qquad (3)$$

Where SED_{CONC} is the sediment concentration of the water column in milligrams per liter (mg/L) and Q is the discharge in cubic meters per second (cms). The observed discharge on each day of the model run was used in this equation to come up with a corresponding sediment load for that day. This method was deemed the most appropriate based on the available data. It keeps the strong relationship between discharge and sediment load intact. However, this method does make some assumptions which introduce error into the process. First of all, the relationship has a non-zero y-intercept, so no matter how low the flow, there is always a minimum sediment load (1.2077 mg/L) present. More importantly, it ignores all temporal relationships. All months are treated the same regardless of season. Due to the small data set, data from the rising limb and falling limb of the hydrograph were not separated. The rising limb often has much higher concentrations of sediment than the falling limb, and thus averaging these gives an average value which may under predict a rising limb. Finally, it may also underestimate total sediment, as there were no measured sediment values during peak discharges on the years measured (it is very hard to obtain a sample during peak discharge). The highest observed value for suspended sediment was approximately 280 mg/L. To compare, in a state-wide study of Montana streams, median suspended sediment concentrations ranged from 1 to over 25,000 mg/L (Lambing and Cleasby, 2006). Additionally, as can be seen in **Figure D4-6**, the best-fit line greatly underestimates some of the higher values. For example, the high point at point (25 cms, 250 mg/L) is almost twice as high as the best-fit line. Therefore, the sediment calibration was completed against a fabricated data set rather than a true observed data set. Thus, the calibration is designed to have the model respond to conditions similar to the 'best-fit observed', but keeping in mind that deviations of several times the 'best fit observed' value may not be a problem if other metrics indicate the fit is good.

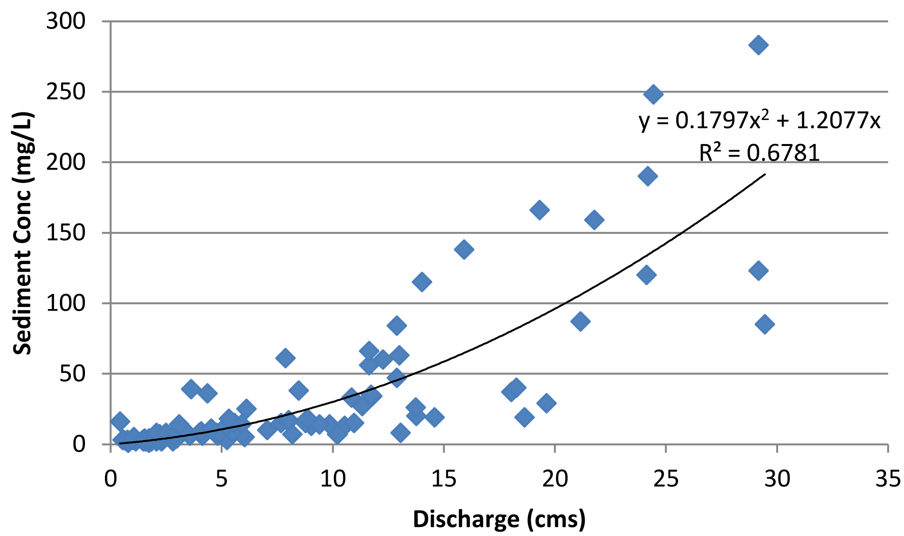


Figure D4-6. Observed total suspended sediment concentrations versus discharge

Best-fit sediment values are compared to simulated sediment values in **Figure D4-7** and **Table D4-5**. The simulated values are generally higher than the best-fit values, especially during times of peak runoff. However, a comparison of actual observed to best-fit observed to simulated shows how variable the sediment data is (**Table D4-5**).

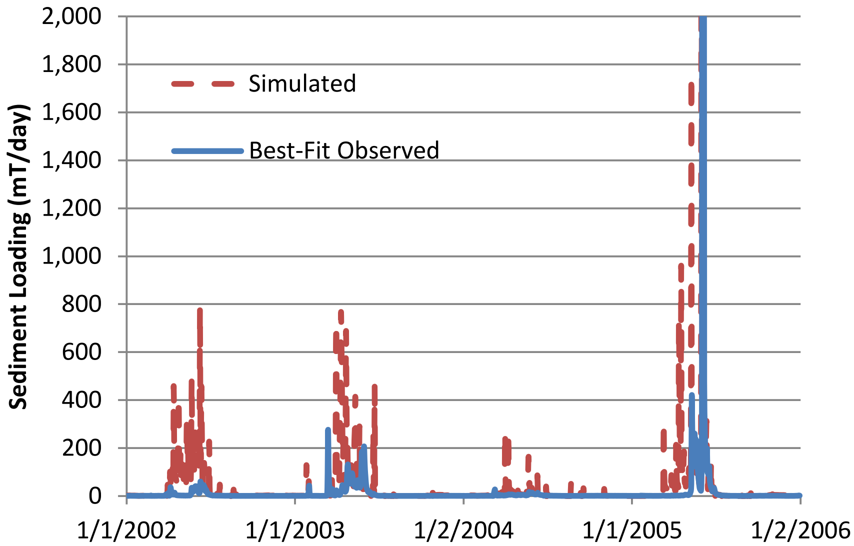


Figure D4-7. Best-Fit versus simulated sediment loading, 2002-2005

Table D4-5. Observed, best-fit, and simulated sediment concentrations, 2002-2005

		Observed (108 data points)	Best-Fit Line (based on 107 data points)	Simulated
TSS (mg/L)	min	1	0.60	0.72
	max	1,410	348	2,850
	mean	41.9	12.2	66.1
	median	8.5	2.8	19.5
Annual Loading (mT/year)		-	6,438	11,990

This is due to the issues associated with estimating the observed sediment values based on a trend line. Overall, the accuracy of the sediment values were determined to be sufficient for the purpose of conducting the sediment reduction scenarios.

D4.5 Nutrient Calibration

Nutrients of concern in this modeling effort are total nitrogen (TN), total phosphorus (TP), and nitrate/nitrites (NO_3/NO_2). Nutrients are similar to sediments in that they are delivered to the river mouth by several separate processes, but there is an additional process in the nutrient modeling – nutrient generation (along with delivery and routing). Nutrients are a dynamic parameter that are constantly being produced and consumed. Nutrient generation is the process by which plants, rain, soils, and management practices (fertilization, cattle) generate nitrogen and phosphorus in the upland areas. Delivery is the process by which nutrients are washed off of the land surface and carried into the river channel. This happens during runoff events, and is modeled by SWAT using equations to calculate surface runoff concentrations, movement through the soil, attachment to soil that is carried away in runoff events, and lateral and groundwater flows. Routing within the river channel is a separate process, where interactions with light, nutrients, algal growth and death, and oxygen levels can be simulated via a QUAL2E sub-routine.

As with the sediment data, the existing nutrient data was not collected on a daily basis. There are 105 samples taken by various groups at the USGS gage over the course of approximately 30 years.

Additionally, a handful of samples have been taken at various points along the Little Blackfoot River and its tributaries. The same problems present in the sediment calibration are present in the nutrient calibration, with the addition that nutrients are not only correlated to discharge, but are also strongly correlated to seasons. Soluble nutrient levels tend to drop in the summer when algal growth occurs, and rise as algae dies off in the fall. Therefore, not only was a daily calibration not possible, but a simple regression of all data points (regardless of season) would over-simplify the nutrient concentrations.

To overcome the calibration obstacles described, the 105 data points observed at the mouth of the Little Blackfoot River were separated by month and plotted (**Figures D4-8** and **D4-9**, **Table D4-6**). Each month was then assigned this mean value for each species - organic nitrogen, nitrate/nitrite, orthophosphate, and organic phosphorus. Observed daily discharges were then multiplied by the mean monthly concentrations to get best-fit observed daily nutrient loadings.

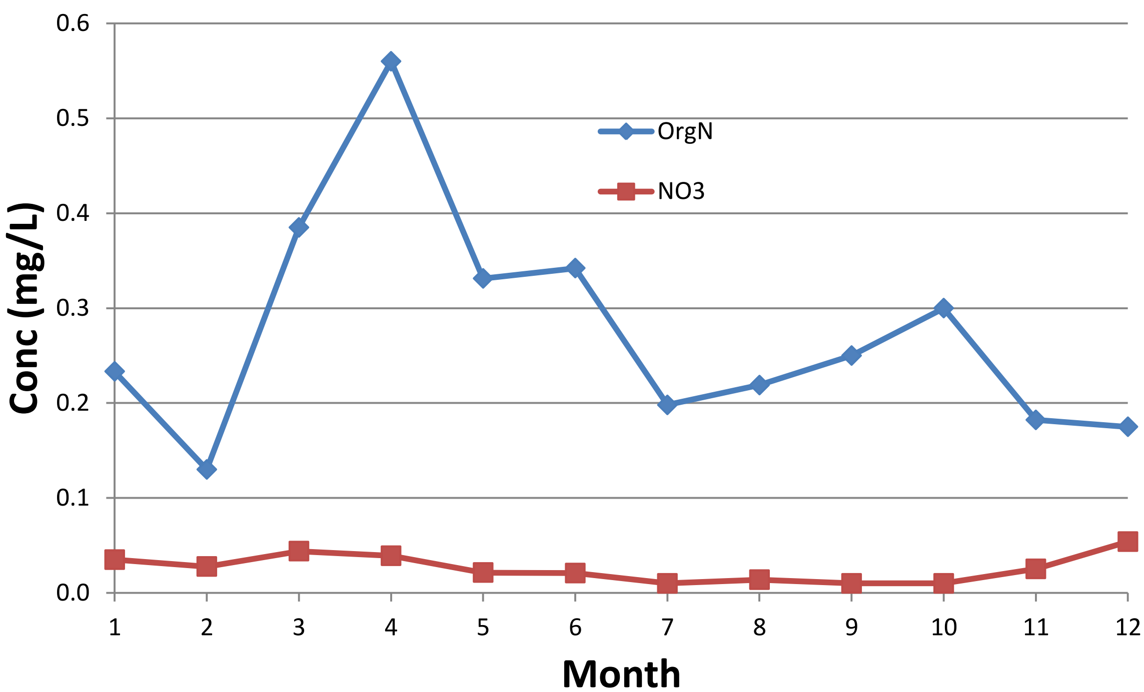


Figure D4-8. Average monthly observed nitrogen concentrations (mg/L)

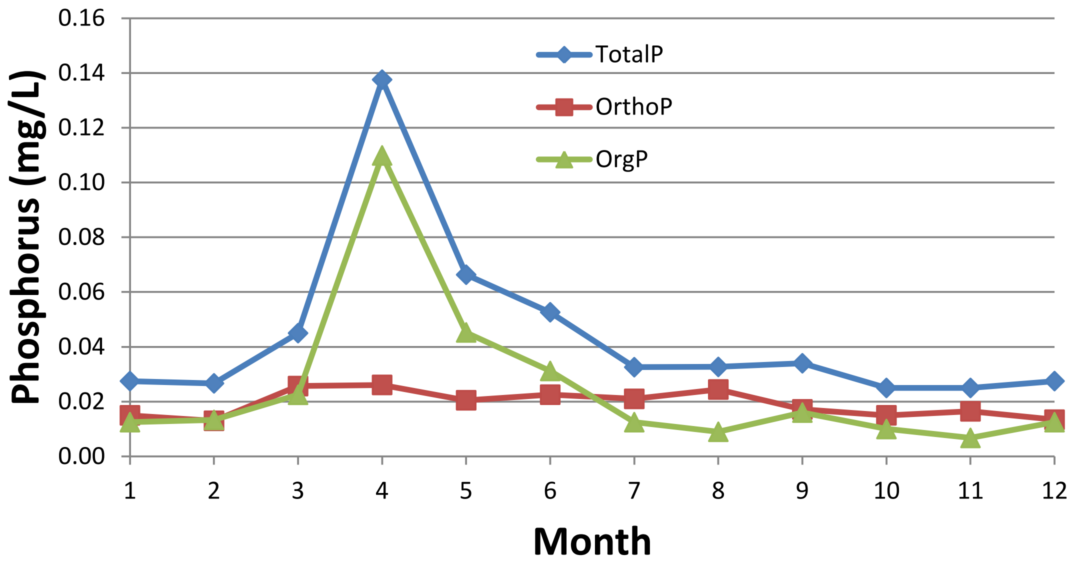


Figure D4-9. Average monthly observed phosphorus concentrations (mg/L)

Table D4-6. Observed mean nutrient concentrations at Little Blackfoot River mouth (mg/L)

Month	OrgN	NO3	TN	OrthoP	OrgP	TP
January	0.233	0.035	0.268	0.015	0.013	0.028
February	0.130	0.028	0.158	0.013	0.013	0.027
March	0.385	0.044	0.429	0.026	0.023	0.045
April	0.560	0.039	0.599	0.026	0.110	0.138
May	0.331	0.021	0.353	0.021	0.045	0.066
June	0.342	0.021	0.363	0.023	0.031	0.053
July	0.198	0.010	0.208	0.021	0.013	0.033
August	0.219	0.014	0.233	0.024	0.009	0.033
September	0.250	0.010	0.260	0.017	0.016	0.034
October	0.300	0.010	0.310	0.015	0.010	0.025
November	0.182	0.025	0.207	0.016	0.007	0.025
December	0.175	0.054	0.229	0.013	0.013	0.028

This method preserves the seasonal and hydrologic correlations with nutrient loadings. However, as in the sediment methodology, this method averages out singular events that may have led to some of the higher observed values. Since nutrient TMDLs apply only to the growing season (July through September), and most of the large singular events happen during the spring runoff, this method is less sensitive to these issues. Mean values during the growing season (**Table D4-6**) corroborate the TMDL listing for the Little Blackfoot River for total phosphorus (0.030 mg/L is the draft numeric criterion), and the lack of a listing in the Little Blackfoot River for total nitrogen (0.300 mg/L is the draft numeric criterion).

Results of the nutrient calibrations at the USGS gage are shown in **Figures D4-10** and **D4-11**. As can be seen, the overall balance of nutrients is good, although from month to month there is some variation. The overall nutrient total balance for the 2002-2005 growing seasons was within 15% for both nitrogen and phosphorus. Although nutrient loadings in the tributaries were not calibrated individually (due to the small amount of data available within each tributary), model output was reviewed at each of these reaches, and the resulting concentrations were reasonable.

Nutrient speciation was also modeled. Although the total nitrogen and total phosphorus values were similar to observed, during the summer season the nitrogen speciation did not align with the observed data. Nitrate was present in the same or higher quantities than organic nitrogen, which is not in line with the observed data (**Figure D4-8**). We were unable to satisfactorily address this issue. However, only one of the developed nitrogen TMDLs was for nitrate/nitrite (Snowshoe Creek). This issue is discussed further in **Section D5.7**.

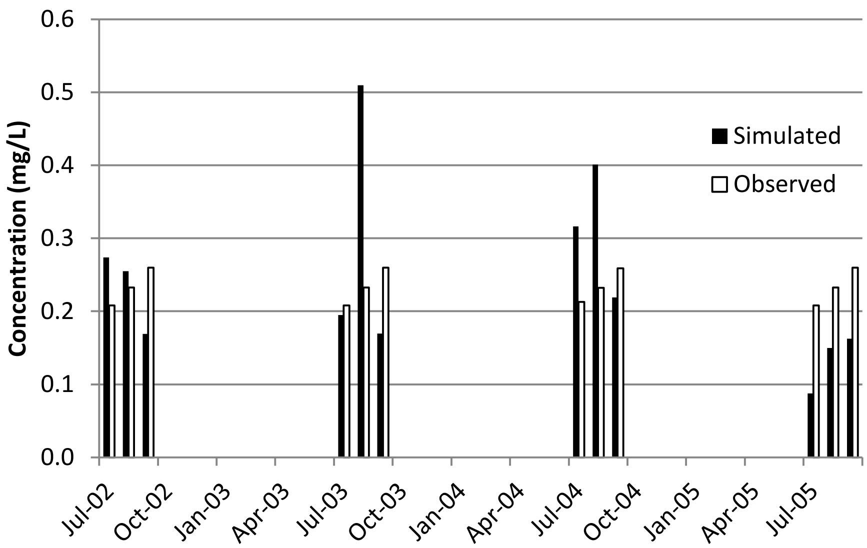


Figure D4-10. Total nitrogen concentrations by month, 2002-2005

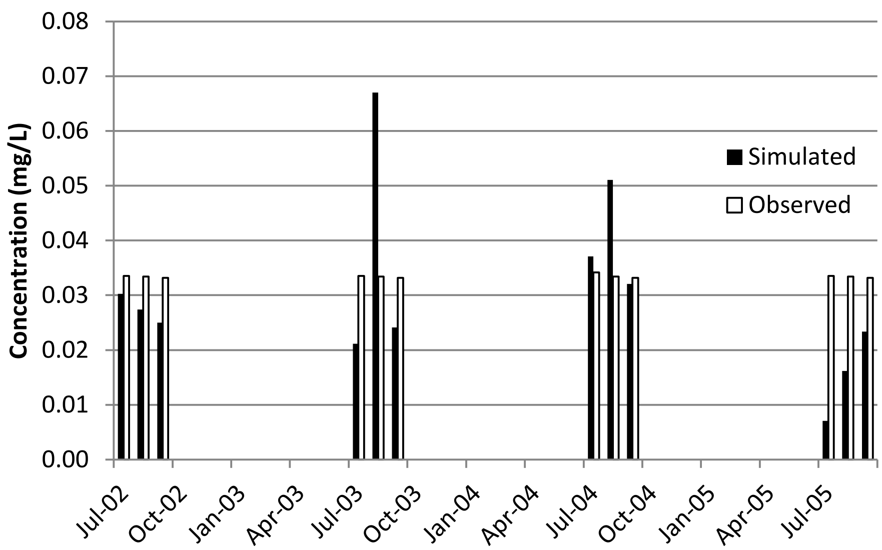


Figure D4-11. Total phosphorus concentrations by month, 2002-2005

D4.7 Model Validation/Confirmation

Model validation is the independent process by which a model is tested against "new" data, usually from a different time period than the calibration period. If the calibrated model predicts the validation period, it is considered to be "validated".

The calibrated model was run for the validation time period 1/1/2006 through 12/31/2008. There was a six month window of missing data from the USGS gage from November 2006 through April 2007. This missing time period was removed from the validation analysis. The validation results were similar to the calibration results (**Figure D4-12**). The model tended to under-predict high flow years (2005, 2008), while slightly over-predicting low-flow years (2004, 2006).

However, the relative error for the validation period was within the allowed range for the annual flow, and just outside of the accepted range for the summer flow (**Table D4-7**). The Nash-Sutcliffe efficiency values were acceptable for both time periods.

For both the calibration period and the validation period, the model accurately predicted flows on an annual basis. The validation period for summer flows trended towards under-predicting. Although the value was just outside the ideal range, this may have the effect of slightly under-predicting water-quality parameters associated with low-flow periods (i.e. nutrients).

There may also be several explanations for why the model slightly under-predicted summer flows in the validation period. Summer flows are difficult to predict due to the highly variable flows from year to year. Landowners tend to over-use water in wet years, and use just enough in dry years. This presents a problem for modeling, as the actual water use by ranchers cannot be accurately predicted from year to year. Additionally, in 2006 the Montana Water Trust purchased 2.52 cfs of water rights from May 1st to September 30th from a local land owner (PBS&J, 2009; Clark Fork Coalition, personal communication 2011) to enhance instream summer low-flows. The value of the water rights purchase was not determined until after the model was completed, so it was not included in the model. The water rights purchase does not affect the calibration period at all, and the small volume (2.52 cfs, or 0.07 cms, over four months) is unlikely to significantly affect the validation period results. However, if it does have a minor effect on the model, it would be to slightly under-predict summer flows in the validation period. Note that the Montana Water Trust was acquired by the Clark Fork Coalition in March 2010 and the water rights were transferred to the Clark Fork Coalition at that time.

In summary, all metrics were within the pre-determined allowed ranges with the exception of the relative error of the summer growing season validation period (and this was close to acceptable range). The model did a good job of predicting system trends, and since this is the overall goal, for this purpose the model was considered calibrated and validated.

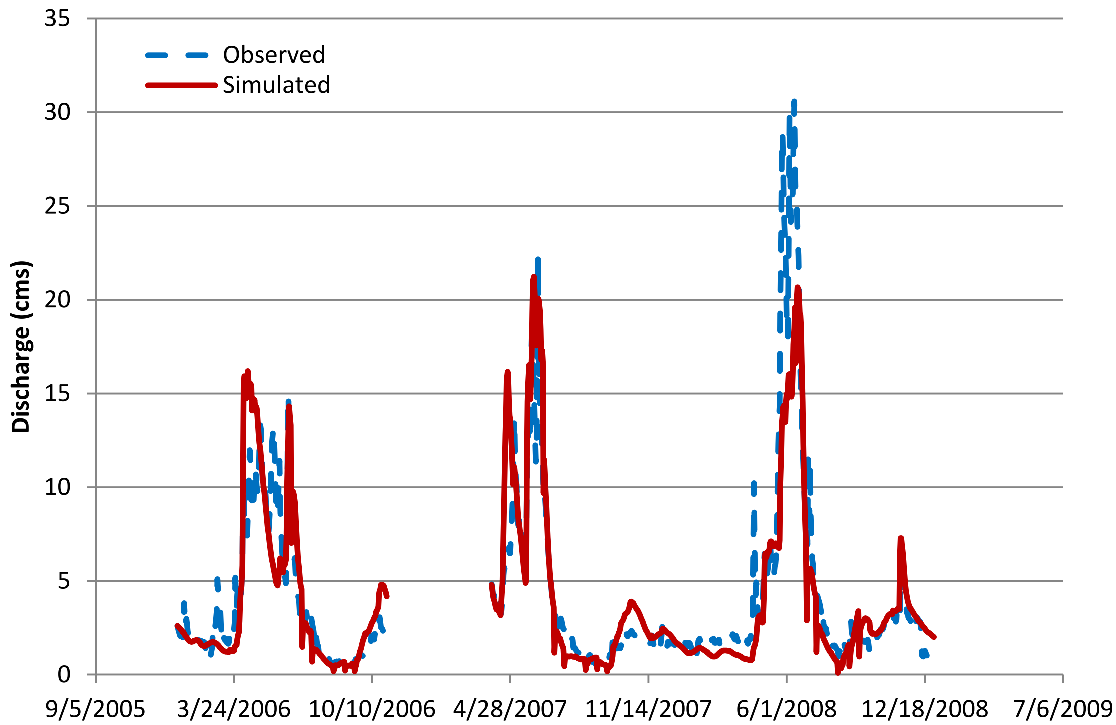


Figure D4-12. Model validation, daily hydrology, 2006-2008

Table D4-7. Daily validation metrics, 2006-2008

	Observed Total Volume (acre-feet)	Simulated Total Volume (acre-feet)	Difference (%)	Relative Error (%)	Nash-Sutcliffe
Annual	277,295	293,936	6.0%	6.0%	0.75
Summer	35,093	29,345	-16.4%	-16.6%	0.61

D5.0 Scenario Analysis

Scenario development was accomplished using the calibrated and validated SWAT Little Blackfoot model. In addition to the baseline scenario (i.e. existing condition), several scenarios were modeled to estimate sediment and nutrient loading reductions associated with various best management practices (BMPs), and to identify the BMP combinations most likely to result in TMDL attainment. Scenarios were focused on sources that tend to be the most significant for sediment and nutrients, and included improvements in management practices that are commonly recommended and applicable to this watershed.

Scenarios modeled for this project include rotational grazing, channel protection, enhancement/protection of riparian areas, improvements to roadways, improved irrigation efficiency, and combinations thereof. These scenarios are further discussed (with results) below. An overall summary of reduction percentages by listed stream segment is given in **Section D5.7**, tables with the upland erosion reductions by source are provided for each watershed in **AppendixDA**. However, before discussing specific scenarios, the ability of SWAT to model BMPs is discussed.

With the exception of improved roads, all other scenarios are directly influenced by agricultural management practices. The scenarios are intended to simulate common BMPs but are not prescriptive. A literature search by Agouridis et al. (2005) provides a comprehensive literature review of common agricultural BMP implementation practices in the United States, and reports in general, that at least one aspect of stream water quality (e.g. chemical, physical, or biological) has improved in watersheds that received one or more of the following measures: livestock exclusion, offstream watering, alternate shade, rotational grazing, supplemental feeding, and buffer strips. As such, DEQ believes that one or more practices could be implemented cost-effectively (e.g. through cost-shares with NRCS) to improve water quality in the Little Blackfoot River watershed.

At the core of SWAT is the hydrologic response unit (HRU). This is SWAT's fundamental computational unit, and most parameter modifications affect SWAT at the HRU level. HRUs are portions of the same sub-basin that share similar land uses, soils, and slopes. An HRU can (and typically does) consist of multiple spatial areas that are located within the same sub-basin, but aren't adjacent to each other. However, these non-adjacent areas are lumped into one HRU as long as they share similar land use, soil, and slope. There is no spatial context to HRUs – every HRU is assumed to deliver its load directly to its reach and it is irrelevant to SWAT whether the HRU is adjacent to the stream, or at a distance from the stream – i.e., it treats all HRUs the same in that regard. Furthermore, most BMPs are applied to the HRU, not to the sub-basin or watershed, so applying a BMP to one stretch of river may require applying it to multiple HRUs (and their associated area), and may be somewhat limited by the breakdown of HRUs in each watershed.

One final point is that SWAT does not currently explicitly model riparian areas within reaches. Rather it allows for edge of HRU buffers which effectively are available to remove pollutants only at the edge of the HRU. It is important to reiterate that HRUs are not routed through each other, but only to the channel. A riparian feature is in the works for future versions of SWAT where HRUs can be routed through other HRUs (such as in the case of a riparian area). Currently, however, this is not an option in the model and therefore, any "improvements to riparian area" cannot directly be modeled without some assumptions about the extent of the riparian area that has an effect on a given HRU and its associated conditions.

D5.1 Baseline Scenario

The calibrated model was used to develop the baseline scenario. The baseline scenario represents the conditions that existed in the watershed in the 2002-2005 time period. The average hydrograph is shown in **Figure D5-1**. The downward spikes in the summer period represent the days when irrigation was turned on. Realistically, all fields and all ranches do not irrigate on the same day in the summer. However, to reduce model complexity, a simple irrigation schedule was used. While this has a minimal influence on an annual basis, it likely reduces the NSE and RE of the model fit for the summer growing season. Additionally, as mentioned in **Section D3.10**, any unused water in the irrigation scheme is returned to its source.

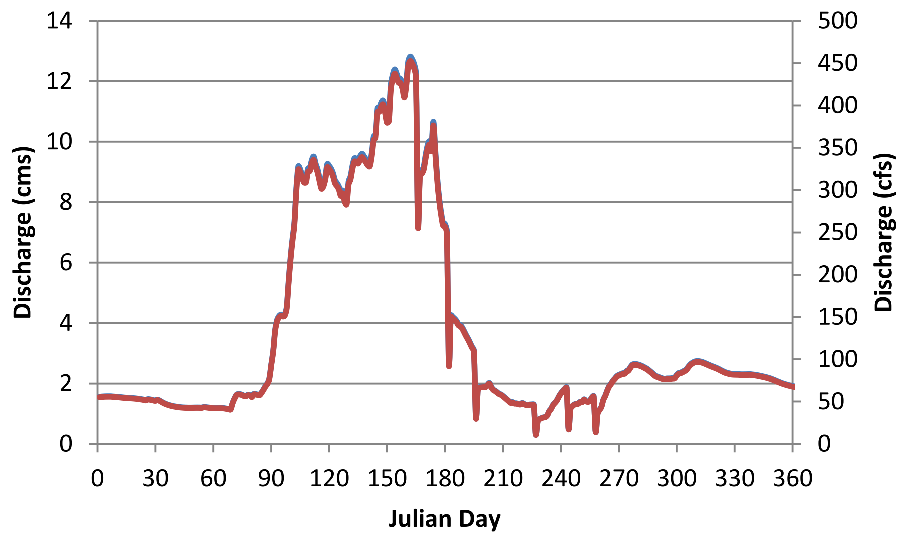


Figure D5-1. Average annual hydrograph (simulated), 2002-2005

D5.1.1 Baseline Scenario - Sediment

Sediment loading was calculated for each of the ten segments in need of sediment TMDLs. Each segment was broken down by the following potentially significant source categories: upland contributions by land use, roads, and streambank erosion. Streambank erosion was not specifically calculated as a source; rather, the difference between the sum of the loadings from all upland sources and roadways (considering any sediment loss in reservoirs if applicable) was determined, and then this value was subtracted from the actual load reaching the reach outlet. This difference was considered to be loading from streambank erosion. The breakdown for the entire watershed (Little Blackfoot River) is shown in **Table D5-1** as an example. The existing loads for the other listed streams, and all future scenario results (including the Little Blackfoot River), can be found in **Appendix DA**.

Table D5-1. Sediment contributions, Little Blackfoot River

Area (sqkm)	Area (ha)	Annual Load (metric tons/year)	Annual Load (%)	Category
592	59,169	1,664	12.4%	Forest
49	4,874	812	6.0%	Pasture
416	41,561	8,288	61.7%	Rangeland
6	582	185	1.4%	Urban
6	557	1	0.0%	Wetlands
-	-	69.5	0.5%	Roads
-	-	2,413	18.0%	Streambanks
1,067	*106,743*	*13,433*	*100.0%*	*Total**

*Total does not reflect actual delivered sediment load of 11,990 metric tons/year, as total includes 1,443 metric tons/year of sediment trapped in reservoirs.

In this watershed, rangeland is the highest contributor to sediment. Streambank erosion accounts for approximately 18% of the sediment loading. Urban and roadway loadings are minimal in this watershed. This trend remained fairly constant for the other listed streams. The sediment breakdowns for these watersheds can all be found in **Appendix DA** (Model Scenario Results).

D5.1.2 Baseline Scenario - Nutrients

A total phosphorus TMDL was developed for the Little Blackfoot River watershed and four tributaries. A total nitrogen TMDL was developed for one tributary (Threemile Creek), and a nitrate/nitrite TMDL was developed for one tributary (Snowshoe Creek). The existing phosphorus loads for the entire Little Blackfoot River watershed due to upland erosion and septic loads are shown in **Table D5-2** as an example. The existing loads for the other listed streams, and all future scenario results (including the Little Blackfoot River), can be found in **Appendix DA**.

Table D5-2 Total phosphorus contributions on the Little Blackfoot River during the growing season

Area (sqkm)	Area (ha)	Summer Load (kg/growing season)	Summer Load (%)	Category
592	59,169	78.2	20.8%	Forest
49	4,874	72.3	19.2%	Pasture
416	41,561	134.5	35.8%	Rangeland
6	582	47.3	12.6%	Urban
6	557	1.0	0.3%	Wetlands
-	-	42.4	11.3%	Septic
1,067	*106,743*	*375.7*	*100.0%*	*Total*

Phosphorus contributions are spread out across the land uses. Septic loads account for approximately 11% of the phosphorus loading in the watershed. The nutrient breakdowns for the other listed streams can be found in **Appendix DA** (Model Scenario Results). The existing results will be used in the next sections to compare to predicted loading for future management scenarios.

D5.2 Improved Roadways Scenario

Approximately 38% of the LBF watershed is managed by the USFS, and 55% is privately owned. Both the USFS land and private ranches are heavily traversed with roadways for access to grazing areas, logging areas, recreational areas, and other sites. Therefore, the watershed contains a large number of gravel and dirt roads, many of which are near or adjacent to streams. A 2010 road sediment assessment report categorized the road sediment loading throughout the watershed ((PBS&J, 2010); **TMDL Appendix E**). The report categorized the degree of impact based on several factors, and then estimated sediment loads based on these factors. Existing and future road conditions (after BMP implementation) and corresponding sediment loads were modeled to determine the amount of reduction that was feasible through road improvements.

The existing road conditions and sediment loadings calculated in the road assessment were introduced into the SWAT model through use of point sources. Since roads are not a separate land use in this model (i.e., they are not explicitly modeled), each sub-basin had a sediment point source added to simulate the road loadings. These loads are distributed evenly throughout the year. Note that the overall contribution from roadways is small in comparison to other upland sources (**Table D5-1**).

D5.2.1 Improved Roadways Scenario - Sediment

To apply future road improvements, the existing condition loadings were replaced by the future conditions loading results from the road sediment assessment report. Implementation of roadway BMPs would result in approximately a 55% drop in the sediment loadings from roadways (**Table D5-3**). Overall, roadways were a small fraction of the overall sediment loading (**Table D5-1**).

Table D5-3. Sediment loadings reductions from improved roadways by stream segment (PBS&J, 2010)

River Segment	Sub-Basin	Reduction (%) in Road Sediment Load
Threemile Creek	9	45%
Snowshoe Creek	15	74%
Spotted Dog Creek	26	79%
Little Blackfoot River - Mouth	27	54%
Little Blackfoot River - Headwaters	25	71%
Elliston Creek	22	56%
Trout Creek	29	37%
Telegraph Creek above Hahn Creek	35	71%
Dog Creek	21	71%
Dog Creek above Meadow Creek	2	70%

D5.2.2 Improved Roadways Scenario - Nutrients

Nutrient loadings were not affected by improvements in roadways. The overall loading from roadways is low, and only a small fraction of nutrient loading is tied to sediment. Therefore, this scenario was insignificant in reducing nutrient loadings.

D5.3 Stabilized Channel Scenario

Currently, many of the channels and reaches in the watershed are open to cattle grazing. This can result in trampled areas with little or no vegetation along the streams, and stream channel beds that become less stable. These processes increase sediment and nutrient loading to the river. Direct excretion of cattle manure into waterbodies adds relatively large loads of nutrients directly into the streams as well (although this aspect is not directly modeled by SWAT). Streambanks are a significant source of sediment in the watershed (**Table D5-1**).

The model at this time has no direct provision for modeling bank trample or increased erosion of streambanks from cattle. However, these processes can be roughly simulated via direct adjustment of the bank cover factors for a given stream reach. Bank cover factors account for the health of the bank by considering the amount of vegetation on the streambanks and channels and the status of the soils along the streambanks and channel beds.

To apply reductions in near-stream grazing and bank erosion, we increased the channel cover in areas that are heavily grazed. Since the Little Blackfoot River channel below Elliston is larger and has steeper and higher banks, and a significant portion of it is adjacent to the highway, it was assumed that cattle did not have easy access to this portion of the channel, and no improvements could be made. No changes were made to tributary areas that are not grazed.

The amount of increase in the channel cover factor was difficult to determine. We ended up using a fairly arbitrary reduction, reducing the channel cover factor from 0.8 (calibrated) to 0.2. This was difficult to justify, as there was no literature on the subject available. Because of the uncertainty in this calculation, we decided to use reductions from the bank erosion field assessment (**TMDL Appendix C**) (rather than from the SWAT model). The field-derived reductions were applied to the SWAT-modeled streambank load to calculate reductions for the final TMDL. These are the reductions listed in **Section D5.7**.

The modeled scenario did provide some benefit, as existing streambank loads and reductions from the model were compared to the field assessment, and the relative magnitude of contributions from each sub-basin was similar.

D5.3.1 Stabilized Channel Scenario - Sediment

Modeled improvements to channel protection and bank erosion have the potential to reduce streambank erosion in the Little Blackfoot River watershed by approximately one to five percent, depending on the sub-basin (**Table D5-4**). As mentioned above, this value was not used in the final TMDL, and relative reductions from the bank erosion field assessment were used.

D5.3.2 Stabilized Channel Scenario - Nutrients

Improvements in streambank erosion did not affect overall nutrient reductions. In reality, decreasing bank erosion will likely reduce phosphorus loading as well. However, because the overall reduction in sediment loading was small, and phosphorus attached to sediment is only a small portion of the overall phosphorus load, and the reduction happened in the actual reach where complex instream nutrient processes are happening (as compared to upland areas in the other scenarios), the model did not predict a phosphorus load reduction. Therefore, a phosphorus load reduction for this category was not used in the final TMDL (**Table D5-5**).

D5.4 Improved Grazing Management Scenario

The third scenario analyzed was an improvement in grazed land conditions. This includes both winter pasture and summer range. It has been well established that grazing decreases ground cover, which influences sedimentation processes. No specific practice was specified for this improvement, as ground cover can potentially be altered through a number of BMPs including alteration of cattle distribution on the landscape (e.g. water, shade), modification of the grazing time-frame and duration through different rotational practices, or reductions in stocking density. To reflect some combination of these changes, modifications were made to the USLE C factor in SWAT. Adjustment was made based on several studies in southwestern and central Montana which relate rangeland ground cover response to grazing practices. According to Evanko and Peterson (1955), bare ground was shown to be 14.9, 18.6, and 6.8 percent higher on the Beaverhead National Forest near Dillon, MT on sites that were heavily, moderately, and lightly grazed than those with no cattle on them. The comparison was made after a 15-18 year exclusion period. Similar results were found in an exclusion study on foothill sheep ranges in Meagher County near White Sulphur Springs, MT. Total cover (e.g. foliage and litter) was 16.7 percent higher between protected and grazed plots in that study after four years of exclusion (Vogel and Van Dyne, 1966). Thus it is apparent that a relationship between ground cover and grazing does exist, and a maximum difference between grazed and ungrazed lands is around 15-20 percent. Thus a conservative estimate of a 10% improvement for range USLE C factor, and a 15% improvement in pasture USLE C factor was used in this scenario (**Table D3-2**).

D5.4.1 Improved Grazing Management Scenario - Sediment

Improvements to grazing management have the potential to reduce overall upland loading of sediment to the listed watersheds by 2 to 22% (**Table D5-4**). The reductions are from loadings associated with grazed rangeland and pasture. Loading reductions by land use for this scenario are provided in **Appendix DA**.

D5.4.2 Improved Grazing Management Scenario - Nutrients

Improvements to grazing management have the potential to reduce overall upland loading of nitrogen and phosphorus to the listed watersheds by approximately 4 to 18% for nitrogen and 8% and 33% for phosphorus (**Table D5-5**), during the growing season (July through September). Loading reductions by land use for this scenario are provided in **Appendix DA**.

D5.5 Enhanced Riparian Health Scenario

Riparian vegetation in the Little Blackfoot River watershed has been degraded by a variety of factors including historic vegetation removal, overgrazing and trampling, mining, silviculture, and residential development. Because riparian areas function as important filters for streamflow and overland runoff, a scenario was run to evaluate the effect of improved riparian health on sediment and nutrient loads.

A riparian habitat assessment was completed for the Little Blackfoot River watershed (PBS&J, 2010); described in **TMDL Appendix C**) to collect data on riparian area extent, health, and locations. Delineated reaches were given a riparian condition category of good, fair, or poor based on land use adjacent to the stream, riparian vegetation type and density, and the presence or absence of human related activities near the stream corridor. Based on this, the riparian areas along each stream investigated were given ratings (and corresponding percentages) of good, fair, or poor based on the results of the assessment.

Literature values were used to determine the buffering capacity potential for a given category. Sediment reduction potential improves by 25% when improving riparian condition from fair to good, and 50% when improved from poor to good (see **Section 5.7.1** of the TMDL for a discussion of this method). Sub-basins were analyzed for riparian health, and then riparian buffer areas (via field strips in the .hru file) were applied based on these results. Filter strips were applied at either a 30 foot, 50 foot, or 100 foot width depending on the health of the riparian area (see **Section 5.7.1** of the TMDL). Most improvements were either 30 feet or 50 feet. These buffer areas represent streambanks that have been removed from grazing and other management by fences or other means.

SWAT applies filter strips at the HRU level. Filter strips reduce the sediment and nutrient loads in both the overland flow and subsurface flow. The filter strip could be considered roughly analogous to a riparian area as they both filter nutrients and sediment from the computed HRU load prior to delivery to the channel for routing. In this scenario, filter strips were applied to areas that tend to be alongside streams (pasture), and areas that are heavily grazed (rangeland and forest). One important limitation (mentioned in **Section D5.0**) is since filter strips are applied to HRUs (and not at a watershed level), their application is somewhat restricted by the model-derived division of HRUs within each sub-basin. For example, if improved riparian areas were supposed to be applied to 50% of a sub-basin, but there were five HRUs each comprising 20% of the sub-basin, then we had to apply the filter strips to either 40% or 60% of the sub-basin (an HRU cannot be split up). We typically took the closer value if confronted with this issue. Therefore, some sub-basins may not be able to achieve the estimated reductions, while others will likely be able to achieve greater reductions.

D5.5.1 Enhanced Riparian Health Scenario - Sediment

Improvements to riparian areas have the potential to reduce overall upland loading of sediment to the listed watersheds by approximately 10 to 40% (**Table D5-4**). The reductions are from loadings associated with grazed rangeland, forest, and pasture. Loading reductions by land use for this scenario are provided in **Appendix DA**.

D5.5.2 Enhanced Riparian Health Scenario - Nutrients

Improvements to riparian areas have the potential to reduce overall upland loading of nitrogen and phosphorus to the listed watersheds by approximately 12 to 40% for nitrogen and 22 to 48% for phosphorus (**Table D5-5**), during the growing season (July through September). Loading reductions by land use for this scenario are provided in **Appendix DA**.

D5.6 Improved Irrigation Scenario

The LBF watershed contains approximately 4,900 hectares (12,500 acres) of irrigated pasture/hay. This land is typically flood irrigated starting in mid-spring when runoff is high, and then routinely irrigated throughout the summer. There is a short break in irrigation in August while hay is being harvested, and then irrigation resumes through the beginning of October.

Irrigation management is handled in SWAT by management files. These files contain detailed irrigation information. In irrigation management within SWAT, a date is specified, and on that date, the amount (mm/ha) of irrigation, irrigation efficiency, and fraction of surface runoff are specified.

In this scenario, it was assumed that the overall irrigation efficiency (either amount of water used, timing and duration of irrigation, delivery method, etc) could be improved by 5%. This value was chosen as being a reasonably attainable number.

Results of this scenario indicated that the overall sediment and phosphorus loading reductions (associated with overland runoff) were less than 1%. The nitrate/nitrite loading reductions (associated with subsurface flow) were higher, between 1 and 10%, depending on the watershed. However, since the only stream that is listed for nitrate/nitrite is Snowshoe Creek (**Table D1-1**), and this method did result in a small reduction in modeled crop yield, this option was not pursued further. This does not mean that an improvement in irrigation efficiency would not facilitate loading reductions, or enhance the overall health of the watershed, but rather that the model parameterization and BMP application need further refinement before this method could be used to make management recommendations.

D5.7 Scenario Summary

Sediment and nutrient reductions based on the different scenarios are shown in **Tables D5-4** and **D5-5**. More detailed breakdowns of upland erosion by land cover type can be found either in the corresponding section (for the entire Little Blackfoot River watershed), or in **Appendix DA**. Reported daily loads for sediment are required by the EPA. Although not analyzed in this report, daily sediment loads are included as **Appendix DB**.

Nutrients were reported on a seasonal basis (July – October) to determine reduction strategies for the growing season. However, they were modeled on an annual basis. In general, annual nutrient load reductions were greater than the summer growing season reductions (**Table D5-6**). Thus, it is likely that overall nutrient reductions will be greater than those reported.

One unaddressed issue is the nitrogen speciation problem, and the developed TMDL for nitrate/nitrite for Snowshoe Creek. The model was not able to accurately predict nitrogen speciation during the summer. However, since total nitrogen and nitrate/nitrite are closely related, the recommended BMPs for TN should also reduce NO3/NO2 by a similar amount.

The combination of improvements to roadways, improvements to grazing management, and improvements/enhancement of riparian health was the combination that achieved the highest total sediment and nutrient reductions of the modeled scenarios (**Table D5-4 and Table D5-5**). As discussed in **Section D5.4**, bank erosion reductions were calculated externally and applied to the results. Bank erosion reductions are also a part of the TMDL allocation.

Table D5-4. Overall reductions in sediment loading by stream segment (on an annual basis)

BMP Scenario	River Segment	Sub-Basin	Sediment Load Reductions (%)
Improved Roadways	Threemile Creek	9	0.5%
	Snowshoe Creek	15	1.2%
	Spotted Dog Creek	26	0.3%
	Little Blackfoot River - Mouth	27	0.3%
	Little Blackfoot River - Headwaters	25	0.2%
	Elliston Creek	22	0.0%
	Trout Creek	29	0.9%
	Telegraph Creek above Hahn Creek	35	1.7%
	Dog Creek	21	0.2%
	Dog Creek above Meadow Creek	2	0.7%
Improved Grazing Management	Threemile Creek	9	22.1%
	Snowshoe Creek	15	13.8%
	Spotted Dog Creek	26	8.1%
	Little Blackfoot River - Mouth	27	8.7%
	Little Blackfoot River - Headwaters	25	5.6%
	Elliston Creek	22	12.3%
	Trout Creek	29	8.2%
	Telegraph Creek above Hahn Creek	35	2.4%
	Dog Creek	21	6.4%
	Dog Creek above Meadow Creek	2	12.1%
Enhanced Riparian Health	Threemile Creek	9	40.4%
	Snowshoe Creek	15	12.9%
	Spotted Dog Creek	26	14.8%
	Little Blackfoot River - Mouth	27	12.0%
	Little Blackfoot River - Headwaters	25	7.0%
	Elliston Creek	22	22.3%
	Trout Creek	29	17.4%
	Telegraph Creek above Hahn Creek	35	13.9%
	Dog Creek	21	8.7%
	Dog Creek above Meadow Creek	2	14.8%
Stabilized Channels	Threemile Creek	9	0.3%
	Snowshoe Creek	15	1.9%
	Spotted Dog Creek	26	2.1%
	Little Blackfoot River - Mouth	27	3.6%
	Little Blackfoot River - Headwaters	25	0.6%
	Elliston Creek	22	0.4%
	Trout Creek	29	5.3%
	Telegraph Creek above Hahn Creek	35	1.2%
	Dog Creek	21	1.5%
	Dog Creek above Meadow Creek	2	0.0%
Enhanced Riparian	Threemile Creek	9	46.0%

Table D5-4. Overall reductions in sediment loading by stream segment (on an annual basis)

BMP Scenario	River Segment	Sub-Basin	Sediment Load Reductions (%)
Health plus Improved Roadways plus Improved Grazing Management	Snowshoe Creek	15	23.1%
	Spotted Dog Creek	26	21.7%
	Little Blackfoot River - Mouth	27	17.9%
	Little Blackfoot River - Headwaters	25	11.8%
	Elliston Creek	22	27.5%
	Trout Creek	29	23.1%
	Telegraph Creek above Hahn Creek	35	15.6%
	Dog Creek	21	14.1%
	Dog Creek above Meadow Creek	2	23.2%

Table D5-5. Overall reductions in nutrient loading by stream segment on a seasonal (July – Oct) basis

BMP Scenario	River Segment	Sub-Basin	Load Reductions (%)	
			TN	TP
Improved Roadways	Threemile Creek	9	0.0%	0.0%
	Carpenter Creek	12	0.0%	0.0%
	Snowshoe Creek	15	0.0%	0.0%
	Dog Creek	21	0.0%	0.0%
	Spotted Dog Creek	26	0.0%	0.0%
	Little Blackfoot River - Mouth	27	0.0%	0.0%
Improved Grazing Management	Threemile Creek	9	7.8%	8.5%
	Carpenter Creek	12	5.7%	10.0%
	Snowshoe Creek	15	18.0%	33.1%
	Dog Creek	21	3.6%	9.2%
	Spotted Dog Creek	26	15.0%	13.2%
	Little Blackfoot River - Mouth	27	8.4%	11.1%
Enhanced Riparian Health	Threemile Creek	9	39.2%	47.5%
	Carpenter Creek	12	17.4%	28.8%
	Snowshoe Creek	15	11.5%	22.1%
	Dog Creek	21	18.4%	28.1%
	Spotted Dog Creek	26	39.0%	45.6%
	Little Blackfoot River - Mouth	27	21.1%	29.6%
Stabilized Channels	Threemile Creek	9	0.0%	0.0%
	Carpenter Creek	12	0.0%	0.0%
	Snowshoe Creek	15	0.0%	0.0%
	Dog Creek	21	0.0%	0.0%
	Spotted Dog Creek	26	0.0%	0.0%
	Little Blackfoot River - Mouth	27	0.0%	0.0%
Enhanced Riparian Health plus Improved Roadways plus Improved Grazing Management	Threemile Creek	9	42.7%	49.2%
	Carpenter Creek	12	20.1%	33.6%
	Snowshoe Creek	15	25.3%	44.6%
	Dog Creek	21	18.5%	36.6%
	Spotted Dog Creek	26	42.5%	50.3%
	Little Blackfoot River - Mouth	27	25.3%	38.4%

Table D5-6. Annual versus summer (July-September) nutrient reductions

Management Scenario	Total Nitrogen Loading Reduction (%)		Total Phosphorus Loading Reduction (%)	
	Annual	Summer	Annual	Summer
Improved Grazing Management	8.1%	8.4%	14.9%	11.1%
Enhanced Riparian Health	24.6%	21.1%	36.1%	29.6%
Combined	29.9%	25.3%	41.3%	38.4%

D6.0 Conclusion and Limitations

Hydrologic modeling was completed on the Little Blackfoot River watershed to identify the contribution of different source categories to sediment and nutrient pollution, and to assess potential land management scenarios that might address these problems. Several management scenarios were evaluated to identify the most effective means of reducing sediment and nutrient loads in the river. These included improved grazing management, preservation and enhancement of riparian areas, protection of streambanks from livestock, improvements in irrigation efficiency, and improvements in road management. Through scenario analysis, it was shown that livestock management was the most sensitive management option for controlling sediment and nutrient pollution. Thus, the key management implications from this study are that sediment and nutrient loading will most effectively be reduced by the protection and enhancement of riparian areas and streamside buffers in grazed and agricultural areas, and improved grazing management, which may include rotational grazing and/or limiting grazing access to streambanks and channels (see **Section D5.4**). The modeling effort suggests that this combination of management practices could potentially reduce sediment and nutrient yields by 15 – 50%.

A model is only as good as the input data, assumptions, and parameterization used to develop it. This model, like any other, has certain limitations based on these factors. Climatic data is always crucial, as precipitation and evapotranspiration (ET) are the two most important processes for determining hydrology in any watershed. This modeling effort had only one precipitation gage located within the physical watershed, and the only available ET data was located in Deer Lodge, which is outside of the watershed in a drier valley. Additionally, the lack of continuous sediment and nutrient data made it impossible to set up a rigorous, daily calibration for either of these constituents.

Many of the assumptions used in this model had to do with land management practices. The Little Blackfoot has a legacy of mining, and mining practices were largely ignored in this model due to lack of sediment and nutrient loadings information (Olsen, 2004b; Milodragovich, 2003b). Management practices for grazing, irrigation, and hay production were largely estimated from personal communication with only a small subset of land owners in the area or from sporadic field visits.

However, the calibrated and validated hydrologic model met nearly all of the pre-determined evaluation criterion metrics, and responded well to climatic inputs. Additionally, the sediment and nutrient calibrations were reasonable. This model is to be used as a relative gage of system response to various management changes, rather than an absolute indicator of sediment and nutrient loadings. And in this capacity, in spite of the limitations discussed above, the model met its objectives and is sufficient for the intended use.

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APPENDIX DA - MODELING SCENARIO RESULTS

DA.1.0 SEDIMENT

DA.1.1 Overview

For each modeling scenario, the total loading was broken down into three categories. These categories include (1) upland erosion by land use - forest, rangeland (including arid rangeland), pasture (including agricultural area), wetlands, and developed areas, (2) roads, and (3) streambanks. For each of the 10 developed TMDLs, there is a table showing the loadings (metric tons/year) by land use for each scenario. These are **Tables DA-1** through **DA-10**. The final column in each table is the "recommended" scenario, where the improved grazing, enhanced riparian areas, streambank protection, and roadway improvement scenarios were combined. This is not necessarily an additive scenario, as the effects of one of these improvements may reduce the efficiency of another one (e.g., less sediment incoming from improved grazing means less sediment trapped by the riparian buffers).

The final reduction percentages may be slightly different than those listed in the TMDL (**Table D5-4**). This is because of the way the streambank erosion values are calculated in SWAT. The existing streambank erosion value was determined by SWAT from the calibrated model. Because SWAT bases its streambank erosion on how much sediment is in the water column, the various reduction scenarios resulted in less sediment in the water column, and therefore slightly affected the overall streambank erosion results. However, since the reduction percentages were applied with external data (from the sediment and bank erosion assessment), they were applied to the existing streambank erosion only, and the slight differences in the SWAT calculations were ignored in the developed TMDL. These differences are rarely more than 1%.

DA.1.2 TABLES

Tables are listed in alphabetical order of the stream segment name.

Table DA-1. Dog Creek Sediment Summary

Category	Area (ha)	Existing Annual Load (mT*/year)	Improved Roadways Annual Load (mT/year)	Stabilized Streambank Annual Load (mT/year)	Improved Grazing Annual Load (mT/year)	Enhanced Riparian Areas Annual Load (mT/year)	Combined** Annual Load (mT/year)
Forest	9,094	458	458	458	458	458	458
Pasture	152	28	28	28	16	7	4
Rangeland	5,774	1,436	1,436	1,436	1,322	1,284	1,181
Developed	90	62	62	62	62	62	62
Wetlands	36	0	0	0	0	0	0
Roads	-	4.68	1.38	4.68	4.68	4.68	1.38
Streambanks		212.7	212.7	178.7	212.7	212.7	178.7
Total	*15,147*	*2,202*	*2,198*	*2,168*	*2,075*	*2,029*	*1,885*
Total Reduction (%)		**-**	**0.1%**	**1.5%**	**5.7%**	**7.9%**	**14.4%**

* mT = metric tons = 1.102 short tons

** Combined scenario includes roadway improvements, improved grazing, and enhanced riparian areas

Table DA-2. Dog Creek (Above Meadow Creek) Sediment Summary

Category	Area (ha)	Existing Annual Load (mT*/year)	Improved Roadways Annual Load (mT/year)	Stabilized Streambank Annual Load (mT/year)	Improved Grazing Annual Load (mT/year)	Enhanced Riparian Health Annual Load (mT/year)	Combined** Annual Load (mT/year)
Forest	1,329	9	9	9	9	9	9
Pasture	1	0	0	0	0	0	0
Rangeland	562	109	109	109	95	92	82
Developed	0	0	0	0	0	0	0
Wetlands	0	0	0	0	0	0	0
Roads	-	1.22	0.4	1.22	1.22	1.22	0.4
Streambanks		0.84	0.84	0.78	0.84	0.84	0.78
Total	*1,892*	*120*	*119*	*120*	*106*	*103*	*92*
Total Reduction (%)		**-**	**0.7%**	**0.0%**	**11.9%**	**14.5%**	**23.5%**

* mT = metric tons = 1.102 short tons

** Combined scenario includes roadway improvements, improved grazing, and enhanced riparian areas

Table DA-3. Elliston Creek Sediment Summary

Category	Area (ha)	Existing Annual Load (mT*/year)	Improved Roadways Annual Load (mT/year)	Stabilized Streambank Annual Load (mT/year)	Improved Grazing Annual Load (mT/year)	Enhanced Riparian Health Annual Load (mT/year)	Combined** Annual Load (mT/year)
Forest	1,419	37	37	37	37	37	37
Pasture	21	23	23	23	14	8	4
Rangeland	140	45	45	45	41	37	34
Developed	4	2	2	2	2	2	2
Wetlands	0	0	0	0	0	0	0
Roads	-	0.83	0.83	0.83	0.83	0.83	0.83
Streambanks	-	3.0	3.0	2.5	3.0	3.0	2.5
Total	*1,585*	*110*	*110*	*109*	*97*	*86*	*80*
Total Reduction (%)		**-**	**0.0%**	**0.4%**	**11.9%**	**21.5%**	**27.0%**

* mT = metric tons = 1.102 short tons

** Combined scenario includes roadway improvements, improved grazing, and enhanced riparian areas

Table DA-4. Little Blackfoot River Sediment Summary

Category	Area (ha)	Existing Annual Load (mT*/year)	Improved Roadways Annual Load (mT/year)	Stabilized Streambank Annual Load (mT/year)	Improved Grazing Annual Load (mT/year)	Enhanced Riparian Health Annual Load (mT/year)	Combined** Annual Load (mT/year)
Forest	59,169	1,664	1,664	1,664	1,662	1,645	1,645
Pasture	4,874	812	812	812	473	239	142
Rangeland	41,561	8,288	8,288	8,288	7,678	7,567	7,019
Developed	582	185	185	185	185	185	185
Wetlands	557	0.9	0.9	0.9	0.9	0.9	0.9
Roads	-	69.5	32.8	69.5	69.5	69.5	32.8
Streambanks	-	2,413	2,413	1,930	2,413	2,413	1,930
*Total****	*106,743*	*13,433*	*13,397*	*12,951*	*12,481*	*12,119*	*10,955*
Total Reduction (%)		**-**	**0.3%**	**3.6%**	**7.1%**	**9.8%**	**18.4%**

* mT = metric tons = 1.102 short tons
** Combined scenario includes roadway improvements, improved grazing, and enhanced riparian areas*** Total does not reflect actual delivered sediment load, as it includes sediment trapped in reservoir.

Table DA-5. Little Blackfoot River (Above Dog Creek) Sediment Summary

Category	Area (ha)	Existing Annual Load (mT*/year)	Improved Roadways Annual Load (mT/year)	Stabilized Streambank Annual Load (mT/year)	Improved Grazing Annual Load (mT/year)	Enhanced Riparian Health Annual Load (mT/year)	Combined** Annual Load (mT/year)
Forest	22,734	779	779	779	777	760	760
Pasture	136	17	17	17	9	4	2
Rangeland	2,921	2,890	2,890	2,890	2,692	2,663	2,486
Developed	4	1	1	1	1	1	1
Wetlands	97	0.2	0.2	0.2	0.2	0.2	0.2
Roads	-	8.9	2.6	8.9	8.9	8.9	2.6
Streambanks	-	237	237	213	237	237	213
Total	*25,892*	*3,933*	*3,926*	*3,909*	*3,726*	*3,674*	*3,466*
Total Reduction (%)		**-**	**0.2%**	**0.6%**	**5.3%**	**6.6%**	**11.9%**

* mT = metric tons = 1.102 short tons
** Combined scenario includes roadway improvements, improved grazing, and enhanced riparian areas

Table DA-6. Snowshoe Creek Sediment Summary

Category	**Area (ha)**	**Existing Annual Load (mT*/year)**	**Improved Roadways Annual Load (mT/year)**	**Stabilized Streambank Annual Load (mT/year)**	**Improved Grazing Annual Load (mT/year)**	**Enhanced Riparian Health Annual Load (mT/year)**	**Combined** Annual Load (mT/year)**
Forest	1,400	24	24	24	24	24	24
Pasture	269	73	73	73	42	53	30
Rangeland	2,996	219	219	219	207	198	189
Developed	0	0	0	0	0	0	0
Wetlands	28	0	0	0	0.0	0.0	0.0
Roads		2.10	0.54	2.10	2.1	2.1	0.5
Streambanks		31	31	25	31	31	25
*Total****	*4,693*	*349*	*348*	*343*	*306*	*308*	*268*
Total Reduction (%)		**-**	**0.4%**	**1.9%**	**12.5%**	**11.8%**	**23.2%**

* mT = metric tons = 1.102 short tons

** Combined scenario includes roadway improvements, improved grazing, and enhanced riparian areas

Table DA-7. Spotted Dog Creek Sediment Summary

Category	**Area (ha)**	**Existing Annual Load (mT*/year)**	**Improved Roadways Annual Load (mT/year)**	**Stabilized Streambank Annual Load (mT/year)**	**Improved Grazing Annual Load (mT/year)**	**Enhanced Riparian Health Annual Load (mT/year)**	**Combined** Annual Load (mT/year)**
Forest	5,123	185	185	185	185	185	185
Pasture	342	80	80	80	44	24	14
Rangeland	6,023	1,268	1,268	1,268	1,180	1,097	1,017
Developed	0	0	0	0	0	0	0
Wetlands	12	0	0	0	0	0	0
Roads	-	3.63	0.75	3.63	3.63	3.63	0.75
Streambanks	-	76	76	42	76	76	42
*Total****	*11,500*	*1,612*	*1,609*	*1,578*	*1,488*	*1,385*	*1,257*
Total Reduction (%)		**-**	**0.2%**	**2.1%**	**7.7%**	**14.1%**	**22.0%**

* mT = metric tons = 1.102 short tons

** Combined scenario includes roadway improvements, improved grazing, and enhanced riparian areas*** Total does not reflect actual delivered sediment load, as it includes sediment trapped in reservoir.

Table DA-8. Telegraph Creek (Above Hahn Creek) Sediment Summary

Category	Area (ha)	Existing Annual Load (mT*/year)	Improved Roadways Annual Load (mT/year)	Stabilized Streambank Annual Load (mT/year)	Improved Grazing Annual Load (mT/year)	Enhanced Riparian Health Annual Load (mT/year)	Combined** Annual Load (mT/year)
Forest	3,890	103	103	103	103	86	86
Pasture	8	3	3	3	2	1	0
Rangeland	274	32	32	32	30	32	30
Developed	0	0	0	0	0	0	0
Wetlands	0	0	0	0	0	0	0
Roads	-	3.40	1.00	3.40	3.40	3.40	1.00
Streambanks	-	22.2	22.2	20.2	22.2	22.2	20.2
Total	*4,172*	*163*	*161*	*161*	*160*	*144*	*137*
Total Reduction (%)		**-**	**1.5%**	**1.2%**	**2.0%**	**11.7%**	**15.9%**

* mT = metric tons = 1.102 short tons

** Combined scenario includes roadway improvements, improved grazing, and enhanced riparian areas

Table DA-9. Threemile Creek Sediment Summary

Category	Area (ha)	Existing Annual Load (mT*/year)	Improved Roadways Annual Load (mT/year)	Stabilized Streambank Annual Load (mT/year)	Improved Grazing Annual Load (mT/year)	Enhanced Riparian Health Annual Load (mT/year)	Combined** Annual Load (mT/year)
Forest	5,086	41	41	41	41	40	40
Pasture	2,112	304	304	304	184	50	34
Rangeland	6,006	276	276	276	248	276	247
Developed	41	7	7	7	7	7	7
Wetlands	28	0.0	0.0	0.0	0.0	0.0	0.0
Roads	-	8.3	4.6	8.3	8.3	8.3	4.6
Streambanks	-	41	41	39	41	41	39
*Total****	*13,273*	*677*	*673*	*675*	*529*	*422*	*372*
Total Reduction (%)		**-**	**0.5%**	**0.3%**	**21.8%**	**37.7%**	**45.1%**

* mT = metric tons = 1.102 short tons

** Combined scenario includes roadway improvements, improved grazing, and enhanced riparian areas*** Total does not reflect actual delivered sediment load, as it includes sediment trapped in reservoir.

Table DA-10. Trout Creek Sediment Summary

Category	Area (ha)	Existing Annual Load (mT*/year)	Improved Roadways Annual Load (mT/year)	Stabilized Streambank Annual Load (mT/year)	Improved Grazing Annual Load (mT/year)	Enhanced Riparian Health Annual Load (mT/year)	Combined** Annual Load (mT/year)
Forest	2,454	42	42	42	42	42	42
Pasture	166	43	43	43	25	9	5
Rangeland	1,864	293	293	293	279	260	242
Developed	33	6	6	6	6	6	6
Wetlands	7	0	0	0	0	0	0
Roads	-	9.60	6.10	9.60	9.60	9.60	6.10
Streambanks	-	102.4	102.4	76.2	102.4	102.4	76.2
Total	*4,524*	*496*	*493*	*470*	*464*	*429*	*378*
Total Reduction (%)		**-**	**0.7%**	**5.3%**	**6.4%**	**13.5%**	**23.9%**

* mT = metric tons = 1.102 short tons

** Combined scenario includes roadway improvements, improved grazing, and enhanced riparian areas

DA.2.0 NUTRIENTS

DA.2.1 Overview

For each modeling scenario, the total nutrient load was broken down into two categories. These categories include (1) upland erosion by land use - forest, rangeland (including arid rangeland), pasture (including agricultural area), wetlands, and developed areas, and (2) septic systems. There is a table for each of the seven developed TMDLs (**Tables DA-11** through **DA-17**). The table loadings are for the summer only (kilograms/season) for each scenario. Since the roadway improvement and the channel streambank stabilization scenarios did not affect nutrients, they are not included in this breakdown. Total reductions of nitrogen and phosphorus values not part of a developed TMDL are listed in **Table D5-5** of the modeling report as totals only.

The final column in each table is the “recommended” scenario, where the improved grazing and enhanced riparian areas scenarios were combined. This is not necessarily an additive scenario, as the effects of one of these improvements may reduce the efficiency of another one (e.g., less nutrients incoming from improved grazing means less nutrients trapped by the riparian buffers).

DA.2.2 TABLES

Table DA-11. Carpenter Creek Phosphorus Summary

Category	Area (ha)	Existing Seasonal* Load (kg/season)	Improved Grazing Seasonal Load (kg/season)	Enhanced Riparian Health Seasonal Load (kg/season)	Combined** Seasonal Load (kg/season)
Forest	3,598	1	1	1	1
Pasture	185	4	3	2	1
Rangeland	2,909	11	10	9	8
Developed	0	0	0	0	0
Wetlands	32	0	0	0	0
Septic	-	0.42	0.42	0.42	0.42
Total	*6,724*	*16*	*15*	*12*	*11*
Total Reduction (%)		**-**	**10.0%**	**28.8%**	**33.6%**

* Seasonal load is the July through September loading on an annual basis.
** Combined scenario includes improved grazing and enhanced riparian health.

Table DA-12. Dog Creek Phosphorus Summary

Category	Area (ha)	Existing Seasonal* Load (kg/season)	Improved Grazing Seasonal Load (kg/season)	Enhanced Riparian Health Seasonal Load (kg/season)	Combined** Seasonal Load (kg/season)
Forest	9,094	35	35	22	22
Pasture	152	8	5	3	1
Rangeland	5,774	9	7	7	6
Developed	90	11	11	11	11
Wetlands	36	0	0	0	0
Septic	-	4.23	4.23	4.23	4.23
Total	*15,147*	*68*	*62*	*49*	*43*
Total Reduction (%)		**-**	**9.2%**	**28.1%**	**36.6%**

* Seasonal load is the July through September loading on an annual basis.
** Combined scenario includes improved grazing and enhanced riparian health.

Table DA-13. Little Blackfoot River Phosphorus Summary

Category	Area (ha)	Existing Seasonal* Load (kg/season)	Improved Grazing Seasonal Load (kg/season)	Enhanced Riparian Health Seasonal Load (kg/season)	Combined** Seasonal Load (kg/season)
Forest	59,152	78.2	78.2	63.6	63.6
Pasture	4,874	72.3	51.3	26.6	11.3
Rangeland	41,566	134.5	113.9	83.6	66.0
Developed	582	47.3	47.3	47.3	47.3
Wetlands	557	1.0	1.0	1.0	1.0
Septic	-	42.4	42.4	42.4	42.4
Total	*106,732*	*376*	*334*	*264*	*232*
Total Reduction (%)		**-**	**11.1%**	**29.6%**	**38.4%**

* Seasonal load is the July through September loading on an annual basis.
** Combined scenario includes improved grazing and enhanced riparian health.

Table DA-14. Snowshoe Creek Nitrogen Summary

Category	Area (ha)	Existing Seasonal* Load (kg/season)	Improved Grazing Seasonal Load (kg/season)	Enhanced Riparian Health Seasonal Load (kg/season)	Combined** Seasonal Load (kg/season)
Forest	1,400	8	8	8	8
Pasture	269	189	140	166	127
Rangeland	2,996	110	102	97	92
Developed	0	0	0	0	0
Wetlands	28	0	0	0	0
Septic		11.50	11.50	11.50	11.50
Total	*4,693*	*319*	*261*	*282*	*238*
Total Reduction (%)		**-**	**18.0%**	**11.5%**	**25.3%**

* Seasonal load is the July through September loading on an annual basis.
** Combined scenario includes improved grazing and enhanced riparian health.

Table DA-15. Spotted Dog Creek Phosphorus Summary

Category	Area (ha)	Existing Seasonal* Load (kg/season)	Improved Grazing Seasonal Load (kg/season)	Enhanced Riparian Health Seasonal Load (kg/season)	Combined** Seasonal Load (kg/season)
Forest	5,123	10	10	10	10
Pasture	342	19	14	5	3
Rangeland	6,023	24	22	14	13
Developed	0	0	0	0	0
Wetlands	12	0	0	0	0
Septic	-	0.28	0.28	0.28	0.28
Total	*11,500*	*53*	*46*	*29*	*26*
Total Reduction (%)		**-**	**13.2%**	**45.6%**	**50.3%**

* Seasonal load is the July through September loading on an annual basis.
** Combined scenario includes improved grazing and enhanced riparian health.

Table DA-16. Threemile Creek Nitrogen Summary

Category	Area (ha)	Existing Seasonal* Load (kg/season)	Improved Grazing Seasonal Load (kg/season)	Enhanced Riparian Health Seasonal Load (kg/season)	Combined** Seasonal Load (kg/season)
Forest	5,086	16	16	15	15
Pasture	2,112	247	225	31	28
Rangeland	6,006	281	258	270	253
Developed	41	9	9	9	9
Wetlands	28	1.0	1.0	1.0	1.0
Septic	-	27.9	27.9	27.9	27.9
Total	*13,273*	*581*	*536*	*353*	*333*
Total Reduction (%)		**-**	**7.8%**	**39.2%**	**42.7%**

* Seasonal load is the July through September loading on an annual basis.
** Combined scenario includes improved grazing and enhanced riparian health.

Table DA-17. Threemile Creek Phosphorus Summary

Category	Area (ha)	Existing Seasonal* Load (kg/season)	Improved Grazing Seasonal Load (kg/season)	Enhanced Riparian Areas Seasonal Load (kg/season)	Combined** Seasonal Load (kg/season)
Forest	5,086	0.4	0.4	0.4	0.4
Pasture	2,112	7	6	2	1
Rangeland	6,006	7	7	3	3
Developed	41	3	3	3	3
Wetlands	28	0	0	0	0
Septic	-	2.4	2.4	2.4	2.4
Total	*13,273*	*20*	*18*	*10*	*10*
Total Reduction (%)		**-**	**8.5%**	**47.5%**	**49.2%**

* Seasonal load is the July through September loading on an annual basis.

** Combined scenario includes improved grazing and enhanced riparian health.

APPENDIX DB - SEDIMENT TOTAL MAXIMUM DAILY LOADS

DB.1 SEDIMENT

DB.1.1 Overview

A percent reduction based on average yearly loading was used as the primary approach for expressing the sediment TMDLs within this document because there is uncertainty associated with the loads derived from the source assessment, and using the estimated sediment loads alone creates a rigid perception that the loads are absolutely conclusive. However, in this Appendix the TMDL is expressed using daily loads to satisfy an additional EPA required TMDL element. Daily loads should not be considered absolutely conclusive and may be refined in the future as part of the adaptive management process. It is not expected that daily loads will drive implementation activities.

DB.1.2 Approach

Since sediment loading in the Little Blackfoot River watershed is associated with nonpoint sources and stormwater-related point sources, the hydrograph is assumed to be a reasonable surrogate for sediment loading to streams in the watershed (i.e. peak contributions during periods of runoff and high flow). Therefore, mean daily discharge values from 40 years of record (1972 - 2011) at the gage near Garrison were used to calculate daily sediment values for TMDLs in the Little Blackfoot River watershed.

Using the mean of daily mean discharge values from the gage, a daily percentage relative to the mean annual discharge was calculated for each day (**Table DB-1**). For each TMDL, the daily percentages in **Table DB-1** can be multiplied by the total average annual load associated with the TMDL percent reductions in **Section D5** and shown in **Table DB-2** to calculate the daily load. For instance, the total allowable annual sediment load for the lower segment of the Little Blackfoot River is 12,068 (short) tons. To determine the TMDL for January 1, 12,068 tons is multiplied by 0.11% which provides a daily load for January 1st for the Little Blackfoot River of 13 tons. The annual daily load for the lower segment of the Little Blackfoot River is shown graphically in **Figure DB-1**. The daily loads are a composite of the allocations, but as allocations are not feasible on a daily basis, they are not contained within this Appendix. If desired, daily allocations may be obtained by applying allocations provided in **Section 5.8.3 (**of the TMDL) to the daily load.

Table DB-1. USGS Stream Gage 12324590 (Little Blackfoot River near Garrison) – Percent of Mean Annual Discharge Based on Mean of Daily Mean Discharge Values for each Day of Record (Calculation Period 1972-09-26 -> 2011-09-30)

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.11%	0.14%	0.15%	0.27%	0.56%	0.99%	0.35%	0.15%	0.09%	0.11%	0.14%	0.12%
2	0.10%	0.12%	0.16%	0.27%	0.56%	0.96%	0.34%	0.15%	0.09%	0.11%	0.14%	0.14%
3	0.10%	0.11%	0.16%	0.26%	0.57%	0.98%	0.32%	0.14%	0.09%	0.11%	0.14%	0.15%
4	0.11%	0.11%	0.17%	0.25%	0.60%	0.98%	0.35%	0.14%	0.09%	0.11%	0.14%	0.14%
5	0.13%	0.11%	0.17%	0.27%	0.61%	0.97%	0.33%	0.13%	0.09%	0.12%	0.14%	0.13%
6	0.12%	0.11%	0.15%	0.34%	0.62%	0.98%	0.31%	0.13%	0.09%	0.12%	0.14%	0.12%
7	0.11%	0.11%	0.16%	0.37%	0.65%	0.94%	0.29%	0.13%	0.09%	0.12%	0.14%	0.11%
8	0.11%	0.12%	0.18%	0.34%	0.65%	0.88%	0.28%	0.13%	0.09%	0.12%	0.14%	0.11%
9	0.10%	0.21%	0.18%	0.33%	0.65%	0.83%	0.26%	0.12%	0.09%	0.12%	0.14%	0.12%
10	0.10%	0.14%	0.21%	0.34%	0.70%	0.78%	0.28%	0.11%	0.09%	0.12%	0.13%	0.12%
11	0.11%	0.12%	0.20%	0.36%	0.76%	0.80%	0.27%	0.11%	0.10%	0.12%	0.13%	0.11%
12	0.11%	0.12%	0.19%	0.37%	0.77%	0.78%	0.25%	0.11%	0.10%	0.13%	0.13%	0.11%
13	0.11%	0.12%	0.20%	0.38%	0.76%	0.76%	0.26%	0.11%	0.10%	0.13%	0.14%	0.11%
14	0.11%	0.13%	0.21%	0.39%	0.79%	0.72%	0.25%	0.10%	0.10%	0.13%	0.13%	0.11%
15	0.14%	0.13%	0.20%	0.39%	0.84%	0.71%	0.24%	0.10%	0.10%	0.14%	0.13%	0.11%
16	0.15%	0.14%	0.20%	0.38%	0.88%	0.70%	0.23%	0.10%	0.10%	0.14%	0.13%	0.11%
17	0.13%	0.17%	0.21%	0.40%	0.91%	0.73%	0.23%	0.10%	0.10%	0.14%	0.13%	0.11%
18	0.12%	0.17%	0.22%	0.42%	0.95%	0.70%	0.23%	0.10%	0.10%	0.14%	0.13%	0.10%
19	0.11%	0.18%	0.23%	0.43%	0.98%	0.72%	0.22%	0.09%	0.11%	0.14%	0.13%	0.10%
20	0.11%	0.19%	0.23%	0.45%	0.97%	0.71%	0.21%	0.10%	0.11%	0.14%	0.13%	0.10%
21	0.11%	0.20%	0.24%	0.46%	0.98%	0.68%	0.20%	0.10%	0.11%	0.14%	0.13%	0.10%
22	0.11%	0.16%	0.26%	0.49%	1.19%	0.61%	0.19%	0.10%	0.11%	0.14%	0.12%	0.10%
23	0.11%	0.15%	0.28%	0.53%	1.10%	0.57%	0.19%	0.10%	0.11%	0.14%	0.12%	0.10%
24	0.11%	0.15%	0.28%	0.55%	1.12%	0.53%	0.18%	0.10%	0.11%	0.14%	0.12%	0.10%
25	0.11%	0.17%	0.25%	0.56%	1.16%	0.49%	0.17%	0.10%	0.11%	0.14%	0.12%	0.12%
26	0.11%	0.17%	0.25%	0.54%	1.12%	0.46%	0.17%	0.09%	0.11%	0.14%	0.12%	0.13%
27	0.11%	0.15%	0.26%	0.53%	1.07%	0.44%	0.17%	0.09%	0.11%	0.14%	0.12%	0.11%
28	0.11%	0.14%	0.24%	0.53%	1.03%	0.41%	0.17%	0.09%	0.11%	0.14%	0.12%	0.10%
29	0.11%	0.13%	0.23%	0.53%	1.02%	0.38%	0.16%	0.09%	0.11%	0.14%	0.12%	0.10%
30	0.11%		0.23%	0.54%	1.02%	0.36%	0.16%	0.09%	0.11%	0.14%	0.12%	0.10%
31	0.12%		0.26%		1.01%		0.16%	0.09%		0.14%		0.10%

Table DB-2. TMDL expressed as an average annual load for each waterbody segment

Stream Segment	Waterbody #	TMDL Expressed as Average Annual Load (short tons/year)	TMDL Expressed as Average Annual Load (metric tons/year)
DOG CREEK, headwaters to Meadow Creek	MT76G004_071	101	92
DOG CREEK, Meadow Creek to the mouth (Little Blackfoot River)	MT76G004_072	2,076	1,884
ELLISTON CREEK, headwaters to the mouth (Little Blackfoot River)	MT76G004_040	88	80
LITTLE BLACKFOOT RIVER, the headwaters to Dog Creek	MT76G004_020	3,813	3,460
LITTLE BLACKFOOT RIVER, Dog Creek to the mouth (Clark Fork River)	MT76G004_010	12,068	10,951
SNOWSHOE CREEK, headwaters to the mouth (Little Blackfoot River)	MT76G004_080	295	268
SPOTTED DOG CREEK, forest boundary to the mouth (Little Blackfoot River)	MT76G004_032	1,383	1,255
TELEGRAPH CREEK, headwaters to Hahn Creek	MT76G004_051	151	137
THREEMILE CREEK, Quigley Reservoir to the mouth (Little Blackfoot River)	MT76G004_112	418	379
TROUT CREEK, headwaters to the mouth (Little Blackfoot River)	MT76G004_120	416	377

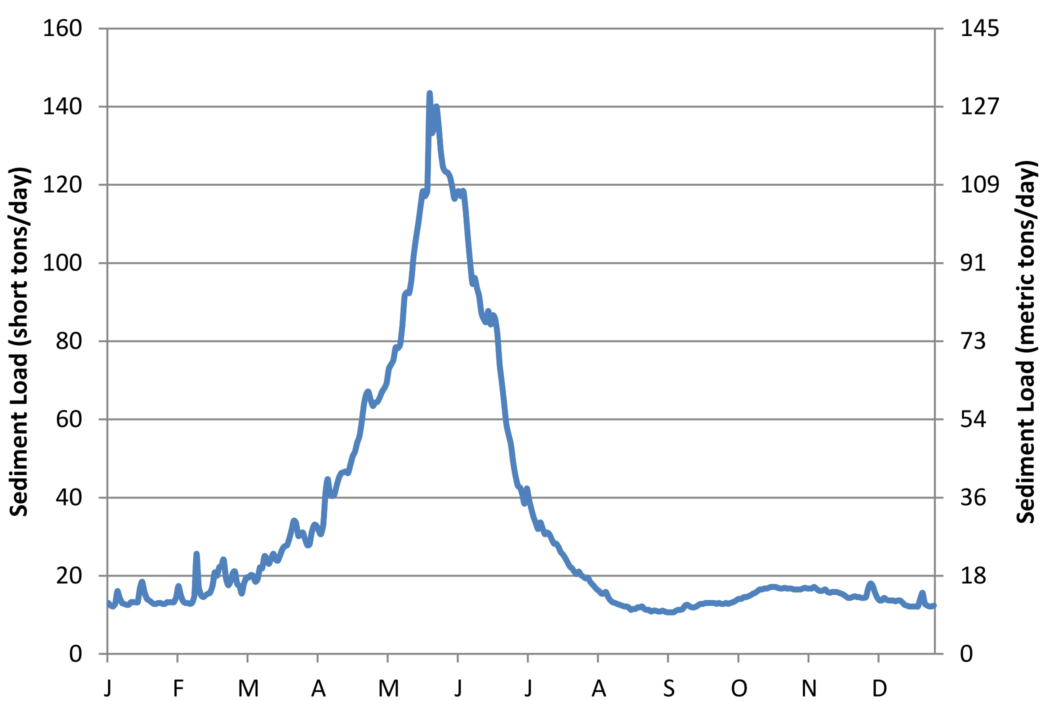

Figure DB-1. Average daily sediment load for the lower segment of the Little Blackfoot River

APPENDIX DC – MODEL INPUT

Will be furnished upon request

APPENDIX DD – MODEL OUTPUT

Will be furnished upon request.