APPENDIX D
REDWATER RIVER NUTRIENT MODELING REPORT

Prepared By:

Montana Department of
Environmental Quality

Watershed Management Section, Water Quality Planning Bureau
1520 East Sixth Avenue
PO Box 200901
Helena, MT 59620-0901

May, 2010

DOCUMENT PURPOSE

The Redwater River Nutrient Modeling Report has been prepared to document loading estimates and pollutant reduction values as part of the nutrient total maximum daily load (TMDL) analysis for the Redwater River TMDL planning area. The report is intended to: (1) provide a brief synopsis of the project, (2) overview the load reduction modeling effort, and (3) present the numerical estimates of nitrogen (N) and phosphorus (P) from both landscape and discrete sources within the Redwater TMDL planning area (TPA).

LIST OF ACRONYMS

BMP	Best Management Practices
CN	Curve Number
CFS	Cubic Feet Per Second
CRP	Conservation Reserve Program
EMC	Event Mean Concentration
EPA	Environmental Protection Agency
EMC	Event Mean Concentration
GIS	Geographic Information System
GWIC	Ground Water Information Center
HUC	Hydrologic Unit Code
K	Soil Erodibility Factor
LULC	Land Use/Land Cover
NED	National Elevation Dataset
NHD	National Hydrography Dataset
NLDC	National Land Cover Dataset
NRCS	Natural Resources Conservation Service
SDR	Sediment Delivery Ratio
STEPL	Spreadsheet Tool for Estimating Pollutant Load
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TPA	TMDL Planning Area
USGS	U.S. Geological Survey
USDA	United State Department of Agriculture
USLE	Universal Soil Loss Equation

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Congress passed the Water Pollution Control Act in 1972 to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The Clean Water Act requires each state to set water quality standards to protect designated beneficial water uses and to monitor the attainment of those uses. Fish and aquatic life, wildlife, recreation, agriculture, industrial, and drinking water are all types of beneficial uses designated in Montana. Streams and lakes not meeting the established standards are referred to as *impaired waters*. Seven waterbodies within the Redwater River TPA have been listed as impaired due to excess nutrient loading. Section 75-5-701 of the Montana Water Quality Act and section 303(d) of the federal Clean Water Act require the development of total maximum daily loads (TMDLs) for impaired waters where a measurable pollutant, such as nutrients, is the cause of the impairment. A TMDL refers to the maximum amount of a pollutant a stream or lake can receive and still meet water quality standards. The development of TMDLs requires quantifying the magnitude of pollutant contribution from the pollutant sources. The Spreadsheet Tool for Estimating Pollutant Load (STEPL) was used to estimate current loading from landscape and livestock sources and estimate loading reductions achievable by applying best management practices (BMPs) to sources.

1.1 Project Background and History

Nutrient impairment determinations in the Redwater TPA were made for Prairie Elk and Sand creeks in 1990, for Nelson Creek and the Redwater River in 2000 and for East Redwater Creek, Pasture Creek and Timber Creek in 2006. The impairments caused partial or non-support for aquatic life, warm water fisheries and primary contact recreation among these C-3 classified streams. Anthropogenic nutrient sources in the Redwater TPA are primarily agricultural. Tilled croplands, grazed rangelands and livestock confinement areas near or adjacent to stream channels are suspected sources.

1.2 Purpose

The purpose of the modeling effort was to estimate current nutrient loading conditions and loading reductions achieved with BMPs applied to nutrient sources. Specific objectives include the following:

- Characterize the main climatic, hydrologic, land cover and soil properties influencing growing season nutrient loading to surface waters from uplands for each modeled subbasin,
- Identify and characterize nutrient loading from agricultural and other sources as a basis TMDL allocations,
- Characterize nutrient loading to surface waters from groundwater discharges,
- Identify effective and affordable means for agricultural producers to reduce nutrient loading from dispersed upland surface sources and near-stream livestock sources.

1.3 Load Reduction Modeling Effort

The purpose of the Redwater River Nutrient Modeling Report is to provide information on the modeling techniques employed to substantiate and validate the department's pollutant load and load reduction calculations for TMDL development. The large watershed area (2.1 million acres), predominance of agricultural sources, homogeneous nature of the land cover geology and general lack of site-specific monitoring data prompted selection of a simple spreadsheet tool for identifying sources and estimating load reductions. The STEPL tool was selected for the modeling task due to its simplicity in calculating source loads and BMP effects on loading and its endorsement by the Environmental Protection Agency (EPA).

1.4 Report Organization

The Redwater River Modeling Report has been organized in a way to (1) provide information on the project site and conditions, (2) outline the technical approach used for modeling, (3) describe the modeling processes and parameters, and (4) explain the modeling results and outcome. An outline of the remaining document is shown below.

- **Section 2.0 –** Study Area Description: provides background information on the project location, climate, hydrologic setting, land use demographics, and water quality.
- **Section 3.0 –** Modeling Approach: describes the basic modeling methodology, including assumptions and inherent limitations of estimating pollutant load reductions for the Redwater River TMDL project using STEPL.
- **Section 4.0 –** STEPL Modeling: provides information on the general STEPL model setup, specific model parameters, and data sources used during the modeling effort.
- **Section 5.0 –** Modeling Results: presents the results of the STEPL modeling effort including load reduction estimates of sediment and nutrients.
- **Section 6.0 –** References: summarizes the references sources used during the modeling effort.

Technical information related to the load reduction calculations are included in **Appendix-A**. These include STEPL spreadsheet input and computation tables.

2.0 STUDY AREA DESCRIPTION

The Redwater River TPA is located in northeastern Montana (and includes parts of Hydrologic Unit Codes (HUCs) 10060002 (Redwater River), 10060001 (Prairie Elk-Wolf) and 10040104 (Fort Peck Reservoir). The Redwater River flows for approximately 160 miles from its headwaters to the Missouri River. Horse Creek, Pasture Creek and East Redwater Creek are Redwater River tributaries. Prairie Elk Creek and Sand Creek are Missouri River tributaries. Nelson Creek and Timber Creek flow into Fort Peck Reservoir.

2.1 Study Area Location

The Redwater River TPA is located on Montana's northeastern plains and occurs within portions of Dawson, Garfield, McCone, Prairie and Richland counties (**Figure 2-1**).

Figure 2-1. Redwater TPA Location Map

2.2 Climate

The project area has a semi-arid, continental climate characterized by warm summers and cold, dry winters. The average annual precipitation for most of the Redwater TPA is approximately 13 inches. The southern portion is somewhat drier with a 12 inch annual average; the northern portion nearer the Missouri River receives about 16 inches annually. Slightly over half of the annual precipitation occurs as rainfall during the 100 to 135 day growing season. Maximum average daily temperatures climb to 85°F in summer and range from 25-30°F during the winter months.

2.3 Hydrologic Setting

The Redwater River drains northeastward from upland prairie benches into glaciated terrain nearer its mouth on the Missouri River. Redwater River tributaries form roughly parallel basins that drain southeastward from the Redwater-Fort Peck divide, or northwestward from the Redwater-Yellowstone divide (**Figure 2-1**). Nelson and Timber creeks flow northwest into Fort Peck Reservoir. Prairie Elk and Sand creeks flow north to the Missouri River downstream of Fort Peck Dam.

The hydrology is driven primarily by the combination of snowmelt runoff during early spring (e.g. late February through March) and rainfall occurring sporadically from May through late July. **Figure 2-2** is the hydrograph of the Redwater River at Vida for USGS Station 06177825 in cubic feet per second (cfs) for the period of record 1975 to 1985.

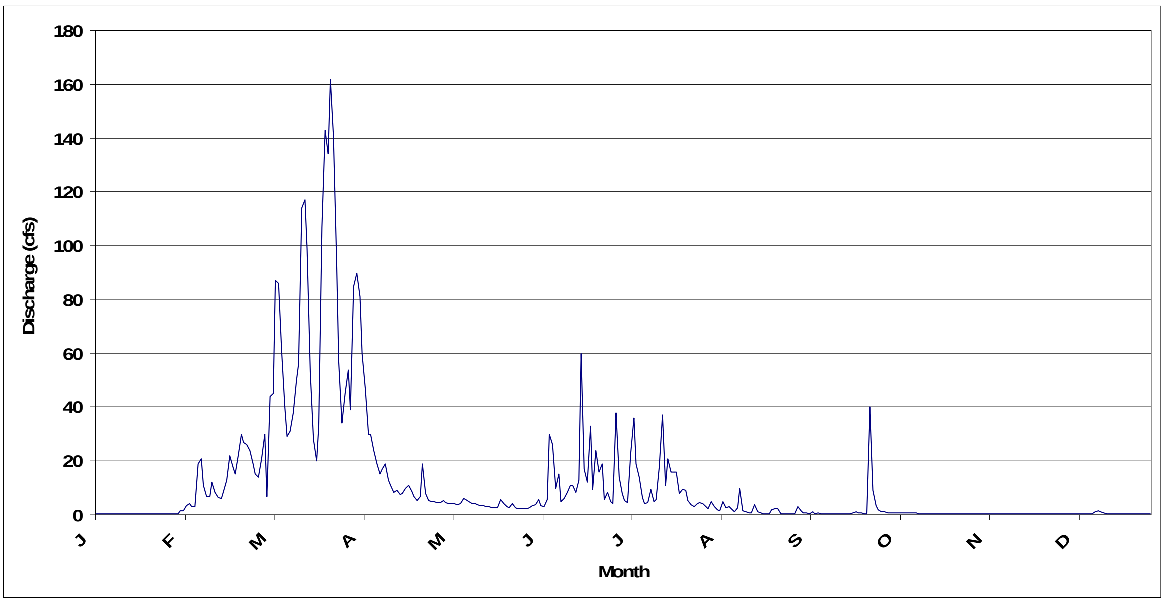

Figure 2-2. Mean Daily Discharge (cfs) at USGS Station 06177825, Redwater River near Vida, MT, for 10 years of record.

2.4 Topography, Soils and Land Use

Topography is generally of low relief with ephemeral headwater channels forming dissected, woody breaks toward drainage divides. Elevations range from 3,400 feet at the southern Missouri-Yellowstone divide to 1,950 feet at the mouth of the Redwater River. Soils vary from strongly sloping, silty and sandy units developed from weakly consolidated sedimentary beds near upland divides, to gently sloping to level sedimentary, glacial and alluvial surfaces at lower elevations. Glaciation occurred over the approximate northern third of the planning area. Soils have developed from sedimentary residuum, glacial moraine, local glacial lakebed deposits and recent alluvium. Soils are generally deep and well-drained and are eroded easily due to the silt content.

Native rangeland comprises about 70 percent of the planning area land cover and is used mainly for livestock grazing. Cropland for small grain production covers about 20 percent of the area and is cultivated in a traditional up-down slope farming practice. About 10 percent of the planning area has been converted from tilled cropland to perennial grassland under the federal Conservation Reserve Program (CRP).

3.0 MODELING APPROACH

A lumped watershed-scale modeling approach was used to estimate existing nonpoint source nutrient loading conditions within the drainage areas of listed streams as well as the remaining unlisted portion of the planning area with STEPL. The modeled subbasins of listed streams conform to the 5th Code HUC boundaries of East Redwater Creek, Horse Creek, Nelson Creek, Pasture Creek, Prairie Elk Creek, Sand Creek and Timber Creek .The unlisted subbasins are combined 5th Code HUCs within the Redwater River watershed above and below the mouth of Horse Creek and the McGuire Creek subbasin draining to Fort Peck Reservoir. The model was used to estimate reductions in nutrient loads from current conditions with BMPs applied to tilled cropland, rangeland and livestock confinement areas. The model also includes an estimate of nutrient loading from residential septic systems.

STEPL was selected for its relative ease in application, minimal amount of required forcing data and its development and endorsement by the EPA. STEPL calculates annual sediment and nutrient loads from runoff and groundwater sources by land cover category using local precipitation records, surface and groundwater nutrient concentrations, soil characteristics and livestock populations. Groundwater recharge and discharge to surface water is governed by coefficients for precipitation infiltration rather than from programs simulating evapotranspiration and soil water movement. Nutrient cycling processes are simplified in STEPL into a loading calculation that is derived by multiplying runoff and groundwater volume estimates by N and P concentration inputs. The model was developed by the EPA to estimate nitrogen, phosphorus, and sediment loads and load reductions within watersheds. The model parameterization for the Redwater project is described further in the following sections.

3.1 STEPL Model Description

STEPL was developed by the EPA to compute non-point source pollutant loads from urban, agricultural, and forested lands. The model employs simple algorithms to calculate nutrient and sediment loads from various land uses practices, as well as load reductions from the implementation of BMPs. For each watershed, the annual nutrient loading is calculated based on the runoff volume and the pollutant concentrations in the runoff water as influenced by land cover, soil type, slope and management practices. Runoff volume is estimated from annual precipitation data using the SCS runoff curve number equation. Annual sediment load from sheet and rill erosion is calculated based on use of the Universal Soil Loss Equation (USLE) and an area based sediment delivery ratio (SDR); nutrient loads are determined using event mean concentration,. The sediment and pollutant load reductions that result from the implementation of BMPs are computed using literature-based pollutant removal efficiencies for various BMPs. Pollutant sources incorporated into the model include farm animals, cropland, rangeland, urban runoff (mainly from roadway surfaces), and septic systems.

3.1.1 Hydrology

Hydrology in STEPL is calculated using the NRCS runoff CN methodology. The NRCS method relates accumulated rainfall excess (or runoff) to accumulated rainfall with an empirical CN. The CN is a function of land use and land cover (LULC), soil classification, hydrologic condition, and antecedent moisture conditions. The following NRCS equations were originally developed for agricultural watersheds and have subsequently been modified for a variety of land cover types.

S = (1000/CN) – 10
Q = (P-0.2S)2/(P+0.8S)

Variables used in the NRCS method include: cumulative precipitation (P), excess rain or accumulated runoff in inches (Q), the surface retention factor (S), and the NRCS runoff CN. Annual rainfall input to the model is supplied from station summaries for stations maintained by the Western Regional Climate Center. Annual rainfall figures for the Brockway, Circle, Haxby, Jordan, Lambert, and Vida stations were interpolated with input from local stakeholders to provide a value for each modeled subbasin. Rain day information was extracted from the web-based STEPL Model Input Data Server with values for McCone County. In order to provide a representative account of runoff history in the area, the model partitions annual rainfall into a number of storms based on the number of rain days and the percentage of storms causing measurable runoff. The model uses an initial precipitation interception abstraction to represent surface depression storage of approximately 0.15 S (i.e. precipitation losses to surface storage must be satisfied prior to the accumulation of excess rain on the soil surface generating runoff), which is close to the original representation of 0.20 S proposed by the NRCS.

3.1.2 Sediment Delivery

STEPL computes rill and interill erosion using the Universal Soil Loss Equation (USLE). The generalized equation is one of the most widely used to represent sheet erosion where soil loss (A) in tons acre^{-1} year^{-1} is a function of the rainfall erosivity index (R), soil erodibility factor (K), overland flow slope and length (LS), crop management factor (C), and conservation practice factor (P). The USLE equation is shown below.

A = RK(LS)CP (in tons/acre/year)

Although USLE calculates soil erosion for a given slope, much of the eroded soil in a watershed is not delivered to a point downstream. Rather, it is re-deposited at locations where the momentum of transporting water is insufficient to keep the material in suspension, or to move the soil particles along the watershed surface. To account for such deposition, a sediment delivery ratio (SDR) is applied to the USLE estimate to determine gross erosion for the watershed. The SDR is based on watershed area and reflects the actual percentage of sediment delivered to stream channels.

3.1.3 Nutrient Delivery

The nutrient modeling capability of STEPL is limited to the use of event mean concentration (EMC) coefficients or input concentrations of N and P for surface and groundwater to calculate the corresponding total loads of N and P. The underlying premise is that overland flow from various land uses produces a specific mass of pollutant per unit runoff volume. Excess rain values are derived from the NRCS runoff curve number method and the total EMC (mg/L) is applied to this volume to calculate the total load. Additional mass is introduced to the system through soil erosion from USLE as well as groundwater. Soil loss loads in the USLE are identified by the relative nutrient enrichment ratio of the eroded soil and the specific percentage of N and P in the soil matrix (N-0.08%, P-0.03% for the Redwater River Project area). Nutrient concentrations in groundwater are specified by the user.

3.2 Assumptions and Limitations

The empirical nature of STEPL makes the model applicable for pollutant loading and BMP reduction efficiency estimation. The tool and approach are adequate for comparative source loading and BMP scenario analysis purposes as opposed to adoption of absolute values as TMDLs or pollutant load allocations.

4.0 STEPL MODELING

STEPL modeling was completed according to the guidelines outlined in the STEPL Users Guide with guidance for USLE parameters and CN values suggested in Hydrologic Analysis and Design (McCuen, 1998) and Hydrology and the Management of Watersheds (Brooks et al. 1997). Parameter values were also discussed with and evaluated by planning area stakeholders who recommended adjustments to STEPL Data Server values for annual precipitation, livestock populations, animal confinement locations and several USLE parameters. The general model setup and descriptions of modeling parameters and processes are described in the following sections.

4.1 Watershed Configuration

The STEPL model is configured at the watershed level. Land cover categories (cropland, pastureland/range, forest, urban, feedlot, and a user defined category) are combined with soils, topography, and hydrologic condition to define the model's hydrologic and water quality response.

The drainage basin boundaries of listed streams conform to USGS 5th code hydrologic unit boundaries as illustrated in **Figure 4-1**. Therefore, the model configuration and discretization are based on the size and characteristics of these basins. Thus, the Redwater River TPA was modeled as 10 subbasins. The watershed boundaries define the extent of subbasin climate, land cover and soil characteristics used to estimate loading.

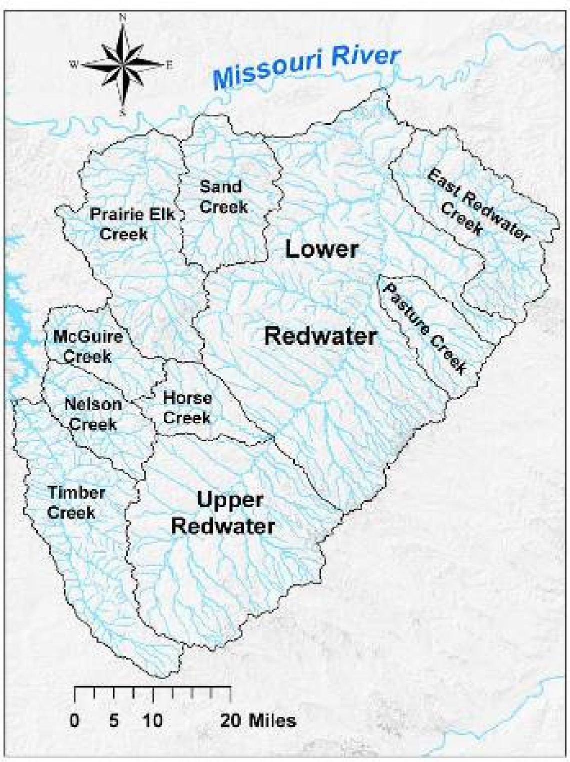

Figure 4-1. Modeled STEPL Subbasins in the Redwater TPA

4.2 Watershed Parameters

A Geographic Information System (GIS) was used to determine the subbasin area and identify land cover, soil and geomorphic properties required by the model. Raster datasets include the USGS National Land Cover Database (NLDC) and the National Elevation Dataset (NED) and the NRCS STATSGO soils maps and attributes. The datasets provided information at 30-meter resolution, considered adequate for subbasins ranging from 100 to 1,000 square miles and soil information available at a scale of 1:250,000. Values for the USLE rainfall intensity (R) factor were obtained from Prism (Parameter-elevation Regressions on Independent Slopes Model), a national raster dataset developed by Oregon State University for the U. S. Department of Agriculture (USDA). Reference runoff curve numbers for land covers types are those selected to represent McCone County croplands; planning area range, pasture and woodlands in good to fair condition; and conservation reserve acreage with good ground cover. The input parameter values were developed from combined interpretation of the following sources:

- STEPL Input Data Server information for McCone County,
- USDA, National Agricultural Aerial Imagery Program (NAIP) imagery for 2005,
- 2001 USGS NLCD raster data,
- The Soil Survey of McCone County.

The STEPL program calculates loads for land cover categories within the modeled watersheds. Interpretation of the 2001 USGS NLCD provided acreages of land cover categories by subbasin. Subbasin acreage values for lands enrolled in the CRP program were provided by the McCone County Farm Service Agency through the McCone County Conservation District. McCone County CRP percentages were extrapolated to the subbasins in other counties. **Table 4-1** contains the acreage of land cover categories by subbasin.

Table 4-1. Acreage of Land Cover Categories by Subbasin for the Redwater River TPA

Subbasin	Urban (Roadways)	Cropland	Rangeland	Woodland	CRP	Subbasin Acreage Totals	Subbasin Area (mi^2)	Percent of Total
Horse	1,787	24,610	32,346	34	8,057	66,834	104.4	3%
Upper Redwater	6,981	83,420	233,195	5,677	20,855	350,128	547.1	17%
Pasture	1,571	25,685	42,018	1445	6,421	77,140	120.5	4%
East Redwater	3,296	40,676	108,177	2,518	15,818	170,485	266.4	8%
Lower Redwater	14740	231,884	375,644	6,628	54,979	683,875	1068.6	33%
Timber	445	18,630	178,702	104	7,206	205,087	320.4	10%
Nelson	317	4,767	75,019	0	950	81,053	126.6	4%
Prairie Elk	1,523	15,302	200,564	178	3,825	221,392	345.9	11%
Sand	1,716	24,086	96,706	75	6,021	128,604	200.9	6%
McGuire	272	5606	67,119	9	1,401	74,407	116.3	4%
Land Cover Acreage Totals	32,648	47,4666	1,409,490	16,668	125,533	2,059,005	3,217.2	
Percent of Total	2%	23%	67%	1%	7%			

4.3 Soil and Nutrient Parameterization

STATSGO soil maps with corresponding attribute tables were used to select Universal Soil Loss Equation (USLE) soil erodibility (K) factors used in the model. Subbasin soil maps combined with the land cover layer helped identify K factors for land cover types in each subbasin. Cover management factors were derived as follows:

1. The value for cropland with 750 pounds of stubble mulch per acre cover type is taken from McCuen (1998) and is (0.20),
2. The rangeland C factor value for grass dominated rangeland with 25 percent canopy cover is from Brooks et al. (1997) and is (0.14),
3. The forested C factor for woodland with 25 percent canopy covered and a grass understory with and 40 percent ground cover was 0.10. (Brooks et al. 1997), and
4. The C factor for CRP acreage is that described for grass-dominated idle land with 50 percent ground cover is 0.07 (Brooks et al. 1997).

Values for the overland flow length and slope parameter (LS) were developed from STATSGO soil slope values combined with flow length interpreted from aerial imagery and guided by values suggested by McCuen (1998) and the National Engineering Handbook (USDA 1991) for various slope gradients. Crop and rangeland slope gradients within the planning area are generally from 2-6 percent with distances ranging from 200-300 feet. Slope length factors for cropland range from 0.4 to 0.8. All conservation practice factors (P) were set to unity, representing minimal application of conservation practices. Table 4-2 identifies the USLE coefficients used in the STEPL Model for each subbasin. Values selected for model analysis through the USLE method reflect existing field conditions and are within the variation of literature-based suggestions for these parameters.

Table 4-2. USLE Parameters by Cover Type and STEPL Subbasin, Redwater TPA.

Subbasin	Cover Type	R[1]	K[2]	LS[3]	C[4]
Horse	Cropland	27.2	0.37	0.40	0.200
	Rangeland	27.2	0.37	0.40	0.140
	Woodland	27.2	0.37	0.10	0.041
	CRP	27.2	0.37	0.40	0.070
Upper Redwater	Cropland	25.0	0.35	0.40	0.200
	Rangeland	25.0	0.35	0.40	0.140
	Woodland	25.0	0.35	0.10	0.041
	CRP	25.0	0.35	0.40	0.070
Pasture	Cropland	30.2	0.35	0.50	0.200
	Rangeland	30.2	0.35	0.50	0.140
	Woodland	30.2	0.35	0.10	0.041
	CRP	30.2	0.35	0.50	0.070
East Redwater	Cropland	31.6	0.37	0.70	0.200
	Rangeland	31.6	0.37	0.70	0.140
	Woodland	31.6	0.37	0.10	0.041
	CRP	31.6	0.37	0.70	0.070
Lower Redwater	Cropland	30.0	0.37	0.46	0.200
	Rangeland	30.0	0.37	0.46	0.140

Table 4-2. USLE Parameters by Cover Type and STEPL Subbasin, Redwater TPA.

Subbasin	Cover Type	R[1]	K[2]	LS[3]	C[4]
	Woodland	30.0	0.37	0.10	0.041
	CRP	30.0	0.37	0.60	0.070
Timber	Cropland	23.9	0.37	0.80	0.200
	Rangeland	23.9	0.37	0.80	0.140
	Woodland	23.9	0.37	0.10	0.041
	CRP	23.9	0.37	0.46	0.070
Nelson	Cropland	26.0	0.35	0.75	0.200
	Rangeland	26.0	0.35	0.75	0.140
	Woodland	26.0	0.35	0.10	0.041
	CRP	26.0	0.35	0.75	0.070
Prairie Elk	Cropland	28.9	0.38	0.75	0.200
	Rangeland	28.9	0.38	0.75	0.140
	Woodland	28.9	0.38	0.10	0.041
	CRP	28.9	0.38	0.75	0.070
Sand	Cropland	31.5	0.37	0.54	0.200
	Rangeland	31.5	0.37	0.54	0.140
	Woodland	31.5	0.37	0.10	0.041
	CRP	31.5	0.37	0.54	0.070
McGuire	Cropland	27.2	0.32	0.75	0.200
	Rangeland	27.2	0.32	0.75	0.140
	Woodland	27.2	0.32	0.10	0.041
	CRP	27.2	0.32	0.75	0.070

(1) Rainfall erosivity factor
(2) Soil erodibility factor
(3) Topographic factor
(4) Cropping factor

4.3.1 Nutrient Concentrations in Shallow Groundwater

The model inputs for N and P concentrations in shallow groundwater were estimated using well water quality data from the Montana Groundwater Information Center (GWIC) database. Well locations were projected onto combined GIS coverages of land cover and 2005 NAIP imagery and wells were stratified by surrounding landcover. Wells having a depth of 150 feet or less below ground surface were selected as representing the shallow aquifer. Mean nitrate nitrogen concentrations were calculated for each subbasin. These were combined into planning area means by land cover category (**Table 4-3**). The small number of analytical results for groundwater P only allowed development of a single planning area mean of 0.082 mg/L P that was applied to urban, cropland, rangeland and CRP. Due to lack of well data for woodland, the program default values for both N and P were applied in the model. The values for livestock confinement areas are from wells adjacent to livestock corral complexes. Program default value for N was applied to the urban category that consists mainly of road surfaces.

Table 4-3. Shallow Groundwater Concentrations of NO3-N and P By Land Use Category Used as Input to the STEPL Model.

Land Cover Category	Mean Groundwater NO_3-N (mg/L)	Mean Groundwater P (mg/L)
Cropland	1.7	0.082
Rangeland	1.3	0.082
Woodland	0.11	0.007
Urban	0.35	0.082
Livestock Confinement Areas	7.7	1.0

4.3.2 Nutrient Concentrations in Runoff

Default nutrient concentrations in runoff within the STEPL model were refined according to median values calculated from N and P monitoring data collected from with in the planning area. The input table in the program requires entries for cropland, pastureland (rangeland), woodland and CRP acreage. **Table 4-4** contains the median runoff concentrations of N and P for the four land cover categories.

Table 4-4. Surface Runoff Concentrations of Total N and Total P By Land Use Category Used as STEPL Model Input

Land Cover Category	Median Runoff Total-N (mg/L)	Median Runoff Total P (mg/L)
Cropland	1.5	0.075
Rangeland	1.3	0.090
CRP	1.4	0.083
Woodland	0.2	0.1

The STEPL input table for runoff nutrient concentrations also contains entries that correspond to low, moderate and high levels of livestock manure application to cropland. Livestock numbers in the Redwater TPA are small compared to the large number of cropland acres available for land application of manure and stakeholders advised that a single, low rate is most appropriate. Therefore, a single pair of values is used repeatedly in the table to reflect the single manure application practice. The model default values of 3.0 mg/L N, 0.5 mg/L P and 150 mg/L TSS were assumed to characterize urban (roadway) runoff.

4.3.3 Livestock and Septic System Density

Livestock population data was acquired from the STEPL Model Input Data Server for each of the five counties in the Redwater TPA. These data originate from from the 1997 National Resource Inventory database, 1997 USDA Census of Agriculture, 1998 National Small Flows Clearinghouse, and the STATSGO soil database (Tetra Tech, 2009). The county totals were multiplied by their aerial proportion of the planning area to obtain a TPA total for each animal class. These totals were then distributed by the proportion of grazing land within each of the 10 modeled subbasins. Septic system numbers by subbasin were estimated from STEPL Model Input Data Server values by county, adjusted by proportional area within the TPA. Model defaults were used for system discharge, assumed failure rate and degree of improvement with system upgrades. In some cases, parameter values were refined based on stakeholder knowledge of local conditions.

4.4 STEPL Model Calibration

The STEPL model calculates both annual runoff volume and annual infiltration volume, by land cover category, for each subbasin. The annual infiltration volume is assumed in the model to equal the annual groundwater contribution to subbasin water yield. The model output for annual infiltration volume is dependent upon on the assumed fraction of total precipitation that enters the shallow aquifer. This infiltration coefficient is called the "reference soil infiltration fraction" in the model. The approach to model calibration was to balance the modeled sum of runoff plus infiltration with measured stream discharge by modifying the model input values for soil infiltration fraction. This approach assumes that the shallow aquifer discharges to local streams and that percolation to deep aquifers leaving the subbasin is minimal. Measured stream discharge is assumed to consist mainly of surface runoff plus groundwater baseflow.

There are three USGS gaging stations in the planning area that are located to measure discharge from modeled subbasins:

1. The Redwater River near Circle (06177500),
2. Prairie Elk Creek (06175540),
3. Nelson Creek (06131200) and,

With the environmental and nutrient source characterization parameters set as described above, the reference soil infiltration fraction was adjusted until the model output for runoff plus infiltration approximately equaled the mean annual discharge volume measured at each gage. Table 4-5 gives the measured and modeled annual discharge volumes and corresponding departures of the modeled from the measured values at the three gaging stations.

Table 4-5. Calibration Results for Four Modeled Redwater TPA Subbasins

Subbasin Name	USGS Station Number	Period of Record	Measured Mean Annual Discharge Volume (Acre-Feet)	Modeled Mean Annual Discharge Volume (Acre-Feet)	Percent Departure from Measured Discharge
Upper Redwater	06177500	1929-2004	8,311	8,590	3.3
Nelson Creek	06131200	1975-2009	1,074	998	7.1
Prairie Elk Creek	06175540	1975-1985	11,861	11,702	1.3

There was reasonably good agreement between the measured and modeled annual discharge volumes in the three subbasins. The percent departures from measured discharges were single digit values. The small differences between modeled and measured discharge suggest that the assigned climate variables, USLE parameters, curve numbers and infiltration fractions used in the model give a reasonable estimate of current loading conditions.

4.5 Best Management Practices

With the model input parameters set to reflect a reasonable approximation of current conditions, BMPs were applied to subbasins of nutrient impaired watersheds to quantify achievable nutrient source reductions from contributing land uses. Single BMPs were selected by land use in each subbasin based on their practical feasibility. Rangeland is by far the most extensive land use followed by cropland. Because the default STEPL BMP list contained no entries for rangeland, a prescribed grazing BMP was added with nutrient and sediment reduction efficiencies suggested by (Evens and Corradini 2001). Prescribed grazing is the controlled harvest of vegetation with grazing or browsing animals, managed with the intent to achieve specified objectives (USDA 2009). Management objectives for prescribed grazing include improving the quality and quantity of forage, reducing erosion and improving water quality. Use of vegetative filter strips was the BMP judged most practical on the low-relief topography and ephemeral and intermittent channel systems of Redwater croplands. Runoff diversion to a vegetated filter strip was the BMP specified for livestock confinement sources.

The STEPL model contains a separate menu for applying BMPs to urban land use sources depending on the type of urban source. The dominant urban type in all Redwater subbasins was transportation (i.e. runoff from road surfaces). The selected BMP for this category was direction of runoff through a grass swale. This practice was selected to simulate pollutant removal by well vegetated borrow areas adjacent to roadways. BMPs were not specified for septic systems, woodlands or CRP acreage. Neither septic systems nor woodlands registered as a pollutant loading source in the current conditions modeling scenario. BMPs were not specified for the CRP landuse because loading from lands managed for stable, perennial plant cover offer few opportunities for controllable reductions.

STEPL uses a BMP nutrient removal efficiency factor to numerically account for the load reduction. The removal efficiencies used for each BMP are listed in **Table 4-6.** The efficiency values for cropland, Livestock confinement areas and urban BMPs are those from the STEPL database (Tetra Tech, 2006); values for prescribed grazing on rangeland are from Evens and Corradini (2001).

Table 4-6. Pollutant Removal Efficiencies for BMPs Applied in the Redwater STEPL Model

Source Category	Selected BMP	N Effeciency	P Efficiency	Sediment Efficiency
Cropland	Vegetated Filter Strip	0.70	0.75	0.65
Rangeland	Prescribed Grazing	0.43	0.34	0.13
Livestock Confinement Areas	Diversion to Filter Strip	0.45	0.70	ND
Urban	Grass Swale	0.10	0.25	0.65

BMPs were applied to 100 percent of the area for each land use source category. Extensive BMP application was assumed as an achievable long-term watershed management goal. STEPL calculates nutrient loading from the livestock confinement area source from an input runoff concentration and a runoff volume. Thus, there is no sediment reduction efficiency value in **Table 4-6** for this source category.

5.0 MODELING RESULTS

5.1 Modeled Existing Loads By Land Use

Table 4-7 gives the model-derived percentages of total nutrient and sediment loading by land use category under current conditions. Rangeland, cropland and livestock confinement area sources combined accounted for 95 percent of N loading and 96 percent of P loading. Loading from urban (mostly road surfaces) and CRP acreage was less than five percent. Woodland and septic systems did not register as nutrient loading sources.

Table 4-7. Current Condition Nutrient and Sediment Loading Summary by Land Use Source

Land Use Category	Percent of TN Load	Percent of TP Load	Percent of Sediment Load
Urban	3	2	0
Cropland	25	19	26
Rangeland	50	61	71
Woodland	0	0	0
Livestock Confinement Areas	20	16	0
CRP Acreage	2	2	3
Septic Systems	0	0	0

Figure 5-1 shows the relative TN and TP loading contributions from each of the land use source categories.

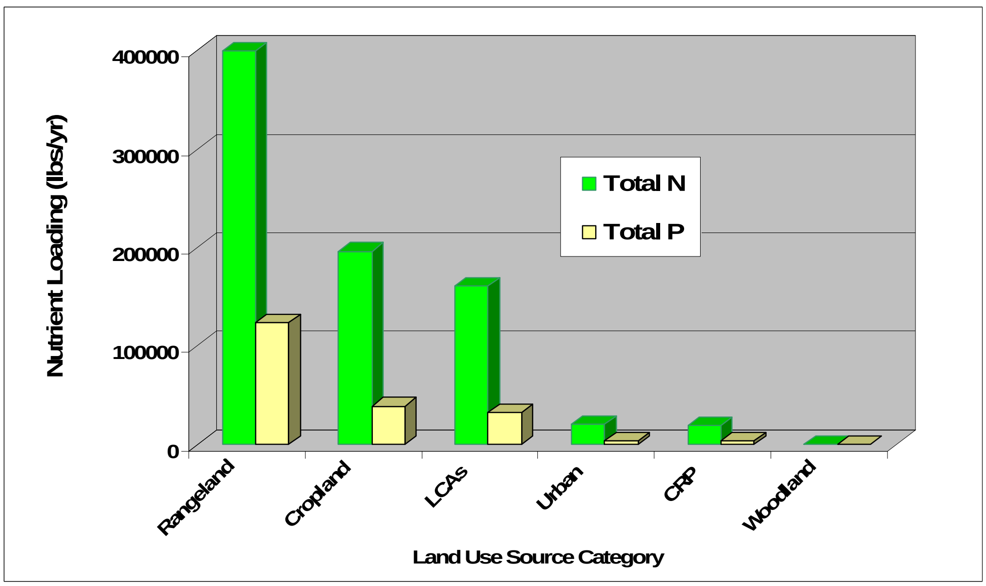

Figure 5-1. Total Annual Nutrient Load By Land Use Category

Rangelands are the largest source of nutrient loading due mainly to their 1.4 million acre extent. Rangelands are 67 percent of the planning area land cover (**Table 4-1**) and contribute 50 percent of the TN load and 60 percent of the TP load. Cropland, covering 23 percent of the planning area, contributes 25 percent of the TN load and 19 percent of the TP load.

Figure 5-2 shows the nutrient loading rates per acre for each land use category on a logarithmic scale Although livestock confinement areas cover only 170 acres, the high nutrient concentration of the runoff from manure pack conditions makes this source the largest generator on a per acre basis.

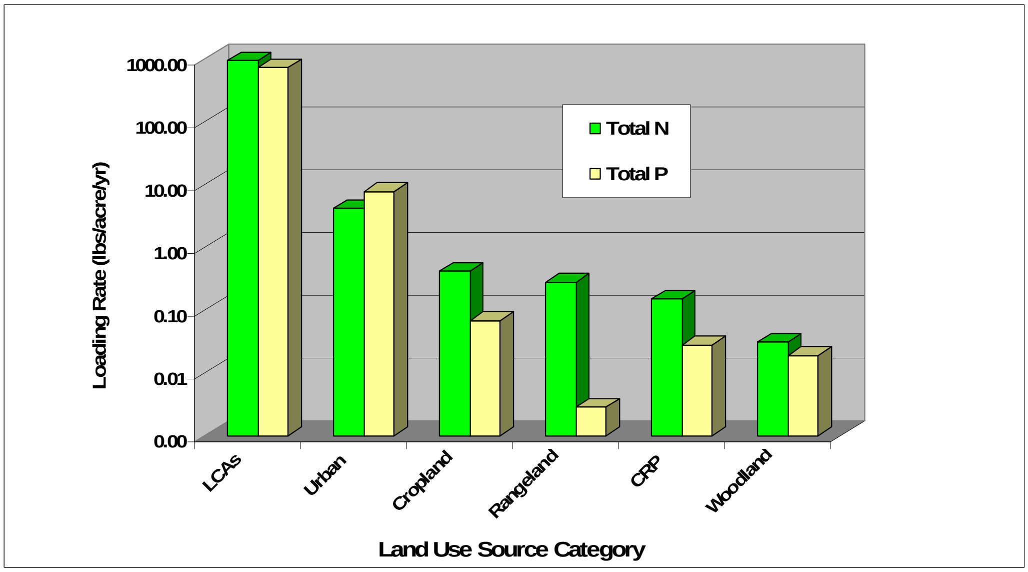

Figure 5-2. Annual Nutrient Load Rates of Land Use Categories

5.2 Modeled Nutrient Load Reductions

Simulated implementation of the selected BMPs across all subbasins resulted in a mean TN loading reduction of 32 percent, a mean TP loading reduction of 34 percent and a mean sediment loading reduction of 27 percent. The TN and TP loads and reductions are summarized in **Figure 5-3** for the eight subbasins where BMPs were applied.

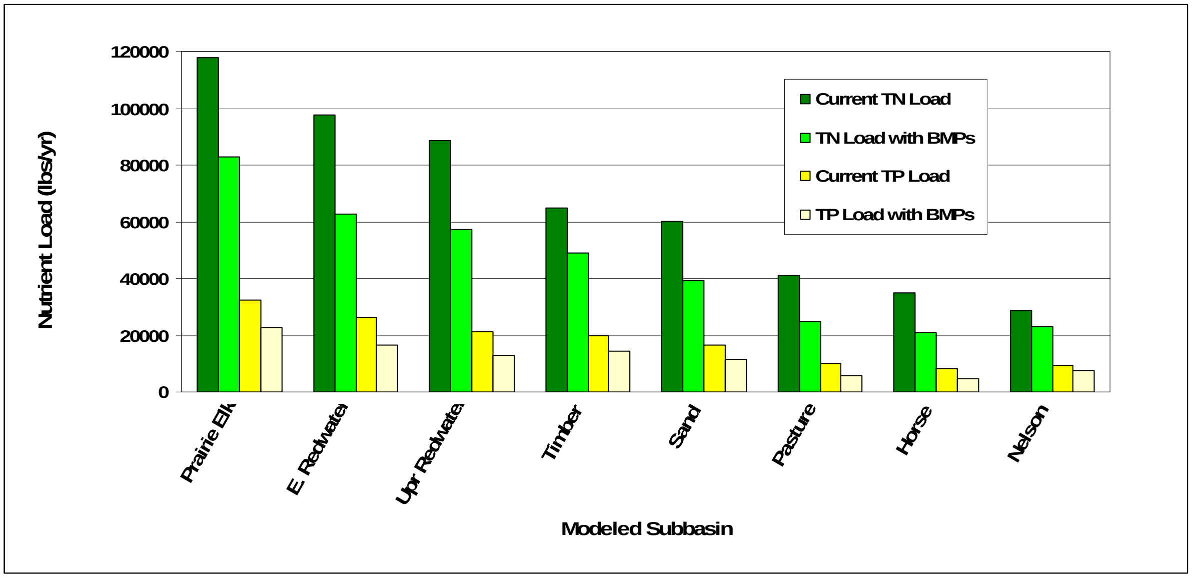

Figure 5-3. Current Condition TN and TP Loads and Load Reductions with BMPs for the Eight Redwater Subbasins Where BMPs Were Applied.

The listed subbasins are arranged from left to right in the figure from the largest to the smallest contributor to nutrient loading. The Prairie Elk subbasin's rank as the largest contributor is likely due to the combined effects of its large area (345 square miles) and its low soil infiltration capacity (soil hydrologic group "D") that produces larger sediment yields than soils with greater precipitation infiltration. East Redwater Creek and the upper Redwater River are both large subbasins with similar soil infiltration properties. Although the Nelson Creek subbasin is larger than either Pasture Creek or Horse Creek, its small cropland area and favorable infiltration conditions combine for the lowest existing nutrient loads and the smallest reductions with BMP implementation.

Figure 5-4 gives modeled nutrient and sediment reduction percentages by land use source. This information, combined with knowledge of the acreage for each source, helps to identify appropriate sources for TMDL allocations and the best opportunities for effective BMP application. The sizable reductions from rangeland, cropland and livestock confinement areas, combined with their large nutrient loads, (**Figure 5-1**), justifies and agricultural allocation to these sources. The model simulated large reductions in sediment and TP loading from the "urban" land use category. This result may justify a load allocation to road erosion despite the small overall load from this source. Although the modeling showed a large total nitrogen reduction from woodland, the small extent of woodland in the planning area does not justify a nutrient allocation or BMP implementation. The low septic system density in the sparsely populated planning area does not justify a separate allocation to this source. Although the model simulated a moderate total nitrogen reduction for CRP acreage, BMP options are limited where the management goal is maintenance of stable perennial vegetation cover.

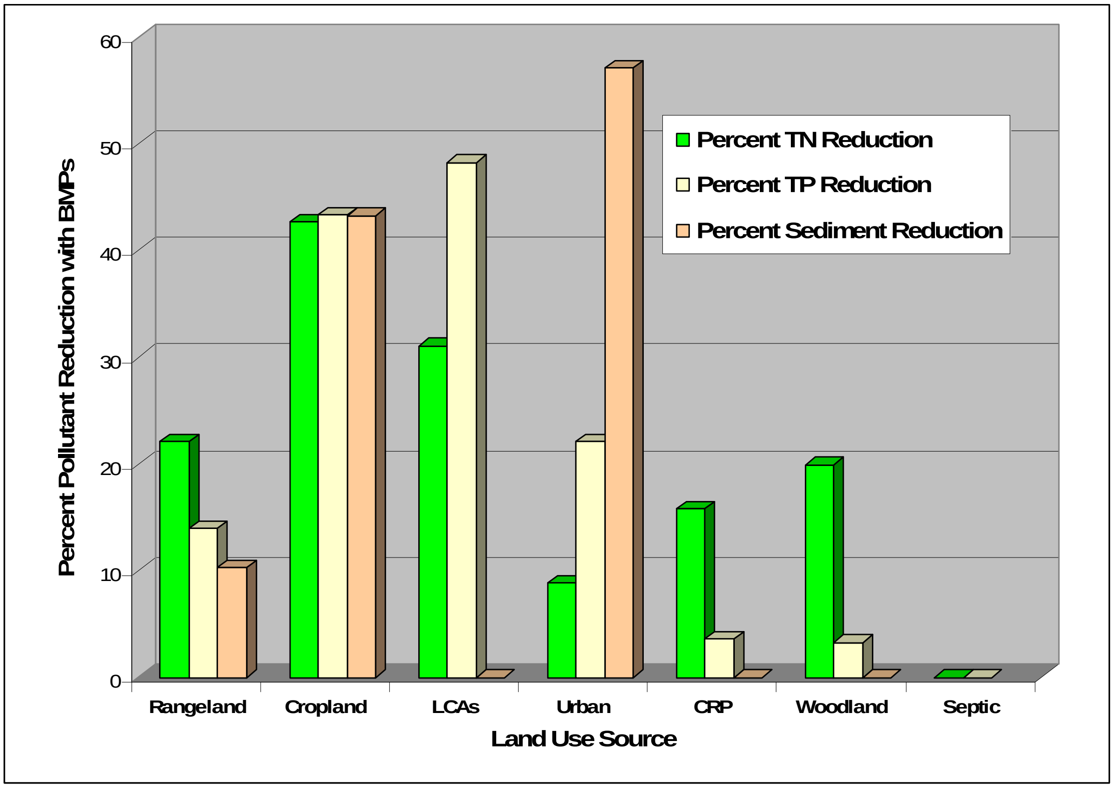

Figure 5-4. Modeled Pollutant Load Reductions by Land Use Source

In summary, the modeling results suggest that nutrient load allocations be developed for combined agricultural livestock, cropland and grazing sources as well as roadway surface sources. Significant reduction in nutrient and sediment contributions can be achieved by applying common roadway, cropland, grazing and livestock confinement BMPs.

6.0 REFERENCES

Brooks, K.N., 1987. Hydrology and the Management of Watersheds – second edition. Iowa State University Press. Ames, Iowa 50014.

Evans, B. M. and Corradini, K. J. 2001. BMP Pollution Reduction Guidance Document. Environmental Resources Research Institute, Pennsylvania State University. Prepared for: Bureau of Watershed Conservation, PA Department of Environmental Protection, December, 2001.

McCuen, R.H., 1998. Hydrologic Analysis and Design" – second edition. Prentice-Hall, Inc., Upper Saddle River, New Jersey 07458.

Tetra Tech, Inc. 2006. Spreadsheet Tool for the Estimation of Pollutant Load (STEPL), Version 4.0. Fairfax, VA. USEPA.

Tetra Tech, Inc. 2009. STEPL Model Input Data Server. Fairfax, VA. USEPA. URL – http://bering.tetratech-ffx.com/website/stepl/viewer.htm

United States Department of Agriculture (USDA), Natural Resources Conservation Service. 1991. National Engineering Handbook, Second Edition.

USDA, NRCS. 2009. National Range and Pasture Handbook. Grazing Lands Technology Institute. Revised 2009. Web Link: http://www.glti.nrcs.usda.gov/technical/publications/nrph.html

APPENDIX A
REDWATER RIVER TMDL PLANNING AREA NUTRIENT MODELING REPORT, SELECTED STEPL INPUT AND LOAD CALCULATION TABLES

March 2010

A-1. Input watershed land use area (ac) and precipitation (in)

Subbasin	Urban	Cropland	Rangeland	Woodland	CRP	LCAs	Total	Annual Rainfall	Rain Days	Average Rain Event Producing Runoff (in)
Horse Creek	570	24610	33563	34	8057	14	66848	13.38	58.9	1.026
Upper Redwater	1937	83420	238239	5677	20855	30	350158	11.52	58.9	0.884
Pasture Creek	51	25685	43538	1445	6421	14	77154	13.76	58.9	1.055
East Redwater Creek	881	40676	110592	2518	15818	16	170501	14.06	58.9	1.078
Lower Redwater	420	231884	389964	6628	54979	36	683911	14.05	58.9	1.078
Timber Creek	518	18630	178629	104	7206	16	205103	11.42	58.9	0.876
Nelson Creek	95	4767	75241	0	950	2	81055	12.45	58.9	0.955
Prairie Elk Creek	403	15302	201684	178	3825	28	221420	12.8	58.9	0.982
Sand Creek	59	24086	98363	75	6021	6	128610	14.19	58.9	1.088
McGuire Creek	92	5606	67299	9	1401	8	74415	13.38	58.9	1.026

A-2. Inputs of agricultural animals

Subbasin	Beef Cattle	Swine (Hog)	Sheep	Horse	Months/Year Manure Applied
Horse Creek	842	14	235	34	2
Upper Redwater	4389	75	1226	177	2
Pasture Creek	963	16	269	39	2
East Redwater Creek	2131	36	595	86	2
Lower Redwater	8553	146	2390	344	2
Timber Creek	2651	45	741	107	2
Nelson Creek	987	17	276	40	2
Prairie Elk Creek	2796	48	781	113	2
Sand Creek	1644	28	459	66	2
McGuire Creek	867	15	242	35	2
Total	25824	440	7215	1039	

A-3. Modified Universal Soil Loss Equation (USLE) parameters

Subbasin	Cropland					Rangeland					Woodland					CRP				
	R	**K**	**LS**	**C**	**P**	**R**	**K**	**LS**	**C**	**P**	**R**	**K**	**LS**	**C**	**P**	**R**	**K**	**LS**	**C**	**P**
Horse Creek	27.2	0.37	0.4	0.2	1.0	27.2	0.37	0.40	0.14	1.0	27.2	0.37	0.1	0.041	1.0	27.2	0.37	0.4	0.07	1.0
Upper Redwater	25.0	0.35	0.4	0.2	1.0	25.0	0.35	0.40	0.14	1.0	25.0	0.35	0.1	0.041	1.0	25.0	0.35	0.4	0.07	1.0
Pasture Creek	30.2	0.35	0.5	0.2	1.0	30.2	0.35	0.50	0.14	1.0	30.2	0.35	0.1	0.041	1.0	30.2	0.35	0.5	0.07	1.0
East Redwater Creek	31.6	0.37	0.70	0.2	1.0	31.6	0.37	0.70	0.14	1.0	31.6	0.37	0.1	0.041	1.0	31.6	0.37	0.7	0.07	1.0
Lower Redwater	30.0	0.37	0.46	0.2	1.0	30.0	0.37	0.46	0.14	1.0	30.0	0.37	0.1	0.041	1.0	30.0	0.37	0.6	0.07	1.0
Timber Creek	23.90	0.37	0.80	0.2	1.0	23.9	0.37	0.80	0.14	1.0	23.90	0.37	0.1	0.041	1.0	23.9	0.37	0.46	0.07	1.0
Nelson Creek	26.0	0.35	0.75	0.2	1.0	26.0	0.35	0.75	0.14	1.0	26.0	0.35	0.1	0.041	1.0	26.0	0.35	0.75	0.07	1.0
Prairie Elk Creek	28.9	0.38	0.75	0.2	1.0	28.9	0.38	0.75	0.14	1.0	28.9	0.38	0.1	0.041	1.0	28.9	0.38	0.75	0.07	1.0
Sand Creek	31.5	0.37	0.54	0.2	1.0	31.5	0.37	0.54	0.14	1.0	31.5	0.37	0.1	0.041	1.0	31.5	0.37	0.54	0.07	1.0
McGuire Creek	27.2	0.32	0.75	0.2	1.0	27.2	0.32	0.75	0.14	1.0	27.2	0.32	0.1	0.041	1.0	27.2	0.32	0.75	0.07	1.0

A-4. Selected average soil hydrologic group and soil nutrient concentrations (percent)

Subbasin	Soil Hyrdologic Group	Soil N Percent	Soil P Percent	Soil BOD Percent
Horse Creek	C	0.080	0.031	0.160
Upper Redwater	C	0.080	0.031	0.160
Pasture Creek	B	0.080	0.031	0.160
East Redwater Creek	C	0.080	0.031	0.160
Lower Redwater	C	0.080	0.031	0.160
Timber Creek	B	0.080	0.031	0.160
Nelson Creek	B	0.080	0.031	0.160
Prairie Elk Creek	D	0.080	0.031	0.160
Sand Creek	C	0.080	0.031	0.160
McGuire Creek	B	0.080	0.031	0.160

A-5. Reference runoff curve number by soil hydrologic group

SHG	A	B	C	D
Urban	83	83	98	98
Cropland	67	75	74	75
Rangeland	49	65	72	74
Woodland	39	60	73	79
CRP	50	62	68	70

A-6. Nutrient concentration in runoff (mg/l)

Land use	N	P	BOD
1. L-Cropland	1.5	0.075	4
1a. w/ manure	1.5	0.075	4
2. M-Cropland	1.5	0.075	4
2a. w/ manure	1.5	0.075	4
3. H-Cropland	1.5	0.075	4
3a. w/ manure	1.5	0.075	4
4. Pastureland	1.3	0.3	4
5. Forest	0.2	0.1	0.5
6. User Defined	1.4	0.083	4

A-7. Nutrient concentration in shallow groundwater (mg/l)

Landuse	N	P	BOD
Urban	0.35	0.082	0
Cropland	1.7	0.082	0
Rangeland	1.3	0.082	0
Woodland	0.11	0.007	0
Feedlot	7.7	1	0
CRP	1.7	0.082	0

A-8. Annual runoff by land uses (ac-ft)

Subbasin	Urban	Cropland	Rangeland	Woodland	CRP	Tot Runoff Volume
Horse Creek	324.1	1090.9	1086.1	1.3	117.8	2620.2
Upper Redwater	918.6	1959.3	3669.8	109.0	96.7	6753.3
Pasture Creek	7.2	1452.7	340.0	0.5	13.6	1814.0
East Redwater Creek	531.5	2169.9	4415.5	116.7	309.4	7543.0
Lower Redwater	253.2	12338.2	15524.4	306.3	1071.0	29493.1
Timber Creek	45.5	507.2	109.6	0.0	0.0	662.3
Nelson Creek	10.5	185.9	211.6	0.0	0.1	408.2
Prairie Elk Creek	217.3	664.3	7504.8	13.3	68.0	8467.6
Sand Creek	36.0	1328.4	4077.3	3.6	123.9	5569.2
McGuire Creek	12.2	286.9	411.5	0.0	1.8	712.4

A-9. Reference soil infiltration fraction for precipitation

SHG	A	B	C	D
Urban	0.36	0.1	0.08	0.05
Cropland	0.45	0.03	0.01	0.02
Rangeland	0.45	0.01	0.008	0.013
Woodland	0.45	0.07	0.026	0.02
CRP	0.45	0.01	0.007	0.007

A-10. Calculated infiltration volume (ac-ft)

Subbasin	Urban	Cropland	Rangeland	Woodland	CRP	Feedlots	Total
Horse Creek	2.0	172.3	188.0	0.6	39.5	0.1	403
Upper Redwater	7.7	502.9	1149.0	89.0	88.0	0.2	1837
Pasture Creek	0.4	554.9	313.5	72.8	46.2	0.1	988
East Redwater Creek	2.7	299.3	651.0	48.2	81.5	0.1	1083
Lower Redwater	2.0	1705.0	2293.9	126.7	283.0	0.3	4411
Timber Creek	2.0	334.0	1067.6	4.4	43.1	0.1	1451
Nelson Creek	0.6	93.2	490.2	0.0	6.2	0.0	590
Prairie Elk Creek	0.9	205.0	1756.3	2.4	17.9	0.1	1983
Sand Creek	0.2	178.9	584.4	1.4	31.3	0.0	796
McGuire Creek	0.3	117.8	471.2	0.4	9.8	0.1	600

A-11. Total load and load reductions with BMPs by subwatershed(s)

Subbasin	N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)	N Reduction	P Reduction	BOD Reduction	Sediment Reduction	N Load (with BMP)	P Load (with BMP)	BOD (with BMP)	Sediment Load (with BMP)	%N Reduction	%P Reduction	%BOD Reduction	%Sed Reduction
	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year	%	%	%	%
Horse Creek	35019.6	8333.7	70761.7	3995.3	13998.9	3668.8	11653.0	1510.5	21020.6	4664.9	59108.7	2484.8	40.0	44.0	16.5	37.8
Upper Redwater	88579.1	21173.5	175686.5	9429.0	31160.3	8256.9	24047.9	2839.3	57418.8	12916.7	151638.7	6589.6	35.2	39.0	13.7	30.1
Pasture Creek	40960.4	10030.0	71956.3	5669.9	16262.3	4345.6	13012.8	2004.8	24698.1	5684.4	58943.6	3665.1	39.7	43.3	18.1	35.4
East Redwater Creek	97615.3	26138.7	203385.7	14170.4	34927.9	9435.5	30509.5	4219.1	62687.4	16703.2	172876.2	9951.3	35.8	36.1	15.0	29.8
Lower Redwater	232635.4	49118.9	501790.5	19465.0	0.0	0.0	0.0	0.0	232635.4	49118.9	501790.5	19465.0	0.0	0.0	0.0	0.0
Timber Creek	64757.5	19677.7	114379.4	13316.0	15642.9	5106.2	18401.9	2624.7	49114.7	14571.5	95977.5	10691.3	24.2	25.9	16.1	19.7
Nelson Creek	28696.1	9545.9	53578.4	7122.3	5631.8	1867.7	8186.5	1230.7	23064.3	7678.2	45391.9	5891.7	19.6	19.6	15.3	17.3
Prairie Elk Creek	117727.0	32514.9	235624.8	16330.1	34990.1	9640.2	20304.4	2948.5	82736.9	22874.7	215320.4	13381.5	29.7	29.6	8.6	18.1
Sand Creek	60238.3	16642.3	129650.3	9229.3	20828.0	5274.8	15552.3	2392.2	39410.4	11367.5	114098.0	6837.1	34.6	31.7	12.0	25.9
McGuire Creek	34373.5	10229.7	61496.0	6451.9	0.0	0.0	0.0	0.0	34373.5	10229.7	61496.0	6451.9	0.0	0.0	0.0	0.0
Total	800602.1	203405.5	1618309.7	105179.2	173442.0	47595.7	141668.2	19769.8	627160.1	155809.8	1476641.5	85409.4	21.7	23.4	8.8	18.8

A-12. Nutrient and sediment loading by subbasin and land uses with BMPs (lb/year)

Watershed	Urban				Cropland				Rangeland				Woodland				Feedlot			CRP				Septic		
	N	P	BOD	Sediment	N	P	BOD	Sediment	N	P	BOD	Sediment	N	P	BOD	Sediment	N	P	BOD	N	P	BOD	Sediment	N	P	BOD
Horse Creek	2259.5	313.0	5657.7	45942.3	3462.6	875.2	16113.4	1330527.8	7238.4	2529.2	21907.4	3157347.4	1.1	0.5	2.6	269.2	5241.3	552.1	12647.0	1145.1	294.9	2674.3	435597.8	26.0	10.2	106.3
Upper Redwater	6443.1	896.6	15621.3	126334.6	5748.2	1390.6	27998.9	2095435.4	24048.8	8388.5	73204.2	10412768.2	92.6	42.5	214.9	20880.9	12918.5	1409.3	31317.6	1206.1	344.5	2727.7	523858.9	135.7	53.1	554.0
Pasture Creek	199.1	27.7	482.5	3901.0	4563.1	1147.0	21361.6	1741853.9	8904.6	3347.6	20135.6	5137477.0	18.6	7.2	37.4	11479.3	6325.7	666.3	15263.5	748.5	271.3	1541.5	435446.5	29.8	11.7	121.6
East Redwater Creek	3861.4	534.8	9399.3	75800.6	7832.5	2104.6	33941.6	3237115.1	33392.4	11808.9	96993.2	15314148.7	90.2	42.0	212.2	16767.3	10176.5	1110.2	24670.4	3190.9	845.2	7390.4	1258842.7	65.9	25.8	269.1
Lower Redwater	1976.0	329.6	6147.8	98731.8	77454.8	12974.7	188432.7	16981249.1	86818.6	24968.1	232689.1	19990396.4	201.1	96.6	485.4	21631.0	41575.8	8315.2	55434.5	7014.8	1373.8	17521.4	1838049.3	264.4	103.6	1079.7
Timber Creek	1748.4	242.9	4217.4	34019.6	2527.7	760.3	9327.3	1192232.2	32045.8	12311.6	64841.7	19890660.1	0.8	0.3	1.6	487.3	6767.6	738.3	16406.3	424.3	163.3	848.5	265161.3	82.0	32.1	334.7
Nelson Creek	338.9	47.1	819.0	6612.9	884.7	262.6	3335.2	410868.7	18480.4	7064.8	38408.8	11283963.4	0.0	0.0	0.0	0.0	1006.8	109.8	2440.8	131.5	50.5	263.5	81880.7	30.5	12.0	124.7
Prairie Elk Creek	1570.0	218.4	3802.2	30731.5	2580.8	714.7	10757.1	1105349.8	55668.9	19652.7	162681.4	25349666.4	8.8	4.2	21.3	1004.1	14884.0	1623.7	36082.4	700.7	185.5	1623.1	276301.3	86.4	33.9	353.0
Sand Creek	264.0	36.7	636.6	5134.0	4241.5	1075.3	19671.6	1635809.5	26807.0	9353.7	81508.8	11623825.0	2.8	1.3	6.7	552.5	3882.4	423.5	9411.9	1125.5	279.8	2655.0	408918.4	50.8	19.9	207.5
McGuire Creek	426.5	71.1	1322.1	21323.7	3341.0	894.6	7461.6	1357349.6	19703.5	7361.7	40972.1	11406312.5	0.1	0.0	0.2	59.6	8423.0	1684.6	11230.6	197.0	73.6	400.0	118725.7	26.8	10.5	109.4
Total	19086.9	2717.8	48105.9	448532.0	112636.8	22199.5	338401.0	31087791.1	313108.4	106786.9	833342.3	133566565.1	416.3	194.7	982.1	73131.2	111201.6	16632.9	214904.9	15884.4	3882.4	37645.4	5642782.6	798.3	312.7	3259.9

A-13. Total load by land uses (with BMP load reductions)

Sources	N Load (lb/yr)	P Load (lb/yr)	BOD Load (lb/yr)	Sediment Load (t/yr)
Urban	19086.86	2717.80	48105.86	224.27
Cropland	112636.80	22199.54	338400.97	15543.90
Rangeland	313108.44	106786.89	833342.30	66783.28
Woodland	416.26	194.67	982.14	36.57
Feedlots	111201.62	16632.92	214904.88	0.00
CRP	15884.44	3882.42	37645.45	2821.39
Septic	798.35	312.69	3259.91	0.00
Groundwater	54027.35	3082.89	0.00	0.00
Total	627160.12	155809.81	1476641.50	85409.40