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REDWATER RIVER NUTRIENT AND SALINITY TMDLS AND FRAMEWORK WATER QUALITY IMPROVEMENT PLAN

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Montana Department of Environmental Quality

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ACRONYM LIST

ARM	Administrative Rules of Montana
BER	Board of Environmental Review
BLM	Bureau of Land Management, United States
BMP	Best Management Practice
BNSF	Burlington Northern Santa Fe
BOD_5	Five-day Biochemical Oxygen Demand
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
CN	Curve Number
CRP	Conservation Reserve Program
CWA	Clean Water Act
DEQ	Department of Environmental Quality, Montana
DO	Dissolved Oxygen
EMAP	Environmental Monitoring and Assessment Program
FWP	Fish, Wildlife, and Parks, Montana Department of
GAP	Gap Analysis Program
GIS	Geographic Information System
GWIC	Groundwater Information Center, MBMG
HUC	Hydrologic Unit Code
in	inches
LA	Load Allocation
lbs/day	pounds per day
MBMG	Montana Bureau of Mines and Geology
MCA	Montana Code Annotated
mg/L	Milligrams Per Liter
MOS	Margin of Safety
MPDES	Montana Pollutant Discharge Elimination System
NAIP	National Agricultural Imagery Program
NOAA	National Oceanic and Atmospheric Administration
NRCS	National Resource Conservation Service
NRIS	Natural Resource Information System
PRISM	Parameter-elevation Regressions on Independent Slopes Model
SC	Specific Conductance
SCD/BUD	Sufficient Credible Data / Beneficial Use Determination
SDWIS	Safe Drinking Water Information System
STATSGO	State Soil Geographic [database]
STEPL	Spreadsheet Tool for Estimating Pollutant Loads
SSURGO	Soil Survey Geographic Database
TDS	Total Dissolved Solids
TN	Total Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TPA	TMDL Planning Area

TRC	Total Residual Chlorine
TSS	Total Suspended Solids
UAA	Use Attainability Analysis
µg/g	microgram per gram
µg/L	microgram per liter
µS/cm	micro-siemens per centimeter
U.S. EPA	United States Environmental Protection Agency
USDA	United States Department of Agriculture
USGS	United States Geologic Survey
USLE	Universal Soil Loss Equation
WLA	Waste Load Allocation
WRCC	Western Regional Climate Center
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

This document presents Total Maximum Daily Loads (TMDL) and a framework water quality improvement plan for 19 pollutant-waterbody combinations on eight impaired waterbodies in the Redwater River TMDL Planning Area (TPA). The Redwater River TPA extends from the headwaters of the Redwater River to its mouth on the Missouri River. The planning area also includes the water sheds of two Missouri River tributaries, Sand Creek and Prairie Elk Creek, located immediately to the west of the Redwater River watershed. In addition, the Redwater River TPA includes the drainage areas of three tributaries to the Dry Creek Arm of Fort Peck Reservoir: Timber Creek, Nelson Creek and McGuire Creek. This plan was developed by the Montana Department of Environmental Quality (DEQ) and submitted to the U.S. Environmental Protection Agency (U.S. EPA) for approval. The Montana Water Quality Act requires DEQ to develop TMDLs for streams and lakes that do not meet, or are not expected to meet, Montana water quality standards. A TMDL is the maximum amount of a pollutant a waterbody can receive and still meet water quality standards. The goal of TMDLs is to eventually attain and maintain water quality standards in all of Montana's streams and lakes, and to improve water quality to levels that support all state-designated beneficial water uses.

The Redwater River TPA occupies portions of five northeastern Montana counties. It is centered in McCone County and includes portions of Richland, Dawson, Prairie and Garfield counties. The TPA is bounded on the east and south sides by the Missouri-Yellowstone drainage divide, by the Dry Creek-Redwater River divide and Fort Peck Reservoir on the west, and on the north by the Missouri River floodplain. The total area is 2,067,992 acres, or approximately 3,231 square miles. Over 85 percent of the TPA is under private ownership. Most of the remaining area is in state and federal Bureau of Land Management ownership.

Through field assessments and related water quality sampling, DEQ determined that eight streams or stream segments do not meet the applicable water quality standards for nutrients, sediment, salinity and metals. The scope of TMDL development in this document addresses nutrient and salinity related water quality problems on these streams (See **Table ES-1**). The DEQ recognizes that there are other pollutant listings for this TPA. Sediment TMDLs for East Redwater Creek and Sand Creek will be developed at a later date, pending focused sediment target development for C-3 streams. The metals impairment cause for Nelson Creek requires further evaluation prior to TMDL development for cadmium and copper.

Nutrients

The DEQ assessment process identified nutrients as a cause of impairment of aquatic life, warm water fisheries, and primary contact recreation on East Redwater Creek, Nelson Creek, Pasture Creek, Prairie Elk Creek, a segment of the Redwater River near the Town of Circle, Sand Creek and Timber Creek. A review of the assessment record and additional water quality sampling on Horse Creek and Nelson Creek determined the need for nutrient TMDLs on Horse Creek and a TP TMDL on Nelson Creek.

Nutrients are impacting beneficial water uses in these streams by creating conditions for accelerated algae growth that reduces the concentration of dissolve oxygen available for other aquatic organisms. Water quality restoration goals for nutrients were based on nutrient parameter targets developed from a set of reference prairie streams and established dissolved oxygen standards. Once these water quality goals are met, beneficial uses currently impacted by sediment will be restored.

Nutrient loads were quantified for natural background conditions based on expected background nutrient parameter concentrations reported in the literature and inferred from the study of reference prairie streams in Montana. Nutrient loading from agricultural sources was assessed through use of a spreadsheet-based loading model. Loading from the Circle wastewater treatment system was estimated from system engineering specifications and records of discharge rate and effluent nutrient concentrations in past discharges. Based on the magnitude of target departures, the nutrient TMDLs call for TN load reductions ranging from 26 to 70 percent; TP reductions ranging from 23 to 77 percent;NO_{3+2}-N reductions ranging from zero to 56 percent.

Salinity

The DEQ assessment process concluded that salinity impacts were causing impairment to aquatic life and warm water fishery beneficial uses in East Redwater, Horse and Nelson creeks. The specified impairment causes were specific conductance (SC), total dissolved solids (TDS) and sulfates in East Redwater Creek, “salinity” in Horse Creek and sulfates in Nelson Creek. The water quality goals for salinity are based on a reference condition approach to target development for SC and TDS.

Dissolved solids loading was assumed to be dominated by groundwater sources during low stream flow conditions. Loading was estimated from existing groundwater concentrations of dissolved solids and groundwater discharge volume estimated through use of a simplified groundwater flow model. Loading from cropland versus native rangeland sources was estimated using a literature-based ratio of 4:1 for TDS loading to shallow groundwater from these two cover conditions.

Based on numeric target departures, the needed reductions in TDS loading during low flow conditions were 30 percent for East Redwater Creek, 57 percent for Horse Creek, and 12 percent for Nelson Creek. Actual load reductions are achieved by increasing crop consumption of available soil moisture, thereby preventing excess percolation of precipitation beneath the crop root zone and into the shallow aquifer that discharges to streams. An achievable 20 percent reduction in the volume of precipitation percolating beneath croplands over a period of several decades has been reported in the literature on saline seep control (Beke et al. 1993). Applying this reduction from cropland sources in each of the three listed streams translates to an overall TDS loading reduction of 10 percent in East Redwater Creek, 19 percent in Horse Creek, and four percent in Nelson Creek.

There is considerable disparity between the needed reductions indicated by the target departures and the reductions assumed as achievable by long-term salt migration studies conducted on croplands. The salinity TMDLs are based on achievable load reductions. They are proposed in a framework of adaptive management whereby corrective and profitable cropping systems are applied to controllable sources, and the estimates of current loading are improved by adequate monitoring of groundwater and surface water quality and crop root zone moisture trends.

Considering the level of uncertainty in the loading analysis, and the lack of cropland sources in the Nelson Creek watershed, the small achievable loading reduction calculated for Nelson Creek is grounds for reevaluating the Nelson Creek salinity (sulfate) impairment determination.

Broad approaches for achieving the pollutant reduction goals are presented in this plan. They include best management practices (BMPs) for agricultural sources of nutrient and TDS loading. Specific BMP recommendations include filter strip installation in croplands and prescribed grazing on rangelands for nutrient reductions. Runoff diversions are prescribed to address nutrient loading from livestock confinement areas. Flexible cropping systems, combined with soil moisture management practices, are recommended to address TDS loading from tilled croplands. Loading source monitoring and wastewater collection system evaluation are recommended for the Circle WWTP components.

Water quality improvement will likely be accomplished with voluntary BMP implementation and monitoring by local stakeholders. The loading estimates, TMDLs, monitoring, and corrective action recommendations in this document are useful as points of departure toward prioritizing water quality improvement activities and improving the understanding of current loading conditions. Selected water quality improvement and monitoring activities can guide development of a watershed restoration plan that is consistent with DEQ and EPA recommendations.

A flexible and adaptive approach to TMDL implementation is essential in light of the discontinuous nature of the existing water quality database and the inherent uncertainty in loading estimates. BMP selection, implementation and monitoring adjustments will need to be tailored to field scale conditions where actual improvements are most likely to occur.

Table ES-1. Impaired Waterbodies, Impairment Causes, and Impaired Beneficial Uses in the Redwater River TPA for Which TMDLs Were Completed.

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category	Impaired Uses
East Redwater Creek, headwaters to mouth (Redwater River)	MT40P002_010	Total Dissolved Solids	Mineralization	Aquatic Life, Warm Water Fishery
		NO_3+NO_2-N	Nutrients	Aquatic Life, Primary Contact Recreation, Warm Water Fishery
		Total Phosphorus	Nutrients	Aquatic Life, Primary Contact Recreation, Warm Water Fishery
		Total Nitrogen	Nutrients	Aquatic Life, Primary Contact Recreation, Warm Water Fishery

Table ES-1. Impaired Waterbodies, Impairment Causes, and Impaired Beneficial Uses in the Redwater River TPA for Which TMDLs Were Completed.

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category	Impaired Uses
Horse Creek, headwaters to mouth (Redwater River)	MT40P002_020	Total Phosphorus	Nutrients	Aquatic Life, Warm Water Fishery
		Total Nitrogen	Nutrients	Aquatic Life, Warm Water Fishery
		Total Dissolved Solids	Mineralization	Aquatic Life, Warm Water Fishery
Nelson Creek, headwaters to the mouth (Fort Peck Reservoir)	MT40E003_020	NO_3+NO_2-N	Nutrients	Aquatic Life, Warm Water Fishery
		Total Phosphorus	Nutrients	Aquatic Life, Warm Water Fishery
		Total Nitrogen	Nutrients	Aquatic Life, Warm Water Fishery
Pasture Creek headwaters to mouth (Redwater River)	MT40P002_030	Total Nitrogen	Nutrients	Aquatic Life, Warm Water Fishery
Prairie Elk Creek, headwaters to mouth (Missouri River)	MT40S002_010	Total Phosphorus	Nutrients	Aquatic Life, Warm Water Fishery
		Total Nitrogen	Nutrients	Aquatic Life, Warm Water Fishery
Redwater River, (Hell Creek to Buffalo Springs Creek)	MT40P001_012	Total Nitrogen	Nutrients	Aquatic Life
		Total Phosphorus	Nutrients	Aquatic Life
Sand Creek, the forks to mouth (Missouri River)	MT40S002_030	Total Phosphorus	Nutrients	Aquatic Life, Warm Water Fishery
		Total Nitrogen	Nutrients	Aquatic Life, Warm Water Fishery
Timber Creek, headwaters to mouth (Fort Peck Reservoir)	MT40E003_010	Total Phosphorus	Nutrients	Aquatic Life, Warm Water Fishery
		Total Nitrogen	Nutrients	Aquatic Life, Warm Water Fishery

SECTION 1.0
INTRODUCTION

1.1 Background

This document, *The Redwater River TMDLs and Framework Water Quality Improvement Plan*, describes the Montana Department of Environmental Quality's current understanding of nutrient and salinity related water quality problems in streams of the Redwater River TMDL Planning Area (TPA) and presents a general framework for resolving them. The Redwater River TPA encompasses the Redwater River watershed from its headwaters to its confluence with the Missouri River near the Town of Poplar. In addition, the Redwater TPA includes the Fort Peck Reservoir tributaries of Nelson Creek and Timber Creek, and the Missouri River Tributaries of Prairie Elk Creek and Sand Creek. The locations of nutrient and salinity listed waters are shown in **Appendix A**, **Figure A-8**. Waterbodies listed for sediment will be addressed in a future document.

Congress passed the Water Pollution Control Act, more commonly known as the Clean Water Act, in 1972. The goal of this act is 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 called *impaired waters*, and those not expected to meet the standards are called *threatened waters*.

The waterbodies with their associated impairment and threatened causes are identified within a biennial integrated water quality report developed by DEQ. Impairment causes fall within two main categories: pollutant and pollution. Both Montana state law (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 and threatened waters where a measurable pollutant (for example, sediment, nutrients, or metals) is the cause of the impairment. The waterbody segments with pollutant impairment causes in need of TMDL development are contained within the 303(d) List portion of the State's integrated water quality report. The integrated report identifies impaired waters by a Montana waterbody segment identification, which is indexed to the National Hydrography Dataset. **Table 1-1** identifies the waterbodies identified as impaired or threatened by pollutants and pollution in the Redwater TPA.

Table 1-1. 2008 Impaired Waterbodies, Impairment Causes, and Impaired Beneficial Uses in the Redwater River TPA.

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category	Impaired Uses
East Redwater Creek, headwaters to mouth (Redwater River)	MT40P002_010	Chlorophyll-a	*Not a Pollutant*	Aquatic Life, Primary Contact Recreation, Warm Water Fishery
		Specific Conductance	**Mineralization**	Aquatic Life, Warm Water Fishery
		Total Dissolved Solids	**Mineralization**	Aquatic Life, Warm Water Fishery
		Sulfates	**Mineralization**	Aquatic Life, Warm Water Fishery
		Nitrate/Nitrite (Nitrite + Nitrate as N)	**Nutrients**	Aquatic Life, Primary Contact Recreation, Warm Water Fishery
		Phosphorus (Total)	**Nutrients**	Aquatic Life, Primary Contact Recreation, Warm Water Fishery
		Total Kjeldahl Nitrogen (TKN)	**Nutrients**	Aquatic Life, Primary Contact Recreation, Warm Water Fishery
		Sedimentation/ Siltation	**Sediment**	Aquatic Life, Warm Water Fishery
Horse Creek, headwaters to mouth (Redwater River)	MT40P002_020	Alteration in stream-side or littoral vegetative covers	*Not a Pollutant*	Aquatic Life, Warm Water Fishery
		Physical substrate habitat alterations	*Not a Pollutant*	Aquatic Life, Warm Water Fishery
		Salinity	**Mineralization**	Aquatic Life, Warm Water Fishery
Nelson Creek, headwaters to the mouth (Fort Peck Reservoir)	MT40E003_020	Alteration in stream-side or littoral vegetative covers	*Not a Pollutant*	Aquatic Life, Warm Water Fishery
		Cadmium	**Metals**	Aquatic Life, Warm Water Fishery
		Copper	**Metals**	Aquatic Life, Warm Water Fishery
		Nitrogen, Nitrate	**Nutrients**	Aquatic Life, Warm Water Fishery
		Sulfates	**Mineralization**	Aquatic Life, Warm Water Fishery
Pasture Creek headwaters to mouth (Redwater River)	MT40P002_030	**TKN**	**Nutrients**	Aquatic Life, Warm Water Fishery

Table 1-1. 2008 Impaired Waterbodies, Impairment Causes, and Impaired Beneficial Uses in the Redwater River TPA.

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category	Impaired Uses
Prairie Elk Creek, headwaters to mouth (Missouri River)	MT40S002_010	Alteration in stream-side or littoral vegetative covers	*Not a Pollutant*	Aquatic Life, Warm Water Fishery
		Phosphorus (Total)	**Nutrients**	Aquatic Life, Warm Water Fishery
		Physical substrate habitat alterations	*Not a Pollutant*	Aquatic Life, Warm Water Fishery
		TKN	**Nutrients**	Aquatic Life, Warm Water Fishery
Redwater River, (Hell Creek to Buffalo Springs Creek)	MT40P001_012	**Nitrogen, (Total)**	**Nutrients**	Aquatic Life
		Phosphorus (Total)	**Nutrients**	Aquatic Life
Redwater River, Pasture Creek to mouth (Missouri River)	MT40P001_014	Other Anthropogenic substrate alterations	*Not a Pollutant*	Aquatic Life, Warm Water Fishery
		Physical substrate habitat alterations	*Not a Pollutant*	Aquatic Life, Warm Water Fishery
Sand Creek, the forks to mouth (Missouri River)	MT40S002_030	**Phosphorus (Total)**	**Nutrients**	Aquatic Life, Warm Water Fishery
		Physical substrate habitat alterations	*Not a Pollutant*	Aquatic Life, Warm Water Fishery
		Sedimentation/ Siltation	**Sediment**	Aquatic Life, Warm Water Fishery
		TKN	**Nutrients**	Aquatic Life, Warm Water Fishery
Timber Creek, headwaters to mouth (Fort Peck Reservoir)	MT40E003_010	**Phosphorus (Total)**	**Nutrients**	Aquatic Life, Warm Water Fishery
		TKN	**Nutrients**	Aquatic Life, Warm Water Fishery

This document addresses those pollutant-waterbody combinations identified by bold text.

A TMDL refers to the maximum amount of a pollutant a waterbody can receive and still meet water quality standards. The development of TMDLs and water quality improvement strategies in Montana includes several steps that must be completed for each impaired or threatened waterbody and for each contributing pollutant (or "pollutant/waterbody combination"). These steps include:

1. Characterizing the existing waterbody conditions and comparing these conditions to water quality standards. During this step, measurable target values are set to help evaluate the stream's condition in relation to the applicable standards.
2. Quantifying the magnitude of pollutant contribution from the pollutant sources.
3. Determining the TMDL for each pollutant, based on the allowable loading limits (or loading capacity) for each pollutant/waterbody combination.

4. Allocating the total allowable load (TMDL) into individual loads for each source (referred to as the load allocations or waste load allocations).

In Montana, restoration strategies and recommendations are also incorporated in TMDL documents to help facilitate TMDL implementation.

The above four TMDL steps are further defined in **Section 4.0** of this document. Basically, TMDL development for an impaired waterbody is a problem solving exercise. The problem is excess pollutant loading negatively impacting a designated beneficial use. The solution is developed by identifying the total acceptable pollutant load to the waterbody (the TMDL), characterizing all the significant sources contributing to the total pollutant loading, and then identifying where pollutant loading reductions should be applied to one or more sources to achieve the acceptable load.

1.2 Additional Water Quality Impairments and TMDLs Addressed By This Plan

As shown by **Table 1-1**, there are several types of impairment causes which fall into different TMDL pollutant categories. For each impairment cause, the impaired beneficial uses are also identified. They include aquatic life, warm water fisheries, and primary contact recreation. Because TMDLs are completed for each pollutant/waterbody combination, this document contains several TMDLs which address the pollutant impairment causes identified by bold text in **Table 1-1**. These pollutant impairment causes fall within the categories of mineralization and nutrients. TMDL development for each pollutant category will follow a similar process as reflected by the organization of this document.

In addition to those pollutant-waterbody combinations identified in **Table 1-1**, data reviewed during this project justified the further development of nutrient TMDLs (total nitrogen and total phosphorus) for Horse Creek.

1.3 Pollutant Impairments Not Addressed By This Plan

An early version of Montana's water quality database referred to as "STOREASE" contained exceedences of the aquatic life standards for copper and cadmium in Nelson Creek. A surface water sample from Nelson Creek collected at USGS Station 06131200 ("Nelson Creek near Van Norman") on October 10, 1975 contained 20 ug/L Cd and 50 ug/L Cu. The respective aquatic life standards for these metals at the measured total hardness of 160 mg/L are 0.38 ug Cd/L and 13.94 ug Cu/L. Thus, the results of the 1975 sampling exceeded the applicable standard for both metals.

Since 1975, 12 water samples from Nelson Creek have been analyzed for total recoverable Cd. All but one of these has contained less than detectable amounts of Cd. A Cd concentration of 0.11 ug/L was measured from a sample collected in June of 2008. At a measured harness of 261 mg/L, the applicable Cd standard is 0.55 ug/L. Thus, the 2008 Cd result was within the applicable standard. Nelson Creek sediment samples collected in June of 2008 did not contain detectable amounts of Cd.

Thirteen water samples from Nelson Creek have been analyzed for Cu since 1975. Three of these have exceeded the aquatic life standard for Cu adjusted for measured hardness values. Two of these exceedences were measured in late March of 1978 and 1979. March is typically the height of the runoff season in Nelson Creek. The third exceedence (33 µg/L) occurred in a sampled collected in June of 2008 from a turbid stream after a period of extended rainfall the previous month. Nelson Creek sediment samples collected with the 2008 water samples did not contain elevated Cu concentrations.

There are no known human caused sources of either Cd or Cu in the Nelson Creek watershed. Although sediment sampling has not confirmed elevated Cu concentrations, the timing of the water samples that have exceeded Cu standards suggests a sediment bound source of copper. Due to the general lack of detectable Cd concentration in either water or sediments and the paucity of recent Cu exceedences, metals TMDLs will not be pursued in Nelson Creek at this time.

Review of available data has also determined that sediment TMDLs will not be developed for streams in the Redwater River TPA at this time. TMDL development for sediment is on hold pending more detailed development by DEQ of sediment related targets for C-3 waters.

This document addresses 17 nutrient TMDLs and two salinity TMDLs for a total of 19 TMDLs in the Redwater River TPA.

1.4 Document Layout

The main body of the document provides a summary of the TMDL components. Additional technical details of these components are contained in the appendices of this report. In addition to this introductory section which includes the brief TMDL background and identification of TMDLs developed, this document has been organized into the following sections:

Section 2.0 Redwater River TPA Watershed Characterization: Description of the physical and social characteristics of the planning area

Section 3.0 Montana Water Quality Standards: Discusses the water quality standards that apply to the planning area streams

Section 4.0 Description of TMDL Components: Defines the components of a TMDL and the process by which they are developed.

Sections 5.0 – 6.0 Nutrient and Salinity TMDL components are discussed in sequential summaries of the pollutant category’s impact to beneficial uses, water quality target development, target departures, quantified pollutant contributions from the identified sources, the TMDLs, and allocations.

Section 7.0 Framework Water Quality Improvement Plan: Discusses water quality restoration objectives and presents a framework implementation approach for meeting TMDLs.

Section 8.0 Monitoring Strategy and Adaptive Management: Describes elements of a water quality monitoring plan for improving data quality and evaluating effectiveness of water quality restoration activities.

SECTION 2.0
REDWATER WATERSHED DESCRIPTION

This report describes the physical, biological, and anthropogenic characteristics of the Redwater River watershed and nearby areas (**Appendix A**, **Figure A-1)**. The characterization establishes a context for impaired waters, as background for TMDL planning. The Redwater River TPA includes the Redwater River 4th-order hydrologic unit code (HUC) as well as other watersheds that drain northward into the Missouri River (Prairie Elk and Sand creeks) or drain into Fort Peck Reservoir (Nelson and Timber creeks).

The DEQ has identified eight impaired waterbodies within the Redwater TPA: Redwater River (Hell Creek to Buffalo Springs Creek), Horse Creek, Pasture Creek, East Redwater Creek, Timber Creek, Nelson Creek, Prairie Elk Creek, and Sand Creek. The impairment listings are detailed in DEQ's Integrated 305(b)/303(d) Water Quality Report (DEQ, 2008a), and are shown on a number of the resource-specific maps in **Appendix A**. Impairment listings are summarized in **Section 1**.

2.1 Physical Characteristics

2.1.1 Location

Counties
The majority of the TPA is within McCone County. Portions of Dawson, Richland, Prairie and Garfield counties are also included within the boundary. The total area is 2,067,992 acres, or approximately 3,231 square miles.

Watersheds
The Redwater TPA includes portions of the Missouri – Poplar Basin (Accounting Unit 1006) and the Middle Missouri River Basin (Accounting Unit 1004) of eastern Montana, as shown in **Appendix A**, **Figure A-1**. The Redwater TPA includes the Redwater River and its tributaries of Horse Creek, Pasture Creek and East Redwater Creek. The TPA also includes the two Missouri River tributaries of Prairie Elk Creek and Sand Creek, the Fort Peck Reservoir tributaries of Nelson Creek, Timber Creek and McGuire Creek. All streams but McGuire Creek have impairment listings addressed in this document. The Redwater HUC (2,112 miles^2) is 65% of the TPA area. The Prairie Elk-Wolf Creek (555 miles^2) and Fort Peck Reservoir (564 miles^2) HUCs occupy the remaining 17% and 18%, respectively.

Ecoregions
The TPA includes 2 Level III Ecoregions: Northwestern Glaciated Plains and Northern Great Plains. Five Level IV Ecoregions are mapped within the TPA (**Appendix A**, **Figure A-2**). These include: Glaciated Northern Grasslands (42j), Glaciated Dark Brown Prairie (42i), Missouri Plateau (43a), Montana Central Grasslands (43n) and River Breaks (43c). The Level III and IV ecoregions are established in Woods *et al*., (2002).

2.1.2 Topography

Elevations in the TPA range from approximately 575 to 1,100 meters (1,885 - 3,600 feet) above mean sea level (**Appendix A**, **Figure A-3**). The mean elevation is 767 meters (2,515 feet) above sea level. The lowest point is the confluence of the Redwater and Missouri rivers. The southern and eastern parts of the TPA are characterized by gently rolling to strongly rolling hills and terraces, and the western part is characterized by moderately sloping terraces and benches and by steeper and more dissected river breaks terrain. Several broad glacial lakebeds occupy the north end of the watershed near Vida. Areas of strongly dissected badlands occur in the headwaters of tributaries along the eastern edge of the divide separating the Missouri from the Yellowstone drainage. This uplifted ridge is known as the Big Sheep Mountains. Terrain to the west is generally more gently rolling and gradually sloping up to the hydrologic divide with Little Dry Creek.

2.1.3 Geology

Appendix A, Figure A-4 provides an overview of the geology, based on 1:100,000 scale maps produced by the Montana Bureau of Mines and Geology (MBMG). The TPA includes portions of the Richey, Circle, Fort Peck Lake East, Jordan, Wolf Point and Sidney 1:100,000 quadrangles.

The majority of the TPA is underlain by the Tertiary Fort Union Formation. This unit is composed largely of sandstones and siltstones that were deposited in river channels and associated floodplains. Coal beds are occasionally present. The predominant lithologies are shown in **Appendix A**, **Figure A-4a**. To the north, towards the Missouri River, the underlying Cretaceous rocks are exposed, including the Hell Creek, Fox Hills and Bearpaw formations. Portions of the TPA were glaciated during the last glacial maximum, although significant glacial deposits are limited.

2.1.4 Soils

The USGS Water Resources Division (Schwartz and Alexander, 1995) created a dataset of hydrology-relevant soil attributes, based on the USDA Natural Resources Conservation Service (NRCS) STATSGO soil database. The STATSGO data is intended for small-scale (watershed or larger) mapping, and is too general to be used at scales larger than 1:250,000. It is important to realize, therefore, that each soil unit in the STATSGO data may include up to 21 soil components. The STATSGO soil map units are shown in **Appendix A**, **Figure A-5**. Soil analysis at a larger scale should use NRCS SSURGO data. The soil attributes considered in this characterization are erodibility, permeability and slope.

Erodibility
Soil erodibility is based on the Universal Soil Loss Equation (USLE) K-factor (Wischmeier & Smith 1978). K-factor values range from 0 to 1, with a greater value corresponding to greater potential for erosion. Susceptibility to erosion is mapped in **Appendix A**, **Figure A-5a**, with soil units assigned to the following ranges: low (0.0-0.2), low-moderate (0.2-0.29) and moderate-high

(0.3-0.4). Values of >0.4 are considered highly susceptible to erosion. No values greater than 0.4 are mapped in the TPA.

Nearly 75% of the TPA is mapped with moderately-highly erodible soils. Moderate to low susceptibility to erosion soils cover 18% of the TPA. The remaining 7% of the soils in the TPA are assigned low susceptibility to erosion.

Several patterns are apparent in the distribution of mapped K-factors. The moderate-high erodibility soils correlate generally with the distribution of the Tongue River member of the Fort Union Formation. The majority of the low-susceptibility soils are found in the Prairie Elk – Wolf Creek and Fort Peck HUCs, where lower Tertiary and Upper Cretaceous rocks are exposed.

Permeability

Soil permeability is reported in inches per hour, and is mapped in **Appendix A**, **Figure A-5b.** Soils generally display moderate to low permeability, reflecting the silty geology. Permeability is loosely relatable to the last glacial margin, with the majority of the less-permeable soils found in the unglaciated areas.

Slope

Most of the cropland and gently-rolling rangeland land slopes fall within the range of 0-8 percent. Steeper terrain adjacent to drainage divides or within the river breaks can be highly variable ranging from 8-45 percent. A map of land surface slope is provided on **Figure A-6**.

2.1.5 Surface Water

Within the Redwater TPA, the Redwater River flows a distance of approximately 167 miles. Major tributaries include: Duck Creek, Tusler Creek, Horse Creek, Cottonwood Creek, Cow Creek, Pasture Creek, Lisk Creek, Wolf Creek and the East Redwater Creek. Redwater TPA hydrography is illustrated in **Appendix A**, **Figure A-7**. A total of 172 impoundments (**Appendix A**, **Figure A-7**) are recorded in the TPA, all but 5 of which are privately owned.

Stream Gaging Stations

The USGS maintains 2 gaging stations within the watershed. An additional 5 gages are now inactive. The USGS gaging stations are listed below (**Table 2-1**, and shown in **Appendix A**, **Figure A-7.**

Table 2-1. USGS Stream Gages in the Redwater TPA

Name	Number	Drainage Area	Agency	Period of Record
Nelson Creek nr. Van Norman MT	06131200	100 $miles^2$	USGS	1975 -
Redwater River at Circle MT	06177500	547 $miles^2$	USGS	1929 -
McCune Creek nr. Circle MT	06177400	30 $miles^2$	USGS	1982 - 1985
Redwater River nr. Richey MT	06177650	1,071 $miles^2$	USGS	1982 - 1985
Prairie Elk Creek nr. Oswego MT	06175540	352 $miles^2$	USGS	1975 - 1985
Redwater River nr. Vida MT	06177825	1,974 $miles^2$	USGS	1975 - 1985
Timber Creek nr. Van Norman MT	06131120	287 $miles^2$	USGS	1982 - 1989

Stream Flow
Stream flow data is based on records from the USGS stream gauges described above, and is available on the Internet from the USGS (2010). Flows in the Redwater River and its tributaries vary considerably over a calendar year. Flow in the Redwater River statistically peaks in June, and falls off sharply in August. Mean daily flow data for the Redwater River at Circle are included in **Appendix B**. Annual peak discharges have varied from 2 cubic feet per second (cfs) in 1981 to 6,960 cfs in 1986.

Surface Water Quality
Water quality and chemistry data is available from USGS gaging stations in the Redwater TPA. These data and additional analyses compiled by DEQ efforts in the planning area for nutrient and salinity related parameters are included in **Appendix B**.

2.1.6 Groundwater

Hydrogeology
Groundwater is present in both bedrock aquifers and shallow alluvial aquifers. The latter are limited to stream bottoms in the valleys. Natural recharge occurs from infiltration of precipitation and stream loss.

Near-surface groundwater flow within the valleys is presumed to be from the divides towards the streams and rivers, and then down valley along the central axis. Deeper flow in bedrock aquifers may be more controlled by the regional geologic units, which dip gently to the southeast. The most important bedrock aquifers in the area include the Fox Hills Sandstone, Hell Creek Sandstone and sandstones and coalbeds of the Tongue River member of the Fort Union Formation. In the northern part of the TPA, a few wells have penetrated the Judith River Sandstone. This zone is under artesian head, and surface flow of water has been established at low elevations. These artisan wells are primarily along the flood plain of the Missouri River.

Most of the water is for domestic and livestock use in the study area is obtained from wells. The wells range from shallow dug wells near the creeks to deep drilled wells in the upland areas. They range from 15 to 1,500 feet in depth. The towns of Circle, Brockway, Richey and Vida obtain their water supply from wells.

Groundwater Quality
The Montana Bureau of Mines and Geology (MBMG) Groundwater Information Center (GWIC) program monitors and samples a statewide network of wells (MBMG, 2009).

As of September 2009, the GWIC database reports 2,367 wells within the TPA (NRIS, 2009). Water quality data is available for 195 of those wells. The locations of these data points are shown in **Appendix A**, **Figure A-8**.

The water quality data include general physical parameters: temperature, pH and specific conductance, in addition to inorganic chemistry (common ions, metals and trace elements). MBMG does not analyze groundwater samples for organic compounds.

Water quality tends to vary greatly because of differences in the chemical characteristics and the content of the dissolved solids. These variations depend mainly on geology and the precipitation in an area. The permeability and recharge characteristics of the rock in the area allow groundwater to move slowly and pick up dissolved minerals. In areas where shale zones are hydraulically connected to producing aquifers, the water is more highly mineralized. Mineral content of the water generally increases with depth. There are eight public water supplies within the TPA. Water quality data is available from these utilities via the Safe Drinking Water Information System (SDWIS) that contains data describing the finished water provided to users, not raw water at the source.

2.1.7 Stream Morphology

Stream morphology throughout the TPA is variable and has been historically altered in many cases to accommodate a variety of land uses and/or transportation networks. The Redwater River is a typical example of a low-gradient prairie stream. The valley length is about 110 miles changing elevation from 3,000 feet above mean sea level in the headwaters to 2,000 feet at the mouth. The average valley slope is about 0.2 percent. Average stream channel gradient is about 0.1 percent. The river valley has exhibits alluvial terraces and floodplains. Glacial terraces in the northern part of the watershed stand higher above the river than the alluvial terraces farther down the drainage. The channel bed has a riffle-pool profile. The river channel swings through tight to broad meanders across the valley floor. The degree of stream channel entrenchment into the valley floor varies, but the channel is generally entrenched to some degree. Typical Rosgen stream types (Rosgen, 1996) that occur in this setting are C (slightly entrenched), F (entrenched) and E (slight to not entrenched).

2.1.8 Climate

Climate in the TPA is typical of the plains in eastern Montana. The climate is continental, with warm summers and cold, dry winters.

Precipitation is most abundant in May and June. Vida receives an annual average of 15.01 inches of moisture, compared to 11.46 reported at Brockway. See **Tables 2-2** through **2-4** for climate summaries; **Appendix A**, **Figure A-9** shows the distribution of average annual precipitation and climate stations.

Climate Stations
Climate data for the TPA is based upon the stations at Circle and Vida. **Appendix A**, **Figure A-9** shows the locations of the NOAA stations, in addition to average annual precipitation. The precipitation data is mapped by Oregon State University's PRISM Group, based on the records from NOAA stations (PRISM, 2004). Climate data is provided by the Western Regional Climate Center, operated by the Desert Research Institute of Reno, Nevada (WRCC, 2010).

Table 2-2. Monthly Climate Summary: Brockway
Brockway 3 WSW, Montana (241169) Period of Record : 8/ 1/1959 to 12/31/2009

	Jan	Feb	Mar	Apr	M.ay	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	27.3	33.1	43.9	57.6	68.6	77.8	86.3	85.6	73.7	59.6	42.6	30.6	57.2
Average Min. Temperature (F)	4.3	10.4	19.6	30.1	40	49.2	54.4	52.5	42	31	18.4	7.5	29.9
Average Total Precipitation (in.)	0.25	0.17	0.38	1.06	1.96	2.41	1.7	1.14	1.22	0.75	0.22	0.2	11.46
Average Total SnowFall (in.)	1	0.1	0.3	0.2	0	0	0	0	0	0	0.3	0.4	2.3
Average Snow Depth (in.)	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2-3. Monthly Climate Summary: Circle
Circle, Montana (241758) Period of Record : 9/1/1963 to 12/31/2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	26	32.9	43.3	57.7	68.7	78.1	86.8	85.8	73.6	59.4	42.3	29.7	57
Average Min. Temperature (F)	3.9	10.5	19.4	31	41.4	50.1	55.7	53.9	42.9	31.8	19.2	7.8	30.6
Average Total Precipitation (in.)	0.45	0.3	0.58	1.28	2.05	2.56	1.98	1.3	1.26	0.85	0.36	0.47	13.44
Average Total SnowFall (in.)	5.4	3.2	3.4	2.1	0.4	0	0	0	0.1	0.9	2.4	5.1	23.1
Average Snow Depth (in.)	4	4	1	0	0	0	0	0	0	0	0	2	1

Table 2-4. Monthly Climate Summary: Vida 6 NE
Circle, Montana (248569) Period of Record : 7/1/1948 to 12/31/2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	23.3	29.5	40.8	57	68.3	76.6	85.4	84.6	72.8	59.7	40.9	29.5	55.7
Average Min. Temperature (F)	2	7.5	18.2	30.5	41.3	49.9	55.5	53.7	43.3	33	18.9	8.5	30.2
Average Total Precipitation (in.)	0.59	0.41	0.7	1.33	2.14	3.22	2.1	1.35	1.23	0.93	0.54	0.48	15.01
Average Total SnowFall (in.)	7	4.8	5.5	3.8	0.4	0.1	0	0	0.2	1.7	4.5	5.3	33.2
Average Snow Depth (in.)	4	3	2	0	0	0	0	0	0	0	1	2	1

2.2 Ecological Parameters

2.2.1 Vegetation

The study area has natural mixed grass prairie vegetation, which includes western wheatgrass, green needlegrass, blue grama, needle-and-thread, basin wildrye and buffalograss. Bluebunch wheatgrass, little bluestem, and sideoats grama occur on shallow soils. Kentucky bluegrass is a common introduced species on fine-textured soils. Prairie cordgrass, alkali cordgrass, inland salt grass, foxtail barley, northern reedgrass, slim sedge, three-square bulrush and creeping spike rush commonly occur on wet soils. Western snowberry and prairie rose are common shrubs. Common shrubs in draws and along streams include buffaloberry, chokecherry, snowberry, and sagebrush.

Landcover is shown in **Appendix A**, **Figure A-10**. Landcover data is from the Gap Analysis Program (GAP) project at the University of Montana sponsored by the USGS, Biological Resources Division.

2.2.2 Aquatic Life

The Redwater Planning Area supports a variety of aquatic species typical of northern prairie streams in Montana. The warm water fishery includes over 25 species, at least 20 of which are native to eastern Montana. The fishery includes popular game species such as the northern pike, channel catfish, walleye, and sauger. Sturgeon chub, sauger and redbelly-finescale hybridized dace are designated “Species of Concern” (**Appendix A**, **Figure A-11**) by Montana Department of Fish, Wildlife and Parks (FWP). Data on fish species distribution is collected, maintained and provided by FWP (2010).

2.3 Cultural parameters

2.3.1 Population

Total population in this area is approximately 2,569 (MSL, NRIS, 2000). McCone County makes up about 77% of the population. According to the Census and Economic Information Center (Dept. of Commerce), the peak population for McCone County in 1930 was 4,790 people. The estimated 2002 population is 1,827. The town of Circle had a population of 1,117 in 1960 census. The 2000 census population was 644. The estimated 2004 population was 593 (**Appendix A**, **Figure A-12**).

2.3.2 Land Ownership

Over 85% the TPA is under private ownership (**Table 2-5**). The dominant public landholder is the US BLM, which administers eight percent of the TPA. (**Appendix A**, **Figure A-13**).

Table 2-5. Land Ownership

Owner	Acres	Square Miles	% of Total
Private	1,771,445	2,767.90	85.90%
US Bureau of Land Management	166,431	260	8.10%
State Trust Land	119,313	186.4	5.80%
US Fish & Wildlife Service	4,630	7.2	0.20%
Tribal Land	1,107	1.7	0.10%
Water	398	0.6	0.00%
Private Conservation	10	0	0.00%
Total	2,063,333	3,224.00	—

2.3.3 Land Use

Land use within the TPA is dominated by grazing and small grain cultivation (**Table 2-6**). Information on land use is based on the USGS National Land Cover Dataset (Homer et al. 2004), and is shown in **Appendix A**, **Figure A-14**. The data are at 1:250,000 scale. Agricultural land use is illustrated in **Appendix A**, **Figure A-15.**

Table 2-6. Land Use and Land Cover

Land Use	Acres	Square Miles	% of Total
Grassland/Herbaceous/Shrubland	1,164,869	1,820.11	56.70%
Small Grains/Row crops	289,027	451.61	14%
Pasture/Hay	68,816	107.52	3.30%
Deciduous Forest	14,540	22.72	0.70%
Evergreen Forest	6,650	10.39	0.32%
Open Water	4,304	6.72	0.21%
Exposed Rock	407	0.64	0.02%
Woody Wetlands	330	0.52	0.02%
Developed	714	1.12	0.05%

More detailed information on agricultural land use can be obtained from the United Stated Department of Agriculture data. Grass/pasture accounts for 348,920 acres (545 miles^2). Cultivated crops (including fallow fields) occupy 384,476 acres or 601 miles^2. Wheat and fallow fields comprise the majority of the land under cultivation, followed by barley, peas and Durham wheat. **Appendix A, Figure A-16** is a pie chart of crop species with tilled cropland for the planning area.

2.3.4 Transportation Networks

Transportation networks (road and railroads) are illustrated in **Appendix A**, **Figure A-17**.

Roads
The principal transportation routes in the TPA are Montana Highway 200 and Montana Highway 13. Using estimates from watershed modeling efforts, an estimated 150 miles of paved roads and 1,100 miles of unpaved roads are present in the TPA. The network of unpaved roads on public and private lands will be further characterized as part of the source assessment.

Railroads
The Burlington Northern Santa Fe (BNSF) railroad owns a rail line to Circle, but this line appears to be idle and is not shown on BNSF's interactive system map (BNSF, 2010).

2.3.5 Livestock Operations

No MPDES- concentrated animal feeding operations (CAFO) have been permitted in the TPA. Many livestock operations are present in the TPA. Aerial photo interpretation suggests that these are commonly near or adjacent to surface waters.

2.3.6 Wastewater

One MPDES-permitted wastewater outfall is located within the TPA. The Town of Circle discharges to the Redwater River. This discharge is shown in **Appendix A**, **Figure A-18**.

SECTION 3.0
TMDL REGULATORY FRAMEWORK

3.1 TMDL Development Requirements

Section 303(d) of the Federal Clean Water Act (CWA) requires states to identify waterbodies within its boundaries that do not meet water quality standards. States track these impaired or threatened waterbodies with a 303(d) List. Recently the name for the 303(d) List has changed to Category 5 of Montana's Water Quality Integrated Report. State law identifies that a consistent methodology is used for determining the impairment status of each waterbody. The impairment status determination methodology is identified in **Appendix A** of Montana's Water Quality Integrated Report (DEQ, 2006).

Under Montana State Law, an "impaired waterbody" is defined as a waterbody or stream segment for which sufficient credible data show that the waterbody or stream segment is failing to achieve compliance with applicable water quality standards (Montana Water Quality Act; Section 75-5-103(11)). A "threatened waterbody" is defined as a waterbody or stream segment for which sufficient credible data and calculated increases in loads show that the waterbody or stream segment is fully supporting its designated uses but threatened for a particular designated use because of: (a) proposed sources that are not subject to pollution prevention or control actions required by a discharge permit, the nondegradation provisions, or reasonable land, soil, and water conservation practices; or (b) documented adverse pollution trends (Montana Water Quality Act; Section 75-5-103(31)). State Law and section 303 of the CWA require states to develop TMDLs for impaired or threatened waterbodies.

A TMDL is a pollutant budget for a waterbody identifying the maximum amount of the pollutant that a waterbody can assimilate without causing applicable water quality standards to be exceeded. TMDLs are often expressed in terms of an amount, or load, of a particular pollutant (expressed in units of mass per time such as pounds per day). TMDLs must account for loads/impacts from point and nonpoint sources in addition to natural background sources, and need to incorporate a margin of safety and consider seasonality. In Montana, TMDL development is often accomplished in the context of an overall water quality plan. The water quality plan includes not only the actual TMDL, but also includes information that can be used to effectively restore beneficial water uses that have only been affected by pollution, such as habitat degradation or flow modification that are not covered by the TMDL program.

To satisfy the Federal Clean Water Act and Montana State Law, TMDLs are developed for each waterbody-pollutant combination identified on the states list of impaired or threatened waters and are often presented within the context of a water quality restoration or protection plan. State Law (Administrative Rules of Montana 75-5-703(8)) also directs DEQ to "support a voluntary program of reasonable land, soil, and water conservation practices to achieve compliance with water quality standards for nonpoint source activities for waterbodies that are subject to a TMDL ……". This is an important directive that is reflected in the overall TMDL development and implementation strategy within this plan. It is important to note that water quality protection measures are not considered voluntary where such measures are already a requirement under existing Federal, State, or Local regulations. Montana TMDL laws provide a 5-year review process to allow for an adaptive management approach to update the TMDL and water quality restoration plan.

3.2 Waterbodies and Pollutants of Concern

Recently, a court ruling and subsequent settlements have obligated the U.S. EPA and the State of Montana to use pollutant/waterbody combinations from the Montana's 1996 List of impaired waters. State and federal guidance indicates that the most recent list be used for determining the need for TMDLs. Nutrient and salinity pollutants that have appeared on the 2008 list are addressed in the impairment status review, TMDLs, or watershed restoration plans presented in this document. Most pollutants identified on the 2008 list are addressed; however a few of them are not addressed at this time due to project budget and time constraints. These listings will be identified in a follow up monitoring strategy and addressed within a timeframe identified in Montana's law (*Montana Code Annotated 75-5-703*). However, TMDLs were not prepared for impairments where additional information suggests that the initial listings were inaccurate, or where conditions had improved sufficiently since the listing to an extent that the pollutant no longer impairs a beneficial use. Where a pollutant is recommended for removal from the list, justification is provided in the sections that follow. **Table 3-1** provides a summary of waterbody listings and their beneficial use support status for the 2008 303(d) Lists for the Redwater River TPA. Specific probable causes of impairment for each of the impaired waterbodies is found in **Table 1-1**, in **Section 1**.

Table 3-1. Redwater River TPA impaired waterbody segments and beneficial use support status

Waterbody & Stream Description	Waterbody #	Use Class	Aquatic Life	Fisheries - Warm	Primary Contact (Recreation)
East Redwater Creek, headwaters to mouth (Gardner Gulch)	MT40P002_010	C-3	P	P	P
Horse Creek, headwaters to mouth (Redwater River)	MT40P002_020	C-3	P	P	X
Nelson Creek, headwaters to mouth (Fort Peck Reservoir)	MT40E003_020	C-3	P	P	X
Pasture Creek, headwaters to mouth (Redwater River)	MT40P002_030	C-3	P	N	F
Prairie Elk Creek, East and Middle Forks to mouth (Missouri River)	MT40S002_010	C-3	P	P	X
Redwater River, Hell Creek to Buffalo Springs Creek	MT40P001_012	C-3	P	F	X
Redwater River, Pasture Creek to mouth (Missouri River)	MT40P001_014	C-3	P	P	F
Sand Creek, headwaters to mouth (Missouri River)	MT40S002_030	C-3	P	P	X

Impairment status and impairment list reviews are provided for each waterbody in **Sections 5.0**, **6.0** and **7.0** of this document.

3.3 Applicable Water Quality Standards

Water quality standards include: the uses designated for a waterbody, the legally enforceable standards that ensure that the uses are supported, and a nondegradation policy that protects the high quality of a waterbody. The ultimate goal of this water quality restoration plan, once implemented, is to ensure that all designated beneficial uses are fully supported and all standards are met. Water quality standards form the basis for the targets described in **Sections 5**, **6** and **7**. Pollutants addressed in this Water Quality Restoration Plan include: nutrients and salinity. This section provides a summary of the applicable water quality standards for each of these pollutants.

3.3.1 Classification and Beneficial Uses

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

Montana, unlike many other states, uses a watershed based classification system with some specific exceptions. As a result, *all* waters of the state are classified and have designated uses and supporting standards. All classifications include multiple uses and in only one case (A-Closed) is a specific use (drinking water) given preference over the other designated uses. Some waters may not actually be used for a specific designated use, for example as a public drinking water supply; however, the quality of that waterbody must be maintained suitable for that designated use. When natural conditions limit or preclude a designated use, permitted point source discharges or nonpoint source discharges may not make the natural conditions worse.

Modification of classifications or standards that would lower a water's classification or a standard (i.e., B-3 to a C-3), or removal of a designated use because of natural conditions can only occur if the water was originally mis-classified. All such modifications must be approved by the BER, and are undertaken via a Use Attainability Analysis (UAA) that must meet U.S. EPA requirements (40 CFR 131.10(g), (h) and (j)). The UAA and findings presented to the BER during rulemaking must prove that the modification is correct and all existing uses are supported. An existing use cannot be removed or made less stringent.

All waterbodies addressed in this document have been designated as C-3. A description of Montana's applicable surface water classifications and designated beneficial uses for waters within the Redwater River TPA are presented in **Table 3-2**.

Table 3-2. Montana Surface Water Classifications and Designated Beneficial Uses Applicable to the Redwater River TPA.

Classification	Designated Uses
C-3 CLASSIFICATION:	Waters classified C-3 are to be maintained suitable for bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers. The quality of these waters is naturally marginal for drinking, culinary, and food processing purposes, agriculture, and industrial water supply.

3.3.2 Standards

In addition to the Use Classifications described above, Montana's water quality standards include numeric and narrative criteria as well as a nondegradation policy.

Numeric surface water quality standards have been developed for many parameters to protect human health and aquatic life. These standards are in the Department Circular DEQ-7 (DEQ 2010). The numeric human health standards have been developed for parameters determined to be toxic, carcinogenic, or harmful and have been established at levels to be protective of long-term (i.e., life long) exposure by water consumption, as well as through direct contact such as swimming.

The numeric aquatic life standards include chronic and acute values that are based on extensive laboratory studies that include a wide variety of potentially affected species, a variety of life stages and durations of exposure. Chronic aquatic life standards are protective of long-term exposure to a parameter. The protection afforded by the chronic standards includes detrimental effects to reproduction, early life stage survival and growth rates. In most cases the chronic standard is more stringent than the corresponding acute standard. Acute aquatic life standards are protective of short-term exposures to a parameter and are not to be exceeded.

High quality waters are afforded an additional level of protection by the nondegradation rules (ARM 17.30.701 et. seq.,) and in statute (75-5-303 MCA). Changes in water quality must be "non-significant" or an authorization to degrade must be granted by the Department. However under no circumstance may standards be exceeded. It is important to note that, waters that meet or are of better quality than a standard are high quality for that parameter, and nondegradation policies apply to new or increased discharges to the waterbody.

Narrative standards have been developed for substances or conditions for which sufficient information does not exist to develop specific numeric standards. The term "Narrative Standards" commonly refers to the General Prohibitions in ARM 17.30.637 and other descriptive portions of the surface water quality standards. The General Prohibitions are also called the "free from" standards; that is, the surface waters of the state must be free from substances attributable to discharges, including thermal pollution, that impair the beneficial uses of a waterbody. Uses may be impaired by toxic or harmful conditions (from one or a combination of parameters) or conditions that produce undesirable aquatic life. Undesirable aquatic life includes bacteria, fungi and algae.

The standards applicable to nutrients and salinity in the Redwater River TPA are summarized below.

Nutrients

The narrative standards applicable to nutrients are contained in the General Prohibitions of the surface water quality standards (ARM 17.30.637 et. Seq.). The prohibition against the creation of "*conditions which produce undesirable aquatic life*" is generally the most relevant to nutrients. Undesirable aquatic life includes bacteria, fungi, and algae. Most waters of Montana are protected from excessive nutrient concentrations by the above narrative. The exception is the Clark Fork River above the confluence with the Flathead River, where numeric water quality standards for total nitrogen (300 ug/l) and total phosphorus (20 ug/l upstream of the confluence with the Blackfoot River and 39 ug/l downstream of the confluence) as well as algal biomass measured as chlorophyll *a* (summer mean and maximum of 100 and 150 mg/m2, respectively) have been established. Additionally, numeric human health standards exist for nitrogen (**Table 3-3**), but the narrative standard is most applicable to nutrients as the concentration in most waterbodies in Montana is well below the human health standards and the nutrients contribute to undesirable aquatic life at much lower concentrations than the human health standards.

Table 3-3. Human Health Standards for Nitrogen for the State of Montana.

Parameter	Human Health Standard (µL)1
Nitrate as Nitrogen (NO3-N)	10,000
Nitrite as Nitrogen (NO2-N)	1,000
Nitrate plus Nitrite as N	10,000

Salinity

The standard applicable to dissolved solids concentration in state waters is contained in the narrative general prohibitions of the surface water quality standards (ARM 17.30.637 et. seq.). The prohibition against the creation of "*concentrations or combinations of materials which are toxic or harmful to human, animal, plant, or aquatic life; and create conditions which produce undesirable aquatic life*" is generally the most relevant to effects of excess salinity.

3.3.3 Reference Approach for Narrative Standards

When possible, a reference site approach is used to determine the difference between an impacted area and a "natural" or least impacted waterbody. The reference site approach is the preferred method to determine natural conditions, but when appropriate reference sites are not easily found, modeling, or regional reference literature values are used. The approach for using reference sites for the Redwater River TPA is included in **Appendix C**.

SECTION 4.0
DESCRIPTION OF TMDL COMPONENTS

A TMDL is the pollutant loading capacity for a particular waterbody and refers to the maximum amount of a pollutant a stream or lake can receive and still meet water quality standards. Therefore, when a TMDL is exceeded, the waterbody will be impaired.

More specifically, a TMDL is the sum of the allowable loading from all sources to the waterbody. These loads are applied to individual sources or categories of sources as a logical method to allocate water quality protection responsibilities and overall loading limits within the contributing watershed(s). The allocated loads are referred to as waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources. Natural background loading is considered a type of nonpoint source and therefore represents a specific load allocation. In addition, the TMDL includes a Margin of Safety (MOS) that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving stream. The inclusion of a MOS results in less load allocated to one or more WLAs or LAs to help ensure attainment of water quality standards.

TMDLs are expressed by the following equation which incorporates the above components:

$$TMDL = \Sigma WLA + \Sigma LA + MOS$$

The allowable pollutant load must ensure that the waterbody being addressed by the TMDL will be able to attain and maintain water quality standards for all applicable seasonal variations in streamflow, and pollutant loading. **Figure 4-1** is a schematic diagram illustrating how numerous sources contribute to the existing load and how the TMDL is defined. The existing load can be compared to the allowable load to determine the amount of pollutant reduction needed.

The major components of the TMDL development process are target development, source quantification, establishing the total allowable load, and allocating the total allowable load to sources. Although the way a TMDL is expressed may vary by pollutant, these components are common to all TMDLs, regardless of pollutant. Each component is described in further detail below.

Each of the following four sections of the document (**Sections 5&6**) are organized by the two pollutant categories of concern in the Redwater River TPA: nutrients and salinity. Each section includes a discussion of the waterbody segments of concern, how the pollutant of concern is impacting beneficial uses, the information sources and assessment methods to evaluate stream health and pollutant source contributions, water quality target development along with a comparison of existing conditions to targets, quantification of loading from identified sources, the determination of the allowable loading (TMDL) for each waterbody, and the allocations of the allowable loading to sources.

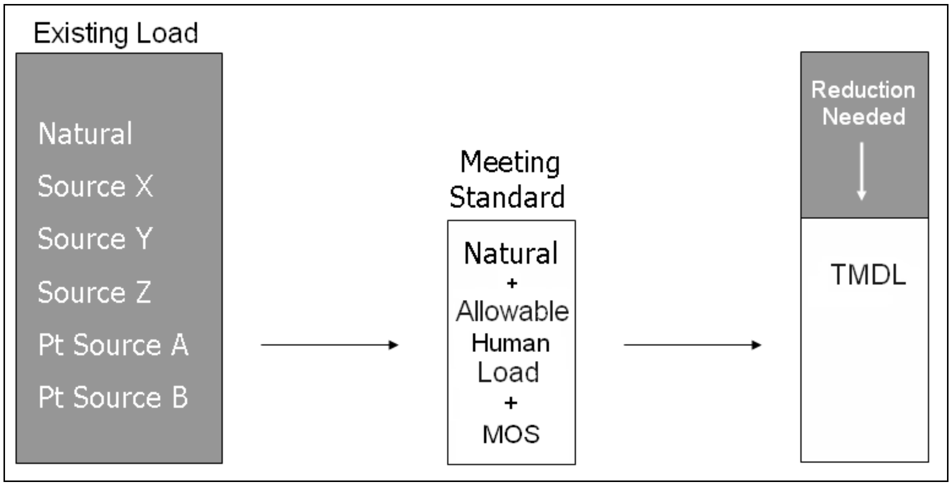

Figure 4-1. Schematic example of TMDL development

4.1 Target Development

Because loading capacity is evaluated in terms of meeting water quality standards, quantitative water quality targets are developed to help assess the condition of the waterbody relative to the applicable standard(s) and to help determine successful TMDL implementation. This document outlines water quality targets for each pollutant of concern in the Redwater River TPA. TMDL water quality targets help translate the applicable numeric or narrative water quality standards for the pollutant of concern. For pollutants with established numeric water quality standards, the numeric value(s) within the standard(s) are used as TMDL water quality targets. For pollutants with only narrative standards, the water quality targets provide a site-specific interpretation of the narrative standard(s), along with an improved understanding of impairment conditions. Water quality targets typically include a suite of in-stream measures that link directly to the impacted beneficial use(s) and applicable water quality standard(s). The water quality targets help define the desired stream conditions and are used to provide benchmarks to evaluate overall success of restoration activities. A comparison of existing stream conditions with target values will improve the understanding of the extent and severity of the water quality problem.

4.2 Quantifying Pollutant Sources

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

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

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

4.3 Establishing the Total Allowable Load

Identifying the TMDL requires a determination of the total allowable load over the appropriate and sensible time period necessary to comply with the applicable water quality standard(s). Although the concept of allowable daily load is incorporated into the TMDL term, a daily loading period may not be consistent with the applicable water quality standard(s) or may not be practical from a water quality management perspective. Therefore, the TMDL will ultimately be defined as the total allowable loading using a time period consistent with the application of the water quality standard(s) and consistent with established approaches to properly characterize, quantify, and manage pollutant sources in the watershed. For example, sediment TMDLs may be expressed as an allowable yearly load whereas the TMDL to address acute toxicity criteria for metals will include a near-instantaneous loading requirement calculated over a time period of one second (based on standard methods for evaluation flow in cubic feet per second).

Where numeric water quality standards exist for a stream, the TMDL or allowable loading, typically represents the allowable concentration multiplied by the flow of water over the time period of interest. This same approach can be applied for situations where a numeric target is developed to interpret a narrative standard and the numeric value is based on an in-stream concentration of the pollutant of concern.

For some narrative standards, such as those relating to nutrients, there may be a suite of targets describing water column concentrations of nitrogen and phosphorus, the concentration of dissolved and the degree of algal growth. In many of these situations, it is difficult to link the desired target values to highly variable and often episodic in-stream loading conditions. In these situations, the TMDL is often expressed as a percent reduction in total loading based on source quantification results and an evaluation of load reduction potential (**Figure 4-1**). The degree by which existing conditions exceed desired target values can also be used to justify a percent reduction value for a TMDL.

Even if the TMDL is preferably expressed using a time period other than daily, an allowable daily loading rate will also be calculated to meet specific requirements of the Clean Water Act. Where this occurs, TMDL implementation and the development of allocations will still be based on the preferred time period as discussed above.

4.4 Determining Allocations

Once the loading capacity (i.e. TMDL) is determined, that total must be divided, or allocated, among the contributing sources. In addition to basic technical and environmental considerations, this step introduces economic, social, and political considerations. The allocations are often determined by quantifying feasible and achievable load reductions associated with the application of reasonable land, soil, and water conservation practices. Reasonable land, soil, and water conservation practices generally include Best Management Practices (BMPs), but additional conservation practices may be required to achieve compliance with water quality standards and restore beneficial uses. It is important to note that implementation of the TMDL does not conflict with water rights or private property rights. **Figure 4-2** contains a schematic diagram of how TMDLs are allocated to different sources using WLAs for point sources and LAs for natural and nonpoint sources. Although some flexibility in allocations is possible, the sum of all allocations must meet the water quality standards in all segments of the waterbody.

Under the current regulatory framework for development of TMDLs, flexibility is allowed in the expression of allocations in that *"TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure."* Allocations are typically expressed as a number, a percent reduction (from the current load), or as a surrogate measure, such as a percent increase in riparian vegetation canopy density for temperature TMDLs.

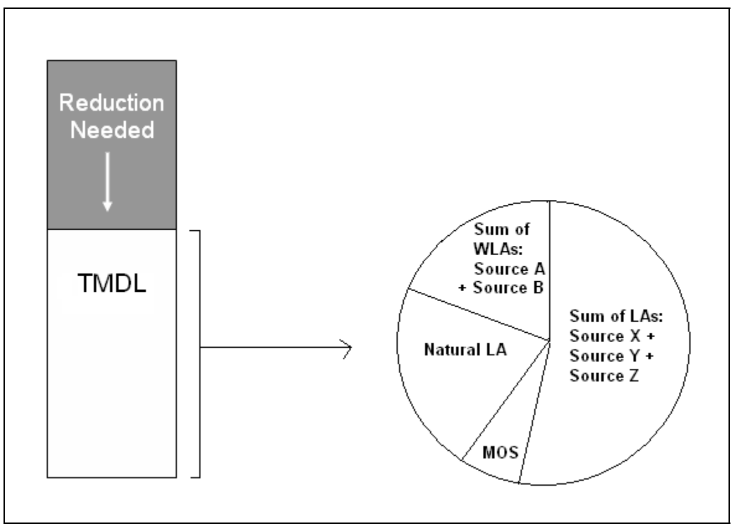

Figure 4-2. Schematic diagram of TMDL and allocations

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

SECTION 5.0
NUTRIENT TMDL COMPONENTS

This portion of the document focuses on nutrients as an identified cause of water quality impairment in the Redwater River TPA. It describes: 1) the mechanisms by which nutrients impair beneficial uses, 2) the specific stream segments of concern, 3) the presently available data pertaining to nutrient impairments in the watershed, 4) the various contributing sources of nutrients based on recent data and studies, and 5) the Nutrient TMDLs and allocations.

The term nutrients is used in this document to refer collectively to the quantities of various chemical forms of nitrogen and phosphorus that can affect the growth of aquatic plant and animal life.

5.1 The Effects of Nutrients on Beneficial Uses

Nitrogen and phosphorus are naturally occurring chemical elements required for the healthy and stable functioning of aquatic ecosystems. Streams in particular are dynamic systems that are dependent on a balance between nutrient additions, consumption by autotrophic organisms, cycling of biologically fixed nitrogen and phosphorus into higher trophic levels, and cycling of organically fixed nutrients into inorganic forms with biological decomposition. Nutrient additions to streams from natural landscape erosion, groundwater discharge and in-stream biological decomposition maintain a balance between organic and inorganic nutrient forms. Human influences may alter nutrient cycling pathways causing damage to biological stream function and water quality degradation.

Additions of readily available nutrients from agricultural or other concentrated human sources can accelerate aquatic algal growth causing euthrophication. Respiration and decomposition of excessive algal biomass depletes the supply of dissolve oxygen (DO) causing mortality among other forms of aquatic life. Nutrient concentrations in surface water are considered controlling factors in formation of blue-green algae blooms. (Priscu 1987). Several species of bloom forming algae produce toxins that can be lethal to aquatic life, wildlife, livestock and humans. The toxicity can disrupt production of algae grazers and affect food supplies at higher trophic levels. Aside from the toxicity effects, the unpleasant sight and odor of algae blooms can detract from enjoyable recreational use. Nitrogen in the form of dissolved ammonia can be toxic to fish and other aquatic life. Elevated nitrate concentrations in drinking water supplies are known to inhibit normal hemoglobin function in infants. The current drinking water nitrate limit is 10 mg/L (DEQ 2010).

5.2 Stream Segments of Concern

The **Table 5-1** presents streams and stream segments that have been listed for nutrient impairment on the 2008 303(d) List.

Table 5-1. Waterbody segments in the Redwater River TPA with nutrient related pollutant listings on the 2008 303(d) List

Waterbody ID	Stream Segment	2008 Probable Causes of Impairment
MT40P002_010	**EAST REDWATER CREEK**, headwaters to the mouth (Redwater River)	**Total Kjeldahl Nitrogen, Phosphorus (Total), Nitrate/Nitrite (Nitrate + Nitrite as N)**
MT40E003_020	**NELSON CREEK**, headwaters to the mouth (Fort Peck Reservoir))	**Nitrogen, Nitrate**
MT40P002_030	**PASTURE CREEK**, headwaters to the mouth (Redwater River)	**Total Kjeldahl Nitrogen**
MT40S002_010	**PRAIRIE ELK CREEK**, East and Middle Forks to the mouth (Missouri River)	**Total Kjeldahl Nitrogen, Phosphorus (Total)**
MT40P001_012	**REDWATER RIVER**, Hell Creek to Buffalo Springs Creek	**Total Nitrogen (TN), Phosphorus (Total)**
MT40S002_030	**SAND CREEK**, from the forks to the mouth (Missouri River)	**Total Kjeldahl Nitrogen, Phosphorus (Total)**
MT40E003_010	**TIMBER CREEK**, headwaters to mouth (Fort Peck Reservoir)	**Total Kjeldahl Nitrogen, Phosphorus (Total)**

Upon review of the nutrient data record, Horse Creek, (Segment ID MT40P002_020) was added to the list of streams needing nutrient TMDLs.

5.3 Information Sources and Assessment Methods

5.3.1 Nutrient Water Chemistry data

The surface water chemistry database used for nutrient TMDL development in the Redwater TPA is contained in **Appendix B** by stream segment. The number of analytical results for nutrient related parameters varies widely among the listed segments. The USGS collected monthly and quarterly stream flow and water quality data at several stream gages during the 1970s and 1980s. These results are the bulk of the available data for the Redwater River, Prairie Elk Creek and Nelson Creek.

Several stream assessments by local stakeholders and DEQ staff occurred intermittently from 1995 through 2005. Most of these results were acquired from the EPA STORET database, stream assessment project files, or from entries in the DEQ Sufficient Credible Data/Beneficial Use Determination (SCD/BUD) files.

Surface and groundwater chemistry, surface flow, groundwater table elevations and climate data were collected in the Nelson Creek drainage by Golder and Associates, Inc. as part of a baseline environmental assessment of a proposed surface coal mine development by Nelson Creek Coal, LLC (NCC). The collection period for the data varies by sampling point. Data from the project that was received by DEQ included measurements and analytical results for the period from September 2006 to January 2008. Stream gage data was provided in the form of gage heights. Rating curves for the gages, that allow the conversion of gage height to flow volume, have not been provided by NCC. Monitoring well construction data has not been received by DEQ.

The number of analytical results for any single nutrient parameter varies by segment from about 90 for the Redwater River in the vicinity of Circle to seven for Pasture Creek. Water chemistry monitoring during the 1970s and 1980s commonly included corresponding flow measurements. These are lacking in the more recent monitoring efforts that occurred from 2003 through 2005.

USGS gaging station records were used to generate hydrographs for gaged streams. Daily percentages of annual discharge were calculated from gage station records. These daily discharge coefficients were multiplied by annual discharge values calculated according to the regional equations of Omang and Parrett (1984) to derive mean daily flow values for ungaged streams. Mean daily flow data were used to generate flow duration curves for each stream. The duration curves were used in conjunction with nutrient concentration data and nutrient targets to illustrate current and maximum daily loading conditions. Distributional statistics were calculated for nutrient parameter concentration data for target comparisons.

Variation over the time period of the chemistry data record required that some records for total nitrogen be calculated as the sum of results for total kjeldahl nitrogen and NO_3+_2-N. Where results were reported as less than the method detection limit, half of the detection limit was used in the calculated TN value. The same approach was used in statistical calculations for other nutrient parameters. The persulfate method for TN analysis replaced TKN analysis for samples collected in 2008. This avoided the need to calculate TN.

5.3.2 2008 Surface Water Sampling and Flow Measurement

DEQ contractors completed high and low flow chemistry sampling, stream flow measurements and algae sampling during 2008. The purpose of the sampling was to:

1. Collect nutrient water chemistry data and measure flows in nutrient listed stream,
2. Quantify loads in predominantly agricultural watersheds,
3. Quantify loading conditions above and below the Circle municipal wastewater treatment facility, and
4. Collect additional benthic algae samples from which to develop values for a diatom-based DO index.

5.3.3 Diatom Inferred Dissolved Oxygen Method for Assessing Aquatic Life Use Support

As discussed above in **Section 5.1**, algae growth caused by excess nutrients can result in low water column concentrations of DO that stress other aquatic life forms. Low DO concentrations are produced by oxygen consumption accompanying microbial decomposition of the algal biomass. Diatom algae exhibit characteristic responses or tolerances to DO supply. A scoring system has been developed to rate the relative response of algae species to DO supply (Van Dam et al.1994). The scores have been used to generate a numeric index for DO called the diatom-inferred DO index.

The index classifies diatom algae species into categories of increasing tolerance to low DO conditions. The percentage of the total diatom population falling into each of five categories, multiplied by the category score (1 to 5), gives a weighted score for each tolerance category. **Table 5-2** contains an example calculation of the index value for a diatom sample collected from the Redwater River at site MCNREDW-03 near Circle.

Table 5-2. Example Diatom-inferred DO tolerance index calculation

Site ID	MCNREDW-03		
Sample Date	8/27/2003		
Sample ID	201002		
Low DO Tolerance Category	**Tolerance Score**	**Percent of Total Diatom Species Sampled**	**Weighted Score**
Continuously High	1	6.12	6.12
Fairly High	2	7.13	14.26
Moderate	3	45.5	136.5
Low	4	6.45	25.8
Very Low	5	3.39	16.95
Percent of Species Not Classified		31.37	
Sum of Weighted Scores			199.63
DO Metric Value:			2.91

The inferred DO metric is calculated by dividing the sum of the weighted scores by the percent of the total diatom species number that could be categorized for DO tolerance (199.63/ (100-31.37)). The percent oxygen saturation at the time of sample collection is calculated by inserting the metric value into the following regression equation developed by Van Dam and others (1994) for freshwater diatoms:

$$y = -0.227x + 1.2825.$$

The metric value of 2.91 inserted into the equation as x, gives a y value of 0.62. This value is multiplied by the DO concentration at saturation obtained from look-up tables of oxygen solubility as a function of elevation, water temperature and dissolved solids concentration (YSI 2006). The DO concentration derived from the **Table 5-2** example is 7.1 mg/L. Compared to the seven-day mean minimum DO standard of 4.0 mg/L for C-3 streams (DEQ 2010), DO was not limited at site MCNREDW-03 at the time of sampling.

Benthic algae samples were collected from 44 sites on eight planning area streams. The results for diatom inferred DO concentrations estimated from algae samples collected in the Redwater TPA are given in **Appendix B**. The accuracy of the metric and the DO concentrations calculated from it are dependent upon the number of diatom species in any sample that cannot be classified. Use of the metric is marginal for samples having greater than 50 percent of unclassified species.

5.3.4 Nutrient Modeling Using STEPL

The Spreadsheet Tool for Estimating Pollutant Loads (STEPL) developed by Tetra Tech, Inc. was used to estimate current nutrient loading conditions and loading reductions achieved with BMPs applied to nutrient sources. The program (version 4.1), support files and documentation were accessed at http://it.tetratech-ffx.com/stepl/models$docs.htm. STEPL calculates annual sediment loads from runoff and nutrient loads from both runoff and groundwater sources by land cover category using 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 evaporative and soil water transport processes. Nutrient loading is calculated by multiplying runoff and groundwater volume estimates by N and P concentration inputs. The model was used to characterize the main climatic, hydrologic, land cover and soil properties influencing growing season nutrient loading from watersheds of both listed and unlisted streams. The model outputs are annual estimates of nutrient loading from designated land use sources, areas of livestock confinement and domestic septic systems within each subbasin. The simulated current conditions loading was used to identify significant sources, quantify relative contribution by source, and quantify potential load reductions with BMP implementation. The results are described in the modeling report and related tables contained in Appendix D.

5.4 Nutrient Water Quality Targets

A comparison of measured concentrations of nutrient parameters in stream samples to numeric water quality nutrient targets is used to determine effects of current conditions on beneficial uses. Targets and supplemental indicators for nutrients are based upon interpretation of Montana's narrative water quality standards. These narrative criteria require, "State surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will create conditions which produce undesirable aquatic life" [ARM 17.30.637(1)(e)]. Nutrient targets and supplemental indicators for the Redwater River TPA include:

1. Numeric nutrient concentrations in surface water,
2. The seven-day mean minimum DO concentration standard of 4.0 mg/L for C-3 streams (DEQ 2010),
3. The one-day minimum DO standard of 5.0 mg/L for C-3 streams with early aquatic life stages (DEQ 2010).

The nutrient concentration targets are numeric indicators of standards attainment.
Numeric nutrient criteria are presently under development by the Montana DEQ, and are established at levels believed to protect against the growth of 'undesirable aquatic life' (i.e algae). Nutrient water quality targets include nutrient concentrations in surface waters and measures of dissolved oxygen in the water column.

The following sections present the targets and compare them to analytical nutrient data from listed streams. The comparisons using nutrient concentration targets are conducted according to DEQ's Assessment Methodology for Determining Wadeable Stream Impairment Due to Excess Nutrients: Nitrogen and Phosphorus (Suplee and Sada de Suplee, 2010). Dissolved oxygen data derived from diatom algae samples and DO field meter readings are compared directly to the applicable numeric DO standard.

5.4.1 Nutrient Concentration Targets

A suite of numeric targets is considered to assess the need for nutrient TMDLs. The numeric targets presented in this section are based on recent analysis and summary of nutrient chemistry data from Montana streams (Suplee 2008). The dataset used to develop criteria for prairie streams was generated from 24 sites on 22 streams in two Great Plains level III ecoregions: the Northwestern Great Plains and Northwestern Glaciated Plains. The data were stratified by ecoregion and season to improve the fit with local environmental conditions affecting streams nutrients during the growing season. The process of developing criteria for prairie streams included both the reference condition approach and a stressor-response study to estimate a harm-to-use threshold for nutrient concentrations.

The reference condition approach (**Appendix C**) compares water quality from a set of reference streams to that of non-reference streams, or both reference and non-reference combined. Suplee (2008) observed that, compared to mountain streams, the difference between the reference and all-samples datasets for prairie streams was small. Compared to the recommended 90th percentile of reference for mountain stream criteria, the study recommended use of the 75th percentile of reference for prairie streams. This value for the plains ecoregion TN data is 1310 µg/L.

The results of the stressor-response study suggested that a TN concentrations greater than 1120 µg/L caused eutrophication sufficient to reduced daily minimum DO levels below those needed by aquatic life (Suplee 2008, Appendix A). Other prairie stream studies recommend similar values. A study by Zheng and Gerritsen (2005) analyzed data from Montana's Milk/Lower Missouri Basin and the Sheyenne River basin in North Dakota suggested a TN criterion of 1.0 mg/L. A compilation of literature values dataset medians by Dodds and others (2008) recommended a TN criterion of 0.96 mg/L. Weighting the field of recommendations toward the Montana stressor-response study, 1120 µg/L is the selected TN target in the Redwater TPA.

Statistical correlations using the Montana data for prairie streams did not find a significant relationship between harm to aquatic life and TP concentration (Suplee 2008). The 75th percentiles of the reference dataset for TP in prairie streams are 123 µg/L and 124 µg/L respectively for the Northwestern Glaciated Plains and Northwestern Great Plains ecoregions. A third approach to selecting a TP criterion is to apply the mass-based Redfield ratio (Redfield 1958) of molecular carbon, nitrogen and phosphorus in phytoplankton to water column nutrient concentrations. The Carbon:Nitrogen:Phosphorus (C:N:P) ratio of 47:7:1 has commonly been used to identify adequate nutrient levels for phytoplankton. An N:P ratio of 8:1 has been suggested for benthic algae (Hillebrand and Sommer 1999). The lack of a relationship between TP and algae growth suggest that nitrogen rather than phosphorus is the limiting nutrient in most prairie streams. A slightly lower ratio than 8 would be appropriate for nitrogen limited aquatic systems. With the TN target set at 1120 µg/L, a TN:TP ration of 7.5 gives a TP target of 150 µg/L. This value is proposed as the TP target in the Redwater.

The study by Suplee (2008) recommends that criteria be set for NO_3+$_2$-N as well as for TN and TP. Nitrate nitrogen is an impairment cause in the assessment records for East Redwater Creek and Nelson Creek. Human sources of nitrate, a soluble inorganic form of nitrogen, include agricultural fertilizer and livestock manure. Naturally occurring nitrate sources include wildlife manure, soil organic matter, rainwater, concentrations in, include animal manure applied to croplands and has the potential to enter surface waters in runoff or through groundwater discharges to streams. The 75th percentiles of the reference datasets for NO_3+_2-N are 20 µg/L and 76 µg/L respectively for the Northwestern Glaciated Plains and Northwestern Great Plains ecoregions in Montana. Lacking specific stressor-response studies for NO_3+_2-N in Montana prairie streams, the 75th percentile values are proposed as concentration targets in the Redwater TPA.

The ecoregional nutrient targets in **Table 5-3** are provisional and subject to review and revision through an adaptive management process, as water quality monitoring in the planning area and similar settings improves the understanding of water quality conditions in the prairie ecoregions.

Table 5-3. Growing season target concentrations (µg/L) for water column nutrient parameters in the Redwater TPA

Reference Ecoregions	TN	TP	NO_3+_2-N
Northwestern Great Plains	1,120	150	20
Northwestern Glaciated Plains			76

The target concentrations for TN, TP and NO_3+_2-N are weighted more heavily in assessing TMDL needs than are the DO parameters described below. The concentration targets are based on data collected from 24 sites on 22 prairie streams representing a continuum of human influence from least disturbed to highly impacted. The target selection integrates the reference approach with the stressor-response approach to target development. Target values for TN, TP and NO_3+_2-N were derived from the combined interpretation of data from high quality streams and oxygen tolerance index scores developed from diatom algae samples.

5.4.2 Dissolved Oxygen Targets

Two dissolved oxygen standards are used as nutrient targets. The oxygen tolerance index results, converted to DO values as described above in **Section 5.3.3**, are compared directly to the seven-day mean minimum DO concentration standard of 4.0 mg/L for C-3 streams. Instantaneous field DO readings are compared to the one-day minimum DO concentration of 5.0 mg/L for C-3 steams (DEQ 2010). Although the diatom index and meter readings are linked to aquatic life use support through the standards, the inherent uncertainty in both measures makes them more suitable as supplemental indicators of nutrient enrichment.

Algae samples contain variable numbers of unclassified species. The accuracy of the inferred DO result also varies with this percentage. **Figure 5-1** illustrates the relationship between 38 diatom-inferred DO values with corresponding TN values. The graph shows the expected negative relationship between the two variables; however, other factors affecting algal growth, such as turbidity and diurnal DO concentration fluctuations, are also influencing inferred DO results.

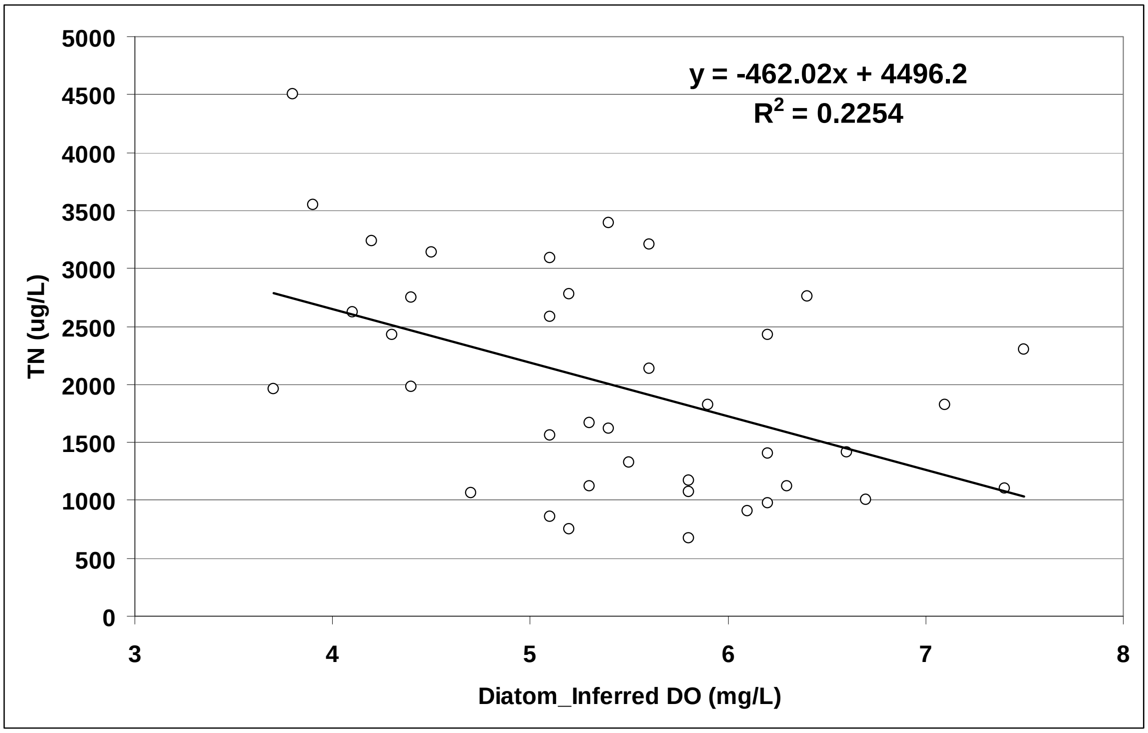

Figure 5-1. Scatter plot of inferred DO-TN relationship for Redwater streams

Field DO readings in the Redwater were typically obtained during daylight hours during the growing season. Daylight reading are typically higher than those taken during predawn hours when DO is best compared to the one-day minimum standard.

The exceedence of one or more targets or supplemental indicators may not automatically equate to beneficial use impairment. However, compliance with specific numeric targets has a dominant influence in assessing the effects of a chemical impairment cause such as nutrients. The frequency of target exceedences, as well as the magnitude of the target departures is considered by following the methodology of Suplee and Sada de Suplee (2010) for water quality assessment. The combination of target analysis, meaningful qualitative observations and sound professional judgment is applied in each assessment of TMDL development needs.

5.4.3 Comparison of Listed Waters to Nutrient Targets and Indicators

Evaluation of nutrient target attainment is conducted by comparing exiting water quality conditions to the nutrient target concentrations in **Table 5-3** following the methodology in the DEQ draft guidance document (Suplee and Sada de Suplee 2010). This methodology uses two statistical tests (Exact Binomial Test and the One-Sample Student’s T-test for the Mean) to evaluate water quality data for compliance with target values. In general, compliance with water quality targets is not attained when nutrient chemistry data demonstrates a target exceedence rate of >20% (binomial test), when mean water quality nutrient chemistry results exceed target values (Student T-test) or when DO concentrations are less than the established applicable DO standard.

The numeric nutrient targets in **Table 5-3** are based on the best water quality information and data reduction analyses current available for wadeable streams in the Northwestern Glaciated Plains and Northwestern Great Plains ecoregions in Montana. They represent water quality concentrations believed to limit algal growth below nuisance levels in prairie streams. As numeric nutrient criteria development efforts by the DEQ progress, nutrient water quality targets may be modified or adjusted based on the outcomes of the State's numeric nutrient criteria development process.

Nutrient TMDLs are developed for all parameters listed as impairment causes in the assessment records. Where nutrient data records indicate a significant number of target exceedences for streams not listed in 2008 for nutrient causes, TMDLs are developed for TN and TP as appropriate.

5.4.3.1 East Redwater Creek, headwaters to the mouth (MT40P002_010)

Table 5-4 contains the analytical results for TN, TP and NO_3+_2-N in samples from eight monitoring locations on East Redwater Creek. Six of the sites are located in the Northwestern Glaciated Plains ecoregion; sites M48RDWEC04 and M48RDWCE05 are in the unglaciated Northwestern Great Plains ecoregion. A considerably higher NO_3+_2-N target applies in the unglaciated portion of the watershed (see **Table 5-3**).

All 11 TN results exceed the applicable TN target and seven of 11 TP results (64%) exceed the applicable TP target. One NO_3+_2-N result in 10 (glaciated ecoregion) exceeded the 20 µg/L target for the glaciated portion of the watershed. The 76 µg/L NO_3+_2-N target was met in all samples collected within the unglaciated portion of the watershed.

Table 5-4. Analytical results for nutrient parameter concentrations (µg/L) and nutrient target exceedences (bolded) in samples from East Redwater Creek

Sample Site ID	Sample Date	TN (ug/L)	TP	NO_3+_2-N
5385EA01	08/23/95	**1,205**	77	< 10
5385EA01	08/27/95	**1,460**	109	< 10
5385EA01	06/17/08	**1,170**	55	< 10
M48RDWEC01	06/19/03	**2,755**	**189**	< 10
M48RDWEC02	06/19/03	**3,235**	**248**	< 10
M48RDWEC03	06/19/03	**2,430**	**187**	10
M48RDWEC03	06/17/08	**2,750**	**345**	< 10
M48RWENF01	06/19/03	**2,620**	**435**	20
M48RWENF01	06/17/08	**2,380**	**205**	10
M48RDWEC04	06/19/03	**1,960**	**151**	40
M48RDWCE05	06/17/08	**3,140**	111	< 10
5288NO01	06/15/76	--	--	**30**
5188TR01	06/15/76	--	--	70

A diatom-inferred DO value of 6.4 mg/L was derived from an algae sample collected at site M48RDWEC01 near the mouth of East Redwater Creek. This value meets the 4.0 mg/L DO standard for a 7-day mean minimum. All instantaneous DO meter readings exceeded the 1-day minimums of 5.0 mg/L.

The large numbers of TN and TP exceedences confirm the need for TN and TP TMDLs on East Redwater Creek. Although only a single sample in 10 exceeded the NO_{3+2}-N target applying to the glaciated ecoregions, the result would justify a listing for this parameter based on DEQ listing criteria (Suplee and Sada de Suplee 2010). Therefore a NO_{3+2}-N TMDL will also be developed for East Redwater Creek.

5.4.3.2 Horse Creek, headwaters to the mouth (MT40P002_020)

Horse Creek was not listed as being nutrient impaired on the DEQ 2008 303(d) List. As mentioned above in **Section 5.2**, the analytical results suggest the need for nutrient TMDLs. **Table 5-5** contains the growing season nutrient chemistry records for Horse Creek.

Table 5-5. Growing season analytical results (µg/L) and target exceedences (bolded) for nutrient parameters in Horse Creek

Sample Site ID	Sample Date	TN (ug/L)	TP	NO_{3+2}-N
06177520	07/12/78	**1,150**	40	< 100
06177520	08/9/78	**1,540**	20	40
06177520	07/10/79	**2,040**	50	40
06177520	08/21/79	**2,710**	--	10
4783HO01	08/23/95	**1,420**	88	20
4881HO01	08/23/95	**1,130**	18	30
MCNHORC-02	07/11/03	**1,325**	40	< 50
MCNHORC-03	06/17/08	965	41	< 10
MCNHORC-03	08/27/08	**3,270**	**247**	< 10
MCNHORC-04	07/11/03	**4,505**	**260**	< 50
MCNHORC-04	06/18/08	**1,670**	37	<10
MCNHORC-05	08/17/00	**3,200**	**220**	10
MCNHORC-05	07/11/03	**2,425**	150	< 50
MCNHORC-05	08/06/03	**4,925**	**580**	< 50
MCNHORC-05	08/13/03	**8,325**	**710**	< 50
MCNHORC-05	08/20/03	**9,725**	**560**	< 50
MCNHORC-05	08/27/03	**7,925**	**360**	< 50
MCNHORC-05	08/05/04	**8,380**	**610**	**2,680**
MCNHORC-05	08/16/04	**4,525**	**270**	< 50
MCNHORC-05	08/23/04	**4,625**	**280**	< 50
MCNHORC-05	08/30/04	**5,225**	**270**	< 50
MCNHORC-05	06/18/08	**2,580**	137	< 10

Twenty-one of 22 (95%) Horse Creek TN results exceed the applicable TN target of 1,120 µg/L; 11 of 21 TP results (50%) exceed the Northern Great Plains TP target of 150 µg/L. Only one of 23 NO_{3+2}-N results exceeded the 76 µg/L target.

Table 5-6 below contains the diatom-inferred DO results for four sample sites on Horse Creek listed in upstream to downstream order. The data suggests a downstream decrease in DO with one result (bolded in the table) being below the 7-day mean minimum of 4.0 mg/L.

Table 5-6. Diatom-inferred DO (mg/L) results for four sample sites on Horse Creek.

Station ID	Stream Miles Above the Mouth	Sample Date	Diatom-inferred DO (mg/L)
MCNHORC-02	20	7/11/2003	5.5
M48HRSEC02	12	6/4/2003	6.2
		6/18/2008	5.7
MCNHORC-04	5	7/11/2003	**3.8**
		6/18/2008	5.3
MCNHORC-05	0.5	6/4/2003	4.1
		7/11/2003	4.3
		6/17/2008	5.1

Both the water chemistry and biological sampling results clearly show the need for TN and TP TMDL development on Horse Creek.

5.4.3.3 Nelson Creek, headwaters to the mouth (MT40E003_020)

Nelson Creek has a nutrient listing for “Nitrogen, Nitrate”. **Table 5-7** contains the nutrient chemistry results for Nelson Creek arranged in chronological order.

Table 5-7. Growing season analytical results (µg/L) and target exceedences (bolded) for nutrient parameters in Nelson Creek

Site ID	Sample Date	TN	TP	NO_{3+2}-N
06131200	06/16/76	**1,200**	**250**	**470**
06131200	07/12/77	**1,330**	**300**	**530**
06131200	09/08/77	**1,270**	**180**	**340**
06131200	07/10/78	1,020	50	< 100
06131200	08/08/78	**1,520**	40	20
06131200	09/12/78	**4,750**	**3,600**	**850**
06131200	07/02/79	**1,200**	40	**100**
472518106001301	07/27/82	--	--	< 100
MCNNLSN-03	07/12/94	1,005	68	< 10
MCNNLSN-03	07/10/03	275	**180**	< 50
MCNNLSN-01	07/14/03	**3,625**	**190**	< 50
MCNNLSN-01	07/14/03	**3,525**	**180**	< 50
NCDS-01	09/26/06	--	--	< 50
NCDS-01	07/09/07	--	--	30
NCUS-02	07/11/07	--	--	< 10
POND-25	07/10/07	--	--	60
SFUS-01	09/26/06	--	--	**110**
SFUS-01	07/11/07	--	--	10
M31NLSNC01	06/17/08	**3,390**	93	< 10
M31NLSNC02	06/17/08	**1,670**	76	< 10
6131200	06/17/08	1,120	74	< 10

The chronology of NO_{3+2}-N sampling on Nelson Creek shows that most growing season results since the 2000 listing have been less than the method detection limits. Four of six growing season samples, collected as part of a baseline water quality assessment related to coal development in Nelson Creek, had positive detections, with one result exceeding the 76 µg/L target. The NO_{3+2}-N cause listing probably stems from the results obtained during the late 1970s by the USGS at station 06131200. Most of the more recent analysis with generally lower detection limits suggest that NO_3+$_2$-N target exceedences occur only periodically. However, the monitoring records for both TN and NO_3+$_2$-N show recent target exceedences and suggest the need for TMDLs. Total phosphorus target exceedences occurred most often in older data collected by the USGS, but persist in more recent sampling as well.

Table 5-8 contains the available diatom-inferred DO values and field DO readings for Nelson Creek. The field meter reading on July 11, 2007 is less that the one-day minimum DO standard of 5.0 mg/L. The remaining readings do not indicate DO shortages but all of the inferred values are below the median values (5.5 mg/L) for the Redwater dataset, with one result falling below the 7-day mean minimum standard of 4.0 mg/L.

Table 5-8. Diatom-inferred DO results and DO field readings (mg/L) from three Nelson Creek sites

Station ID	Sample Date	Diatom-inferred DO	DO Field Readings
M31NLSNC01	7/9/2003	3.9	--
	6/17/2008	5.3	11.05
NCDS-01	07/09/07	--	8.65
NCUS-02	07/11/07	--	**4.64**
POND-25	07/10/07	--	8.71
M31NLSNC02	6/17/2008	--	9.23
06131200	6/17/2008	5.3	8.76

Due to half of the TN and TP results exceeding targets and the algae samples suggesting at least periodic low DO conditions, TMDLs will be developed for both TN and TP on Nelson Creek. Although most of the NO_3+$_2$-N results obtained since 1994 have been less than the 76 µg/L target, the overall number of exceedences is greater than the maximum allowed by the sample size (Suplee and Sada de Suplee 2010), justifying a NO_3+$_2$-N TMDL.

5.4.3.4 Pasture Creek, headwaters to the mouth (MT40P002_030)

Pasture Creek was listed in 2006 for total kjeldahl nitrogen. **Table 5-9** contains the Pasture Creek nutrient monitoring record. Half of the TN results exceed the ecoregional target of 1,120 µg/L. The NO_3+$_2$-N and TP targets were not exceeded in any Pasture Creek sample.

Table 5-9. Growing season analytical results (µg/L) and target exceedences (bolded) for nutrient parameters in Pasture Creek

Site ID	Sample Date	TN	TP	NO_3+$_2$-N
5185PA01	08/23/95	1,110	38	10
M48PSTRC01	06/20/03	975	27	< 10
M48PSTRC01	06/17/08	907	28	< 10
M48PSTRC01	08/28/08	**2,330**	137	< 10
M48PSTRC02	06/20/03	**2,130**	99	20
M48PSTRC03	06/17/08	**1,980**	140	10
MCNREDW-3A	06/22/05	**1,125**	30	< 50

Inferred DO values derived for four Pasture Creek algae samples are given in **Table 5-10** with three field meter DO readings. Although the inferred DO result for site M48PSTRC03 meets the

7-day mean minimum target of 4.0 mg/L, it represents the 15th percentile of the inferred DO dataset and indicates low DO conditions at the time of sampling. The field meter readings to not indicate low DO conditions.

Table 5-10. Diatom-inferred DO results and DO field readings (mg/L) from three Pasture Creek sites

Station ID	Sample Date	Diatom-inferred DO	DO Field Readings
M48PSTRC01	6/20/2003	6.2	--
M48PSTRC01	6/17/2008	6.1	15.7
M48PSTRC01	08/28/08	--	9.03
M48PSTRC02	6/20/2003	5.6	--
M48PSTRC03	6/17/2008	4.4	12.17

The elevated TN that caused the 2006 listing appears to be persisting in Pasture Creek and a TN TMDL will be developed.

5.4.3.5 Prairie Elk Creek, confluence of East and Middle Forks to the mouth (MT40S002_010)

Prairie Creek has nutrient listings from 1990 for both TKN and TP. **Table 5-11** contains the growing season nutrient chemistry results for Prairie Elk Creek.

Table 5-11. Growing season analytical results (µg/L) and target exceedences (bolded) for nutrient parameters in Prairie Elk Creek

Site ID	Sample Date	TN	TP
06175540	7/21/76	540	70
06175540	8/20/76	820	80
06175540	9/22/76	520	60
06175540	7/12/77	910	130
06175540	6/16/77	**1,800**	**2,900**
06175540	8/18/77	520	130
06175540	9/14/77	**13,200**	**5,300**
06175540	7/25/78	710	40
06175540	8/23/78	700	70
06175540	9/13/78	**3,280**	**2,300**
06175540	7/12/79	640	30
06175540	8/13/79	730	50
06175540	9/13/79	930	40
5480PR01	8/10/95	510	48
06175540	06/18/08	**3,090**	**599**
06175540	08/28/08	**1,990**	**201**
M49PREKC02	06/18/08	988	72
M49PREKC06	06/18/08	**2,780**	62
M49PREKC07	06/18/08	**2,810**	81
MCNPREK-01	07/12/03	**2,125**	60
MCNPREK-01	06/21/05	275	80
MCNPREK-03	07/12/03	**1,425**	100
MCNPREK-06	07/12/03	**1,960**	**920**
MCNPREK-4A	06/18/08	**1,410**	**163**
MCNPREK-4A	08/28/08	**1,150**	146

The growing season monitoring record contains 12 TN exceedences (46%) and seven (28%) for TP. Four diatom algae samples were collected in Prairie Elk Creek. The diatom-inferred DO values are given in **Table 5-12** with corresponding field DO meter readings.

Table 5-12. Diatom-inferred DO results and DO field readings (mg/L) from four Prairie Elk Creek sites

Station ID	Sample Date	Diatom-inferred DO	DO Field Readings
MCNPREK-4A	9/16/2003	7.4	--
MCNPREK-4A	6/18/2008	6.6	6.82
M49PREKC-06	6/18/2008	5.2	10.96
06175540	6/18/2008	5.1	6.75

The diatom-inferred values suggest a slightly depressed DO concentration from site MCNPREK-4A, located about 12 miles upstream of the mouth, to sites M49PREKC-06 and 6175540 that are both located near the mouth. This pattern is not reflected in the meter readings. All DO values are above the applicable numeric DO standards for C-3 streams. However, the number of TN and TP target exceedences indicates that TN and TP TMDLs are needed.

5.4.3.6 Redwater River, Hell Creek to Buffalo Springs Creek (MT40P001_012)

This eight-mile reach of the Redwater River near the Town of Circle was listed in 2000 for both TN and TP. The data for each of five monitoring sites are arranged chronologically in **Table 5-13**. The sites are arranged from upstream to down stream from site MCNREDW-01 located about one mile below the mouth of Hell Creek to site MCNREDW-04 located about one mile above the mouth of Buffalo Springs Creek.

Table 5-13. Growing season analytical results (µg/L) and target exceedences (bolded) for TN and TP at five sites on the Redwater River near Circle

Site ID	Sample Date	TN	TP
MCNREDW-01	8/24/2000	1,010	64
MCNREDW-01	8/31/2000	1,005	71
MCNREDW-01	9/7/00	**1,325**	60
MCNREDW-01	08/06/03	1,025	40
MCNREDW-01	08/13/03	**1,225**	40
MCNREDW-01	08/20/03	**1,525**	40
MCNREDW-01	08/27/03	**1,725**	40
MCNREDW-01	08/05/04	**1,225**	30
MCNREDW-01	08/16/04	**1,125**	30
MCNREDW-01	08/23/04	1,025	30
MCNREDW-01	08/30/04	**1,125**	30
MCNREDW-01	06/16/08	815	--
MCNREDW-01	08/27/08	1,070	43
06177500	6/18/75	690	50
06177500	7/22/75	**1,150**	90
06177500	8/19/75	950	70
06177500	9/25/75	**1,320**	40
06177500	7/20/76	840	80

Table 5-13. Growing season analytical results (µg/L) and target exceedences (bolded) for TN and TP at five sites on the Redwater River near Circle

Site ID	Sample Date	TN	TP
06177500	8/18/76	**1,710**	100
06177500	9/22/76	550	70
06177500	7/13/77	980	120
06177500	9/12/77	540	60
06177500	7/12/78	970	60
06177500	8/9/78	770	5
06177500	7/10/79	**1,840**	30
06177500	8/21/79	450	140
06177500	9/12/79	390	20
06177500	7/28/80	**1,700**	70
06177500	8/27/80	**1,800**	**350**
06177500	9/17/80	**1,900**	70
06177500	6/29/81	**1,580**	40
06177500	6/22/82	**1,950**	5
06177500	8/24/82	**1,150**	60
06177500	9/21/82	**2,150**	30
06177500	6/28/83	950	30
06177500	8/22/83	**1,550**	30
06177500	9/27/83	**1,650**	30
06177500	6/27/84	1,050	60
06177500	9/19/84	850	40
06177500	8/21/85	1,050	20
MCNREDW-02	08/24/00	**1,310**	47
MCNREDW-02	08/31/00	1,005	28
MCNREDW-02	09/07/00	**1,325**	40
MCNREDW-02	08/06/03	**1,325**	60
MCNREDW-02	08/13/03	**1,825**	70
MCNREDW-02	08/20/03	**1,625**	60
MCNREDW-02	08/27/03	**1,825**	50
MCNREDW-02	08/05/04	**1,525**	30
MCNREDW-02	08/16/04	**1,425**	40
MCNREDW-02	08/23/04	925	30
MCNREDW-02	08/30/04	**1,125**	30
MCNREDW-02	06/16/08	671	21
MCNREDW-02	08/27/08	**1,470**	34
MCNREDW-03	08/24/00	**1,510**	**164**
MCNREDW-03	08/31/00	**1,310**	111
MCNREDW-03	09/07/00	1,060	100
MCNREDW-03	08/06/03	**1,525**	100
MCNREDW-03	08/13/03	**1,725**	100
MCNREDW-03	08/20/03	**3,225**	**270**
MCNREDW-03	08/27/03	**2,300**	110
MCNREDW-03	08/05/04	**2,325**	**260**
MCNREDW-03	08/16/04	**1,925**	150
MCNREDW-03	08/23/04	**1,825**	140
MCNREDW-03	08/30/04	**1,725**	150
MCNREDW-03	06/23/05	**1,325**	50
MCNREDW-03	06/16/08	751	60
MCNREDW-03	08/27/08	**1,350**	132
MCNREDW-04	08/31/00	**1,600**	145

Table 5-13. Growing season analytical results (µg/L) and target exceedences (bolded) for TN and TP at five sites on the Redwater River near Circle

Site ID	Sample Date	TN	TP
MCNREDW-04	08/24/00	**2,610**	146
MCNREDW-04	09/07/00	**1,800**	**190**
MCNREDW-04	08/06/03	**3,125**	**300**
MCNREDW-04	08/13/03	**2,425**	**340**
MCNREDW-04	08/20/03	**7,325**	**480**
MCNREDW-04	08/27/03	**6,525**	**420**
MCNREDW-04	08/05/04	**4,125**	**330**
MCNREDW-04	08/16/04	**4,625**	**250**
MCNREDW-04	08/30/04	**4,,525**	**270**
MCNREDW-04	06/17/08	859	86
MCNREDW-04	08/27/08	**2,080**	**162**

Fifty-three of 79 growing season TN results (67%) exceeded the 1,120 µg/L target. Thirteen of the 78 TP results (17%) exceeded the 150 µg/L TP target.

Table 5-14 gives the inferred DO concentration derived from eight benthic algae samples collected from four sites along the nutrient listed segment of the Redwater River near Circle.

Table 5-14. Diatom-inferred DO results and corresponding DO field readings (mg/L) from four sites along the nutrient listed segment of the Redwater River.

Station ID	Sample Date	Diatom-inferred DO	DO Field Reading
MCNREDW-01	08/17/2000	7.1	--
MCNREDW-02	8/17/2000	6.7	--
MCNREDW-02	8/27/2003	5.9	7.72
MCNREDW-02	6/16/2008	5.8	12.19
MCNREDW-03	08/17/2000	5.4	--
MCNREDW-03	8/27/2003	7.5	7.45
MCNREDW-03	6/16/2008	5.2	7.42
MCNREDW-04	6/17/2008	5.1	7.33
MCNREDW-04	08/17/2000	5.6	--

While all are above the 7-day mean minimum standard of 4.0 mg/L, the results for sites MCNREDW-03 and MCNREDW-04 appear to show a decreasing DO trend through the segment. The instantaneous field readings do not indicate low DO conditions, but all were taken during daylight hours when photosynthesis is adding oxygen to the water column and do not reflect the diurnal minimum DO condition. The possible decreasing downstream trend in DO through the segment, combined with high percentage of TN target exceedences, indicate the need for a TN TMDL. Eleven TP results exceed the 150 µg/L TP target. Ten target exceedences are allowed by DEQ nutrient impairment protocols (Suplee and Sada de Suplee 2010). Therefore, a TP TMDL will also be developed for the Redwater River segment.

5.4.3.7 Sand Creek, confluence of East and West Forks to the mouth (MT40S002_030)

Sand Creek was listed in 1990 for TKN and TP. **Table 5-15** contains the growing season TN and TP data record for Sand Creek.

Table 5-15. Growing season analytical results (µg/L) and target exceedences (bolded) for TN and TP at seven sites on Sand Creek

Site ID	Sample Date	Total N Calc (ug/L)	Total P (ug/L)
MCNSAND-03	09/16/03	**6,725**	**400**
M49SANDC03	06/18/08	**1,560**	123
M49SANDC03	08/28/08	540	14
M49SANDC02	06/18/08	**1,220**	**454**
MCNSAND-2A	09/16/03	**1,125**	140
5481SA01	08/21/95	**10,030**	**3960**
MCNSAND-01	07/12/03	**1,990**	**1370**
M49SANDC01	06/18/08	**1,860**	**442**
M49SANDC01	08/28/08	730	50

The nine results in the nutrient monitoring record include seven TN exceedences (78%) and five (56%) TP exceedences. Although all of the diatom-inferred DO results for Sand Creek (**Table 5-16**) are above the 4.0 mg/L standard, those derived for the June, 2008 samples from both the East Fork (MCNSAND-030) and West Fork (M49SANDC-03) indicate depressed oxygen levels just upstream of the listed segment.

Table 5-16. Diatom-inferred DO results (mg/L) derived from five Sand Creek algae samples

Station ID	Sample Date	Diatom-inferred DO (mg/L)
MCNSAND-03	9/16/2003	6.4
MCNSAND-03	6/18/2008	4.6
M49SANDC-03	6/18/2008	5.1
MCNSAND-2A	9/16/2003	6.3
MCNSAND-2A	6/18/2008	7.2

Field DO meter readings for Sand Creek during the 2008 sampling are given in **Table 5-17**. All were collected during daylight hours and none indicate limited DO conditions. The reading of 9.05 mg/L at site M49SANDC-03 (West Fork Sand Creek) was taken the same day as the algae sample corresponding to 5.1 mg/L inferred DO value in **Table 5-16**. The difference illustrates the limited value of daytime DO meter readings as stand-alone nutrient targets.

Table 5-17. 2008 field DO meter readings (mg/L) for Sand Creek.

Site ID	Sample Date	Field DO Meter Readings
M49SANDC03	08/28/08	10.00
M49SANDC03	06/18/08	9.05
M49SANDC02	06/18/08	8.02
M49SANDC01	06/18/08	7.18
M49SANDC01	08/28/08	11.70

The number of TN and TP exceedences on Sand Creek and the noticeably low inferred DO values indicate the need for TN and TP TMDLs on Sand Creek.

5.4.3.8 Timber Creek, headwaters to the mouth (MT40S002_030)

Timber Creek, like Nelson Creek, is a tributary to the Big Dry Creek arm of Fort Peck Reservoir. Timber Creek was listed for both TN and TP in 2006. **Table 5-18** contains the nutrient chemistry monitoring record for Timber Creek.

Table 5-18. Growing season analytical results (μg/L) and target exceedences (bolded) for TN and TP in Timber Creek

Site ID	Sample Date	Total N Calc (ug/L)	Total P (ug/L)
MCNTMBR-01	07/10/03	**5,425**	**490**
M31TMBRC05	06/18/04	**2,185**	121
M31TMBRC04	06/17/04	**4,645**	**327**
M31TMBRC04	06/16/08	**2,720**	130
M31TMBRC02	06/16/04	1,020	28
MCNTMBR-04	07/10/03	**5,125**	**180**
M31TMBRC03	06/18/04	**1,765**	48
M31TMBRC03	06/17/08	**2,120**	85
M31TMBRC03	08/29/08	**8,700**	**643**
06131120	07/10/78	**1,150**	70
06131120	08/08/78	**1,420**	50
06131120	07/02/79	970	30
06131120	08/20/79	780	40
06131120	09/11/79	820	50
06131120	06/17/08	1,060	31
06131120	08/28/08	**2,190**	102
MCNTMBR-06	07/10/03	**1,625**	100
4878TI01	07/12/94	1,110	25

The 18 results in the monitoring record include 12 TN exceedences (67%) and four (22%) TP exceedences. A single algae sample collected on June 17, 2008 at site 6131120 yielded an inferred DO result of 4.7 mg/L that meets the 7-day mean minimum standard of 4.0 mg/L but indicates low DO conditions. **Table 5-19** contains the field DO meter readings from 2008. Note the large DO decrease at site M31TMBRC03 from the June to August readings. The August reading of 0.45 mg/L is less than the 5.0 mg/L standard for instantaneous DO concentrations.

Table 5-19. 2008 field DO meter readings (mg/L) for Timber Creek.

Site ID	Sample Date	Field DO Meter Readings
M31TMBRC04	6/16/08	9.62
M31TMBRC03	6/17/08	7.70
M31TMBRC03	8/29/08	**0.45**
6131120	6/17/08	12.42
6131120	8/28/08	9.15

The nutrient monitoring record indicates that TMDLs are needed for both TN and TP in Timber Creek.

5.4.3.9 Nutrient TMDL Development Summary

Based upon the target departures described in **Section 5.4**, the streams and stream segments in **Table 5-20** require nutrient TMDL development. Nutrient sources and estimates of nutrient loads from those sources are investigated in **Section 5.5**, and the TMDLs and of nutrient load allocations are presented in **Section 5.6**.

Table 5-20. Waterbody segments in the Redwater River TPA Needing Nutrient TMDLs.

Waterbody ID	Stream Segment	Probable Nutrient Impairment Causes
MT40P002_010	**EAST REDWATER CREEK**, headwaters to the mouth (Redwater River)	**TN, NO_3+$_2$-N, TP**
MT40P002_020	**HORSE CREEK**, headwaters to mouth (Redwater River	**TN, TP**
MT40E003_020	**NELSON CREEK**, headwaters to the mouth (Fort Peck Reservoir))	**TN, NO_3+$_2$-N, TP**
MT40P002_030	**PASTURE CREEK**, headwaters to the mouth (Redwater River)	**TN**
MT40S002_010	**PRAIRIE ELK CREEK**, East and Middle Forks to the mouth (Missouri River)	**TN, TP**
MT40P001_012	**REDWATER RIVER**, Hell Creek to Buffalo Springs Creek	**TN, TP**
MT40S002_030	**SAND CREEK**, from the forks to the mouth (Missouri River)	**TN, TP**
MT40E003_010	**TIMBER CREEK**, headwaters to mouth (Fort Peck Reservoir)	**TN, TP**

5.5 Nutrient Source Assessment Methods

Nutrient loads must be quantified for each of the significant source categories, and where appropriate, strategies for reducing those loads from human caused sources must be developed such that streams meet all applicable standards. This section describes the methods, rationale, and assumptions in quantifying loads from nutrient sources.

Agricultural production is by far the most extensive planning area land use. Livestock grazing is the dominant land use on rangelands that comprise 70 percent of the land area. Cropland production of small grains and forage covers approximately 23 percent. The remaining seven percent is a combination of cropland in conservation easements, woodlands, roadway surfaces and several hundred acres of urban lands associated with the towns of Brockway, Circle, Richie and Vida. The predominant extent of agriculture over other human nutrient sources prompted use of an area-based loading model as a framework for quantifying loads. The Spreadsheet Tool for Estimating Pollutant Loads (STEPL) is an empirical loading model suited to the range of Redwater source categories. The model input structure accommodates the following land use source categories for user-specified subbasins:

- Pastureland (rangeland),
- Cropland,
- A User-Define Category,
- Woodland,
- Feedlots, and
- Urban Area.

The user-defined category is cropland acreage in the conservation reserve program (CRP) managed for perennial vegetation cover. “Feedlots” consisted of acreage used as seasonal livestock confinement areas. Urban area consisted of road surface acreage plus residential/commercial zones within planning area towns. The model also estimates nutrient loading (nitrogen and phosphorus) from individual septic systems. Local stakeholders provided information on cropping systems, fertilizer application rates, crop residue goals and manure management practices that guided selection of model parameters describing soil, land cover and climate conditions.

STEPL was selected as an assessment tool because the range of sources included in the model framework adequately accounts for the significant agricultural loading sources. A report of the modeling effort using STEPL is contained in **Appendix D**. **Section 5.5.2** below provides more details of the model framework.

The nutrient source assessment also included interpretation of loading derived from flow measurements and nutrient sampling results for each stream. Interpretation of these data indicated that the public wastewater treatment system for the Town of Circle is a source of nutrient loading to the nearby segment of the Redwater River. Design drawings and specifications for the recently upgraded system were obtained from the project engineering consultant. This information was used to estimate loading to the Redwater River from the new system.

The nutrient source assessment identified three major source categories:

1. Loading from natural background sources,
2. Loading from agricultural sources
3. Loading from the Circle wastewater treatment system.

5.5.1 Natural Background Nutrient Levels

Human activities can increase the biologically available supply of nitrogen and phosphorus. An overabundance of these nutrients in aquatic ecosystems accelerates the process known as eutrophication. Eutrophication is the enrichment of a waterbody, usually by nitrogen and phosphorus, leading to increased aquatic plant production (including algae) and its subsequent decay. Eutrophication becomes detrimental when the rates of respiration for growth and decay deplete the oxygen supply available for other aquatic organisms. Such changes can damage beneficial uses of waters for aquatic life, drinking water and recreation. Although human sources of nutrients can accelerate eutrophication, some degree of baseline nutrient enrichment is assumed for natural background sources.

A number of investigators have estimated natural background nutrient concentrations using existing water quality databases stratified by ecoregion (Omernik, 1987). Ecoregions are geographic areas with relatively homogenous climate, geology, soils, vegetation and other factors that influence nutrient concentrations. Approaches to using distributional statistics from reference and non-reference datasets as nutrient criteria are described in Appendix C, **Section C.1.2** of this document. The 75th percentile of a reference dataset and the 25th percentile of an all-observations dataset have been suggested by EPA as potential nutrient criteria (EPA 2000).

Kemp and Dodds (2001) studied TN concentrations in streams draining two undeveloped native tall grass prairie watersheds. They reported a TN range from 200 to 400 µg/L. Corresponding samples from stream transects through tilled cropland had a mean TN concentration of 1,200 µg/L. The study reported a positive correlation between stream discharge and nitrogen concentration in grassland streams, compared to a negative correlation with data from tilled cropland. The increase in nitrogen with decreasing stream flow resulted from base flow groundwater loading beneath fertilized cropland (Kemp and Dodds 2001). Dodds and Oakes (2004) used regression models to identify the land use and population density predictors of TN and TP using surface water data from central and eastern Kansas, as well as a nationwide USGS dataset. The intercepts of the linear regression models (TN and TP concentrations in the absence of human influences) were used to estimate reference nutrient values. Reference values for TN in Great Plains ecoregions were between 500 and 700 µg/L; reference TP values were between 20 and 60 µg/L. Smith and others (2003) used regression models to estimate ecoregional TN and TP yields and concentrations from 63 minimally impacted Great Plains watersheds. Suggested background concentrations ranged from 170 to 350 µg/L for TN and from 50 to 60 µg/L for TP.

In a study to develop nutrient criteria for Montana prairie ecoregions, Suplee (2007) recommended the 50th percentile of the all season reference dataset to represent background conditions. This translates to TN values ranging from 620 to 750 µg /L and a TP range of from 40 to 55 µg/L. The median values of these ranges equate to a background TN concentration of 670 µg/L and a background TP concentration of 48 µg/L. The corresponding range for NO_3+$_2$-N is from five to 40 µg/L, with a mean of 10 µg/L for the reference dataset.

Assembly of a reference dataset for the Redwater TPA is challenging. In part, this is due to a lack of data from planning area streams where land management practices are consistent with the application of all reasonable land, soil and water conservation practices. Water quality data is also sparse where such practices have been in place long enough to minimize the effects of crop production on pollutant loading to groundwater. The reference data used to derive nutrient targets in this document have been collected from agricultural watersheds, and are a logical and appropriate translation of the State’s narrative water quality standard for nutrients.

Literature values for background nutrient concentrations from Great Plains ecoregions within the United States are in good agreement with those suggested by Suplee (2007) for prairie streams in Montana. Favoring estimates based on local data, the natural background concentrations of TN, TP and NO_3+$_2$-N in the Redwater TPA are assumed to be 670, 48 and 10 µg/L, respectively. These values represent the 13th, 40th and 11th percentiles of the respective TN, TP and NO_3+$_2$-N all-season datasets for the Redwater. As expected, these percentiles are well below the 50th percentile recommended by Suplee (2007) from a reference dataset. Background loading is calculated by multiplying these nutrient concentration values by stream discharge and a unit conversion factor.

5.5.2 Loading from Agricultural Sources

Agricultural nutrient sources in the Redwater TPA were inventoried through combined interpretation of 2005 National Agricultural Imagery Program (NAIP) aerial photography (USDA 2005) and the 2001 USGS land cover dataset (Homer et al. 2004) in a geographic information system (GIS). The land cover raster data (30-meter resolution) were used to quantify the acreage of rangeland, cropland, and woodland and urban land use areas. The CRP program acreage was calculated from percent cropland enrollment figures provided by the McCone County UDSA, Farm Service Agency. Percent cropland enrollment figures for McCone County were extrapolated to cropland in the other four planning area counties. Acreage in the CRP program was subtracted from the raster-based estimate of cropland acreage. “Feedlot” area was measured using GIS tools applied to seasonal livestock confinement polygons identified on NAIP photography. The assessment identified 100 confinement areas ranging from 0.1 to 6.5 acres. **Figure 5-2** illustrates a confinement area from the inventory.

Figure 5-2. A five-acre seasonal livestock confinement area in the Redwater TPA (scale: 1:3,000).

The acreage values for each land use source category were used to populate the STEPL data input tables for each of 10 planning area subbasins. These subbasins correspond to the watersheds of the eight **Table 5-20** streams, the Redwater River drainage above and below the listed segment near Circle and McGuire Creek (an unlisted tributary to Fort Peck Reservoir). A map of the modeled subbasins is shown in **Figure 5-3**.

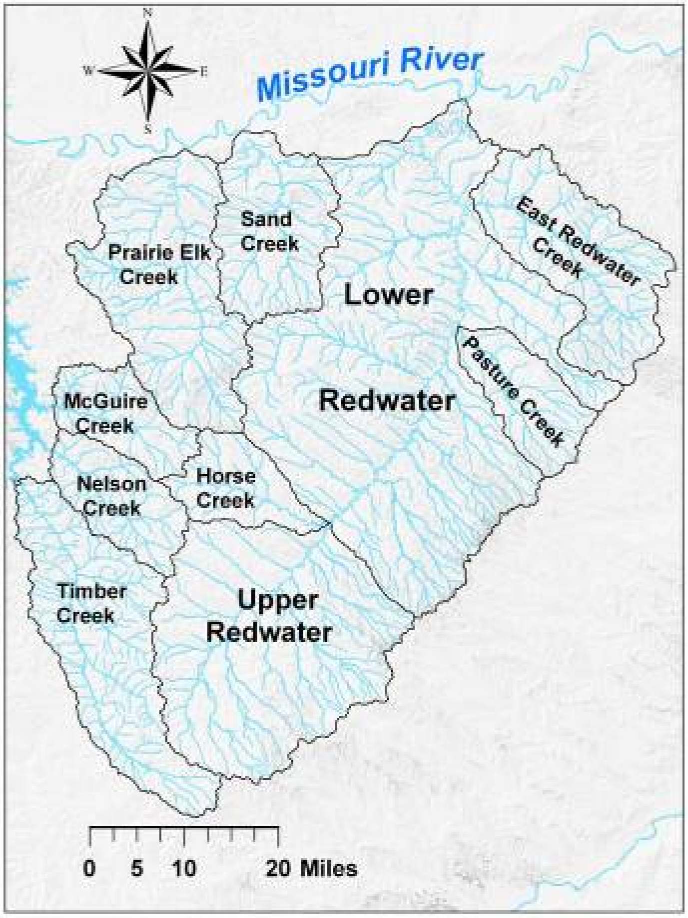

Figure 5-3. Map of modeled subbasins in the Redwater TPA.

The model calculates the annual nutrient loading for each subbasin based on runoff volume and runoff pollutant concentration 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 loading from sheet and rill erosion is calculated from the Universal Soil Loss Equation (USLE) and an area-based sediment delivery ratio. Nutrient loads are determined using event mean concentrations developed from the water quality database for the planning area (**Appendix D**, **Table 4-4**).

STEPL also estimates nutrient loading from groundwater. The volume of groundwater entering streams is calculated as a fraction of precipitation. Groundwater quality analytical results for NO3-N and PO4-P in the Groundwater Information Center (GWIC) database were stratified by surrounding land use for shallow (<150 feet) wells (**Appendix B**). Land use category means were used as model input for nutrient concentrations in groundwater (**Appendix D**, **Table 4-3**).

The sum of modeled runoff volume plus groundwater volume discharging to streams was calibrated to USGS stream flow data from three gaging stations: Prairie Elk Creek at Station 06175540, Nelson Creek at Station 06131200 and the Redwater River at Station 06177500 near Circle. With the environmental and nutrient source characterization parameters set to reflect existing conditions, the soil infiltration fraction was adjusted until the model output for runoff plus infiltration approximated the mean annual discharge volume measured at each gage. The differences between the modeled and measured discharges were single digit values (**Appendix D**, **Table 4-5**), indicating reasonably good agreement between the measured and modeled discharge volumes.

The model was parameterized to reflect existing nutrient loading conditions. Annual loads of TN, TP, five-day biochemical oxygen demand (BOD5) and sediment are calculated by subbasin for each source category. A menu of land use-specific BMPs are applied in STEPL as literature-based nutrient removal efficiency factors. In addition to current loading, STEPL estimates potential load reductions with BMP application by land use category for each subbasin. The suite of BMPs selected for land uses in the Redwater included:

- Vegetative filter strips on croplands,
- Prescribed grazing on rangelands,
- Diversion and containment of runoff from livestock confinement areas,
- Grass swale treatment of urban (roadway) runoff.

BMPs were applied only in subbasins needing nutrient TMDLs. Therefore, no BMPs were specified for McGuire Creek or for the Redwater River below the listed segment near Circle. The model output was used to:

1. Identify significant nutrient sources,
2. Quantify their relative contributions to loading,
3. Quantify potential loading reductions by source.

5.5.3 Loading from the Circle Wastewater Treatment Plant.

"Municipal Point Source Discharges" are listed as a probable source of nutrients to the eight-mile segment of the Redwater River near the Town of Circle (DEQ 2008). The Circle wastewater treatment plant (WWTP) pond system, located east of the Town of Circle, consists of a newly-constructed, three-celled lagoon system. The new lagoons replace the previous two-celled system built in 1954. **Figure 5-4** illustrates the new system footprint on a 2009 pre-construction aerial photograph of the former system. The new lagoons consist of a clay-lined primary treatment cell on the west, a synthetically lined secondary cell in the center and a synthetically lined storage cell to the east.

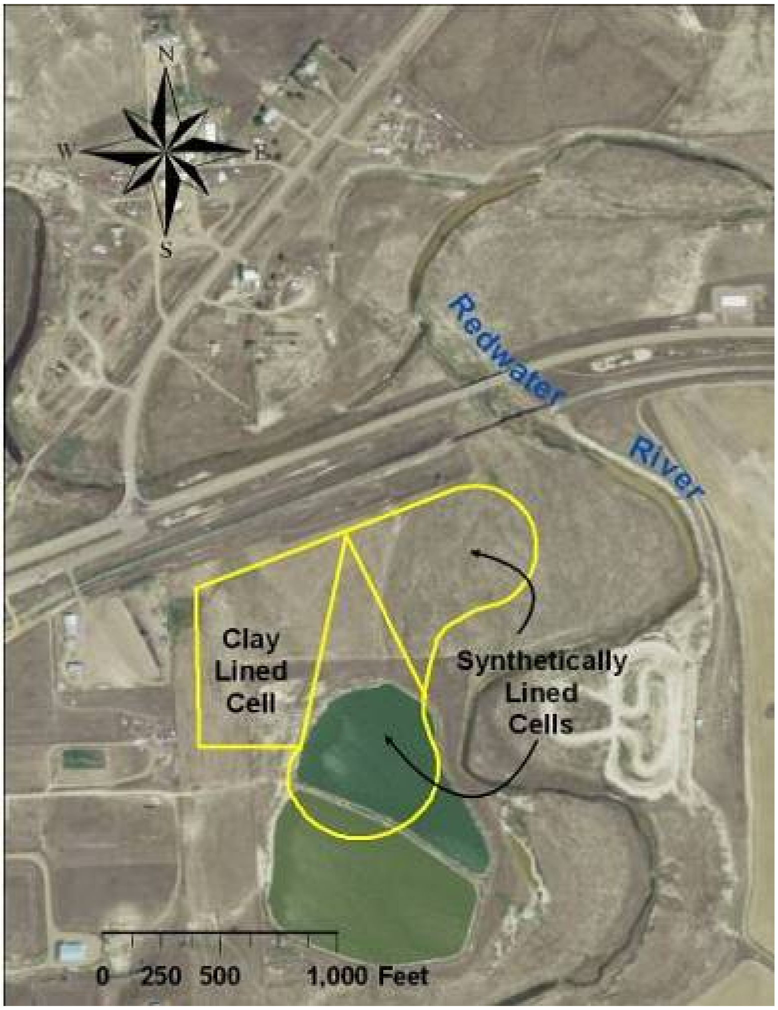

Figure 5-4. Footprint of the newly-constructed Circle wastewater treatment pond system on a pre-construction aerial photograph.

The facility operates under Montana Pollutant Discharge Elimination System (MPDES) permit number MT0020796 that applies to a single outfall (001) from the storage cell to the Redwater River. The permit effluent limits are given in **Table 5-20**.

Table 5-21. Effluent limits for Outfall 001 from the Circle wastewater treatment facility to the Redwater River under MPDES Permit MT0020796

Parameter	Units	Average Monthly	Average Weekly	Maximum Daily
(BOD5)	mg/L	30	45	--
	lb/day	15	22.5	--
	% removal	85	--	--
Total Suspended Solids (TSS)	mg/L	30	45	--
	lb/day	17.8	26.6	--
	% removal	85	--	--
E. coli Bacteria, Winter	cfu/100 ml	630	1,260	--
E. coli Bacteria, Summer	cfu/100 ml	126	252	--
Total Residual Chlorine (TRC)	mg/L	0.011	--	0.019

The permit contains no nutrient limits. Although the facility is designed for total retention, the permit allows for future effluent discharges directly to the Redwater River on an as-needed basis. Future loading from such discharges can be estimated using data from past discharges.

Three discharges reported during the period of January 1, 2005 to December 31, 2009 had rates of 140,000, 40,000 and 20,000 gallons per day (gpd). The average flow rate reported for these three discharges was 69,000 gpd (DEQ 2009). The discharge monitoring record for the facility (USEPA 2010) contains seven TN results for the period November 1, 2001 to April 30. 2009. The mean TN concentration for these samples is 10.6 mg/L. The corresponding mean for TP is 5.6 mg/L. Note the order-of-magnitude difference between these concentrations and target TN and TP concentrations.

The daily TN loading rate from a permitted surface discharge is expressed in the following loading equation:

(0.107 cfs) * (10.6 mg/L) * (5.4) = 6.1 lbs/day

Where: 0.107 = the mean flow rate of 69,000 gpd in cfs
10.6 mg/L = effluent TN concentration
5.4 = unit conversion factor

The product of the same calculation for daily TP loading from the discharge is 3.2 lbs/day: (0.107 cfs) * (5.6 mg TP/L) * (5.4) = 3.2 lbs/day.

In addition to surface discharges, loading from the Circle WWTP has a groundwater component from treatment pond seepage. A 2004 engineering analysis of the Circle facility estimated seepage at 9,611,500 gallons (1,284,871 ft3) per year (Interstate Engineering 2004). This seepage rate from the former pond area of 755,330 ft2 (17.34 acres) equals an annual seepage depth of 1.7 ft (20 inches). The maximum seepage rate allowed by current design standards (DEQ 1999) is six inches per year.

Appendix E includes two spreadsheet computation pages for quantifying groundwater nitrogen loading to the Redwater River both before and after the 2009 pond system upgrade. Each page contains a series of four calculations to:

1. Quantify the effluent seepage rate through the pond bottom,
2. Determine the nitrogen concentration in pond-affected groundwater,
3. Determine the in-stream change in TN concentration after mixing with pond-affected groundwater,
4. Determine TN loading from effluent and upstream sources.

Total N loading from the Circle pond system prior to the upgrade, based on an effluent TN concentration of 10.6 mg/L and a seepage rate of 6,269 ft3/day (0.073 cfs), delivered about 4.2 pounds of nitrogen per day to the river.

Based on engineering specifications for the new ponds and liners and an assumed effluent TN concentration of 10.6 mg/L, the daily seepage volume from the new system is approximately 40 gallons per day, delivering a small fraction (0.004) of a pound of nitrogen per day to the river. Assuming that the permeability test for the liner material is the actual permeability of the primary cell, detectable TN loading to the river from effluent pond seepage has practically been eliminated by the system upgrade. The only remaining seepage load is associated with sewage sludge disposal at the pond site.

Approximately 3,100 tons of sewage sludge that accumulated in the old ponds between 1954 and 2009 has been deposited in the portion of the former two-celled system that is outside of the newly built, three-celled system. The sludge was "bulked up with on-site soils and covered with 3-5 feet of on-site soils as a final cover" (Interstate Engineering 2009). Section I.D.1 (Special Conditions) of the MPDES permit for the domestic wastewater treatment facility addresses water quality effects of the sludge disposal. Appendix E contains a third computation page to estimate residual nitrogen loading to the Redwater River from groundwater affected by precipitation infiltration through the buried sludge.

5.6 Nutrient Source Assessment Results, TMDLs and Allocations

5.6.1 Nutrient TMDLs

Nutrient TMDLs will be developed for the nutrient pollutant causes identified for each waterbody in **Table 5-20**. Nutrient TMDLs are expressed as loading equations in which mean daily flow in cubic feet per second is multiplied by the appropriate concentration targets in **Table 5-3** and a unit conversion factor of 0.0054 that gives maximum allowable loading rates in pounds per day. The TN target of 1,120 µg/L, times the conversion factor of 0.0054, gives a TN loading coefficient of 6.05. **Equation 5-1** gives the TMDL for TN where the coefficient multiplied the stream flow rate gives the maximum daily TN load in pounds.

Equation 5-1:

Total Nitrogen TMDL = CFS*6.05

Where: CFS = mean daily discharge in cubic feet per second

6.05 = the TN target of 1120 µg/L times the 0.0054 conversion factor.

Each value for mean daily stream flow, entered into **Equation 5-1**, gives the number of pounds of allowable TN loading for that day. **Table 5-22** contains example TMDLs calculated using **Equation 5-1** for three stream flow values. The allowable daily load increases with stream discharge.

Table 5-22. Example TN TMDLs for three mean daily stream flow values

Mean Daily Discharge (cfs)	Loading Coefficient	TN TMDL (lbs)
10	6.05	60.50
25	6.05	151.25
45	6.05	272.25

The TMDL can be displayed as a line graph of allowable loading with increasing flow. **Figure 5-5** is the graph of a TN TMDL for the range of mean daily flows from zero to 48 cfs. The vertical dotted lines intersect the graph at the points corresponding to the three stream flow values of 10, 25 and 45 cfs. The horizontal dotted lines, extending from the diagonal TMDL graph to the y-axis, identify the maximum TN load allowed for these three discharge rates.

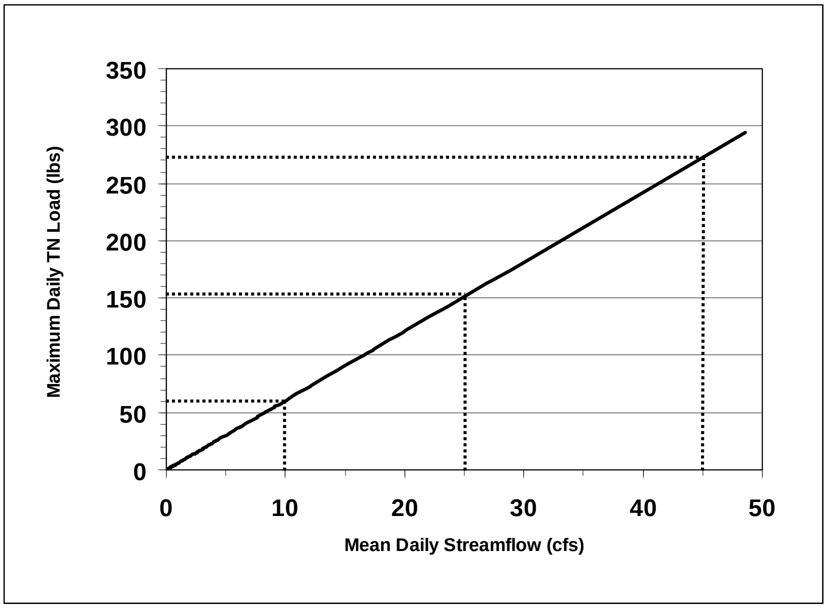

Figure 5-5. Graph of the TN TMDLs for mean daily flows from zero to 48 cfs.

The relationship between flow and loading can be used to link pollutant loading to actual hydrologic conditions. This link provides a simple means of illustrating the seasonal loading distribution so that loading controls can be developed and implemented to target the most critical loading periods. Flow duration curves are a useful way of organizing available flow data to show seasonal conditions. Flow duration curves express stream flows in terms of the percentage of time that flows are equaled or exceeded. **Figure 5-6** is the flow duration curve for mean daily discharge in Nelson Creek at USGS station 06131200. Portions of the curve are characterized in the figure according to prevailing hydrologic condition.

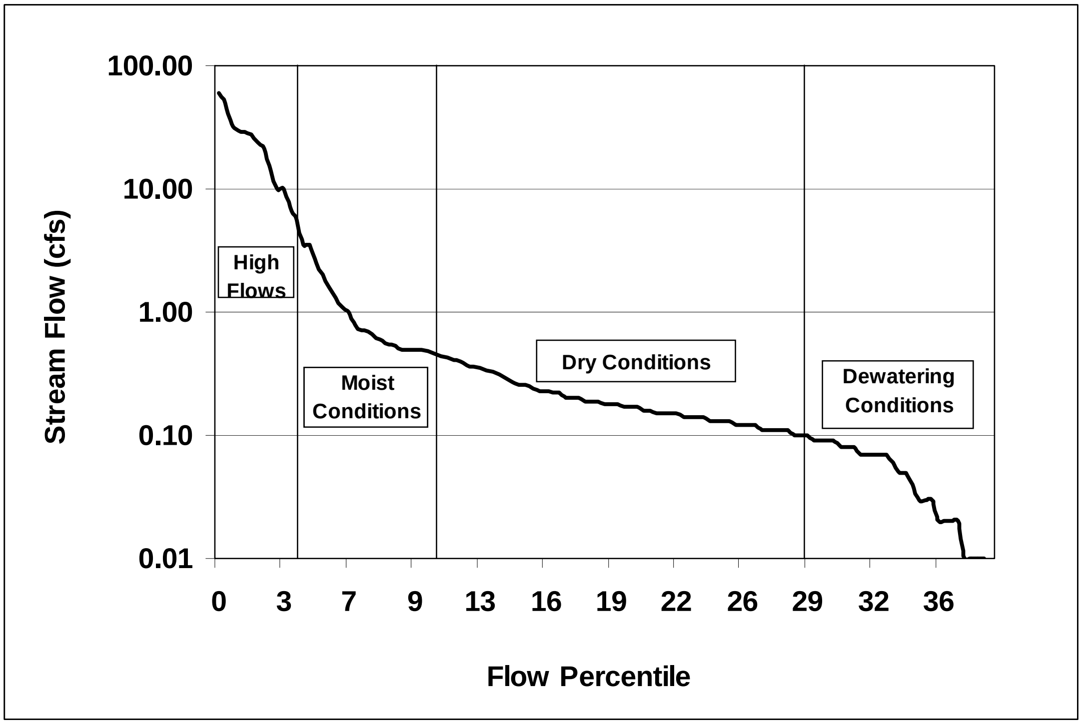

Figure 5-6. Flow duration curve for Nelson Creek at USGS Station 06131200, partitioned by annual hydrologic condition (after Cleland 2003)

The flow duration curve can be converted to a load duration curve by replacing values for mean daily flow on the y-axis with those for allowable daily loading derived by using **Equation 5-1** (the TMDL for TN). A load duration curve illustrating the TMDL, along with loads determined from actual water quality analysis and flow measurement, is a useful tool for correlating existing loads with hydrologic conditions. **Figure 5-7** is a load duration curve for Nelson Creek showing both the graph of the TN TMDL and individual loads calculated from water quality analysis and coincident flow measurements.

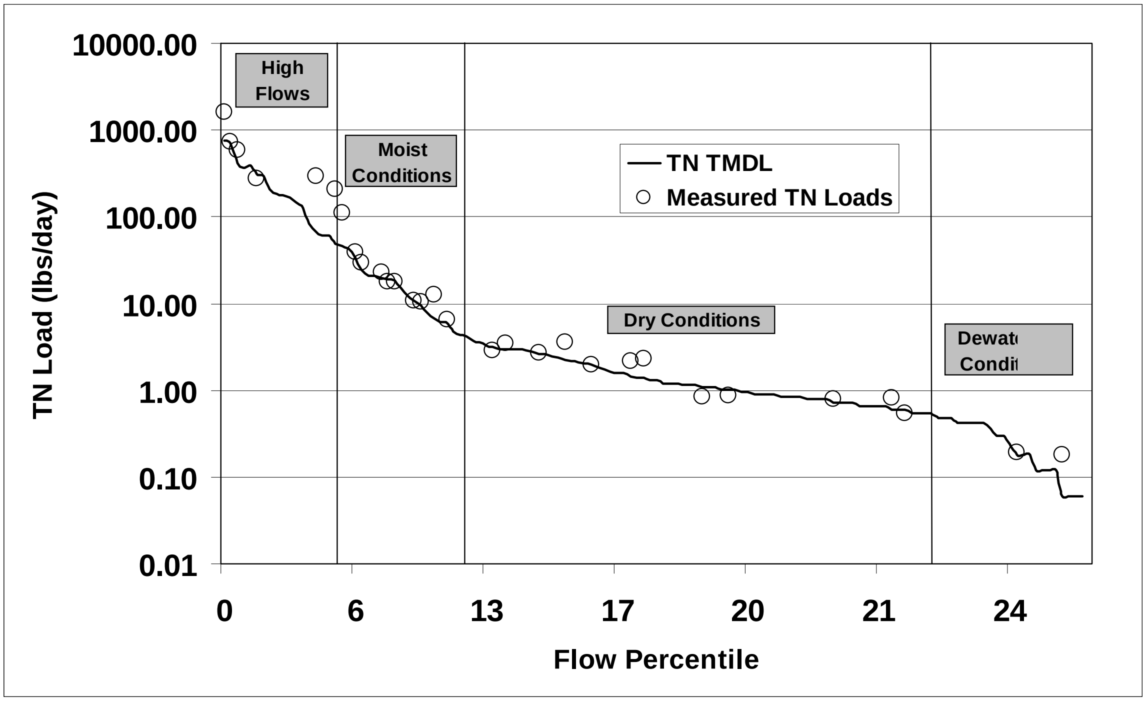

Figure 5-7. Load duration curve for Nelson Creek illustrating the TMDL for TN and measured daily TN loads during the growing season.

Figure 5-7 shows a pattern of consistent TN loading above the TMDL level across a range of flow conditions. Although nutrient targets apply only during the growing season, management practices that target early high flow loading may prevent eutrophication caused by the bioavailability of nutrient accumulations in pools later in the year. Load duration curves will be used in this document to illustrate both existing nutrient loading conditions and nutrient TMDLs. They provide valuable information on the timing and number of exceedences and can help guide future nutrient monitoring efforts.

The format of **Equation 5-1** can also be used to express TMDLs for TP. **Equation 5-2** expresses the TP TMDL. Its loading coefficient of 0.81 is the product of the 150 µg/L TP target and the unit conversion factor of 0.0054.

Equation 5-2:

Total Phosphorus TMDL = CFS*0.81
Where: CFS = mean daily discharge in cubic feet per second
0.81 = the TP target of 150 µg/L times the 0.0054 conversion factor.

Similarly inserting the applicable ecoregional NO_3+_2-N target of either 20 or 76 µg/L into **Equation 5-3** gives the NO_3+_2-N TMDL.

Equation 5-3:

NO_3+_2-N TMDL = CFS*(0.108 or 0.41)

Where: CFS = mean daily discharge in cubic feet per second
0.108 = the NO_{3+2}-N target of 20 µg/L times the 0.0054 conversion factor,
0.41 = the NO_{3+2}-N target of 76 µg/L times the 0.0054 conversion factor

The criteria developed for identifying nutrient impaired waters (Suplee and Sada de Suplee 2010) allow for a maximum 20 percent exceedence rate for samples collected randomly during the growing season extending from June through September. Nutrient TMDLs apply only during this seasonal timeframe. The exceedence rate is intended to allow for a degree of natural variability in water quality while protecting beneficial uses.

5.6.2 Nutrient Source Assessment

Results from the STEPL model are used to identify significant nutrient sources and their relative contributions to human-caused loading. **Figures 5-8** and **5-9** summarize the TN and TP loading percentages attributed to each source considered in the model. The combined contributions from rangeland, cropland and livestock confinements account for 95 percent of TN loading and 96 percent of TP loading. Loading from urban (mostly road surfaces) and CRP acreage is less than five percent. Loading from woodland acreage and septic systems do not register as significant TN or TP sources.

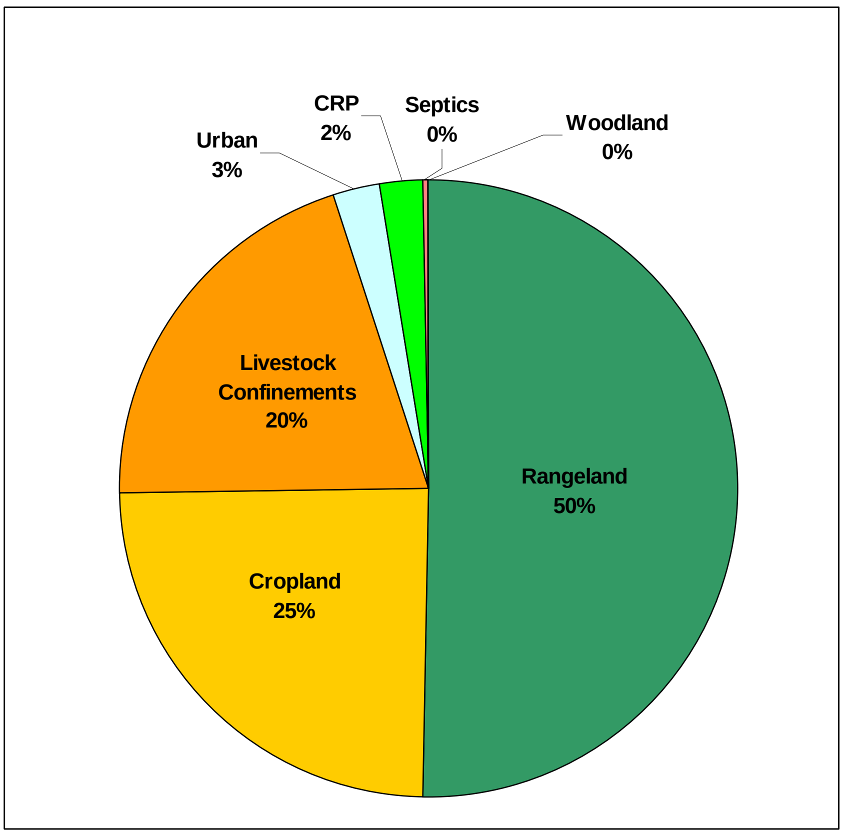

Figure 5-8. Annual TN loading percentages by source category

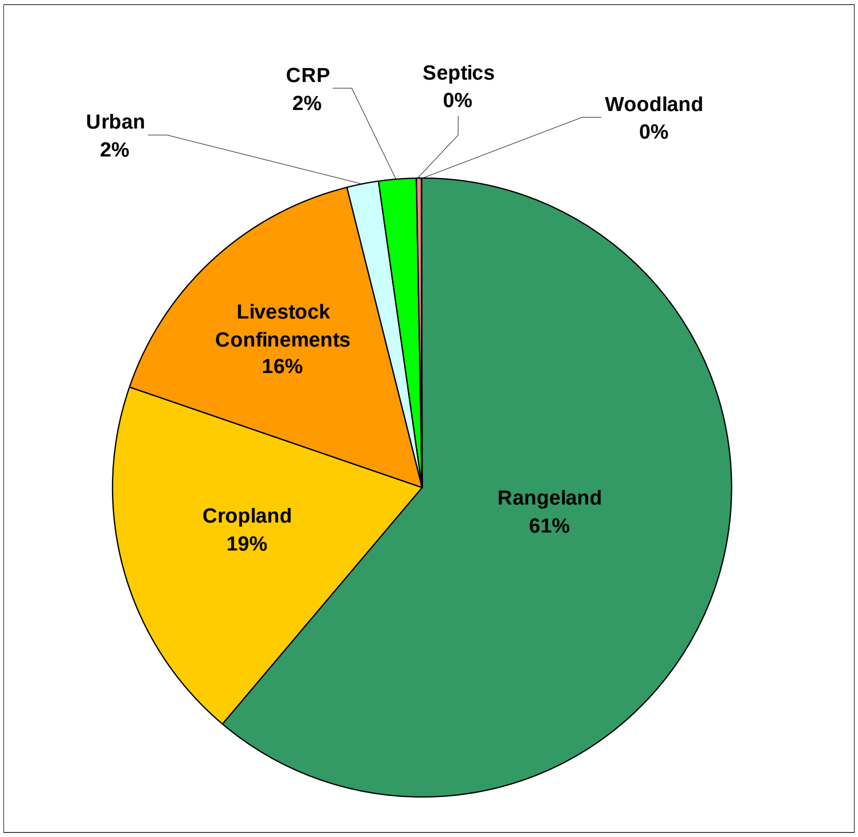

Figure 5-9. Annual TP loading percentages by source category

The results reflect the dominant land area extents of rangeland and cropland in the planning area. The contributions from livestock confinements are driven by the high nutrient concentrations in runoff from these areas rather than the facility acreage. Loading from "urban" land cover mostly reflects runoff from 1,440 miles of roadways. Woodlands occur mainly within steep ravines unsuited for cropland and minimally grazed due to slope and distance to water. The small contribution from septic systems simply reflects their low density of one system per 2.5 square miles.

For this analysis, nutrient loading from rangeland, cropland and livestock confinements are considered significant, controllable sources warranting a composite nutrient load allocation to agricultural sources. With model parameters set to reflect existing conditions, and runoff plus infiltration values calibrated to gaged streamflows, a model run was completed with BMPs applied to land use source categories. The BMP scenario, described above in **Section 5.5.2**, was intended to simulate reasonable land, soil and water conservation practices applied to significant sources.

Application of a simple loading model over 2.1 million acres of the Redwater TPA introduces significant uncertainty in the loading estimates. Much of this uncertainty is associated with the assumed uniformity of precipitation patterns, soil conditions, water quality conditions and land management practices over such a large area. Despite its simplicity, STEPL is considered an adequate load allocation tool for the Redwater because it addresses all of the major land use categories in this predominantly agricultural planning area. However, the lack of information on the current extent and location of BMPs on the landscape and the broad application of BMPs through the model make its output for relative source loading more useful than its absolute nutrient loading estimates. Therefore, load allocations are based on the relative source contributions predicted by the model rather than its absolute load values.

5.6.3 Nutrient Allocations

In **Section 5.6.1** TMDLs are expressed as equations containing terms for mean daily discharge multiplied by a loading coefficient that is the product of a nutrient target concentration and a unit conversion factor. The TMDL is also expressed as the sum of allowable loading from significant sources plus a margin of safety (MOS) to account for uncertainty in the source loading estimates. Conceptually, this definition is expressed by the following equation:

$$TMDL = \Sigma\, WLAs + \Sigma\, LAs + (MOS)$$

Where:
- WLA = wasteload allocations for point sources
- LA = load allocations for nonpoint sources
- MOS = margin of safety.

The approach to allocations in the agricultural Redwater TPA is to allocate allowable nutrient loading to natural background sources, plus a composite load allocation to agricultural sources identified by the STEPL model (croplands, rangelands and livestock confinements), plus an implicit margin of safety. This conceptual allocation approach is illustrated in **Figure 5-10**.

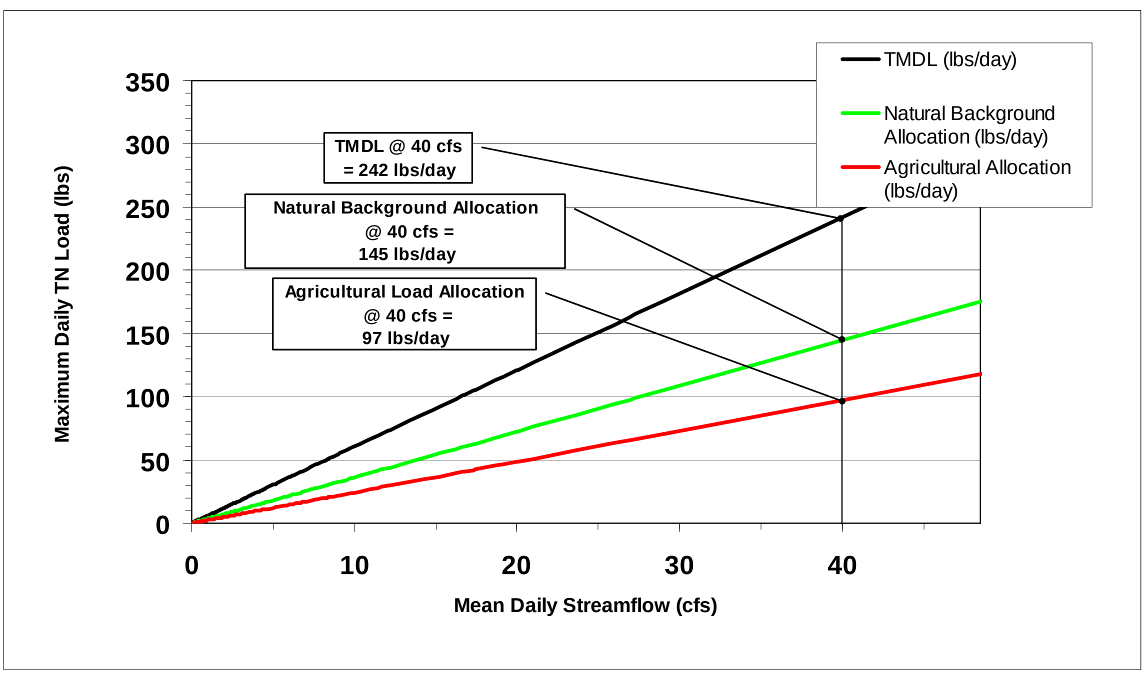

Figure 5-10. Total nitrogen TMDL and allocations to natural background and agricultural sources at a mean daily discharge of 40cfs.

The TMDL graph in the figure is the solution to **Equation 5-1**, based on the TN target of 1,120 µg/L. The green line in the figure is the graph for natural background loading based on the assumed background TN concentration of 670 µg/L for Montana prairie streams. The TN TMDL, minus background loading, is the allowable loading allocated to composite agricultural cropland, rangeland and livestock confinement sources. The vertical line extending from the x-axis at 40 cfs intersects the line graphs of the agricultural and natural background allocations at values that sum to the TMDL at 40 cfs. This relationship between allocations and the TMDL holds for all mean daily stream flow values.

Conservative assumptions implicit in nutrient target development and in the STEPL modeling exercise to identify significant sources provide a margin of safety against nutrient loading at levels that would damage beneficial uses. The elements of the margin of safety are discussed below in **Section 5.8**.

The sections that follow describe nutrient TMDLs, load allocations and needed load reductions for individual streams. TMDLs will be illustrated as graphs of load duration curves for each stream that also show points representing measured loads calculated from analysis results that, in most cases, have coincident flow measurements. This graphing format shows the relationship between loading and seasonal stream hydrologic condition, shows the variability in loading measurements, and helps to identify data gaps to guide future monitoring.

The level of current loading is based on growing season means for nutrient parameters calculated from the available data. Needed reductions to current loading are defined by the difference between nutrient concentrations under current conditions and target concentrations. TMDLs, allocations and needed reductions are presented in tables containing daily loading examples at selected flow values. Nutrient TMDLs and allocations generally apply during the growing season extending from mid-June through September. The period of applicability is extended into the month of May for the Redwater River near Circle, as described below in **Section 5.6.9**.

5.6.4 East Redwater Creek

East Redwater Creek is an intermittent tributary to the lower Redwater River. Continuous stream flow records are not available for East Redwater Creek. Mean daily discharge was estimated using flow data from USGS station 06177825 on the lower Redwater River near Vida. The daily fraction of total annual flow derived from the flows at Vida were multiplied by total annual discharge in East Redwater Creek obtained by inserting basin characteristics into regression equations developed by Omang and Parrett (1984).

5.6.4.1 East Redwater Creek Nutrient Load Analysis

The line in the **Figure 5-11** graph is the TN TMDL based on **Equation 5-1**. The data points in the graph are the daily TN loads based on growing season analytical results. The graph indicates that growing season TN loading in excess of the TMDL has been measured under a variety of flow conditions. The mean TN concentration for East Redwater Creek samples is 2,282 µg/L. **Figure 5-12** shows the load duration curve for the TP TMDL in East Redwater Creek along with measured daily loads based on analytical results.

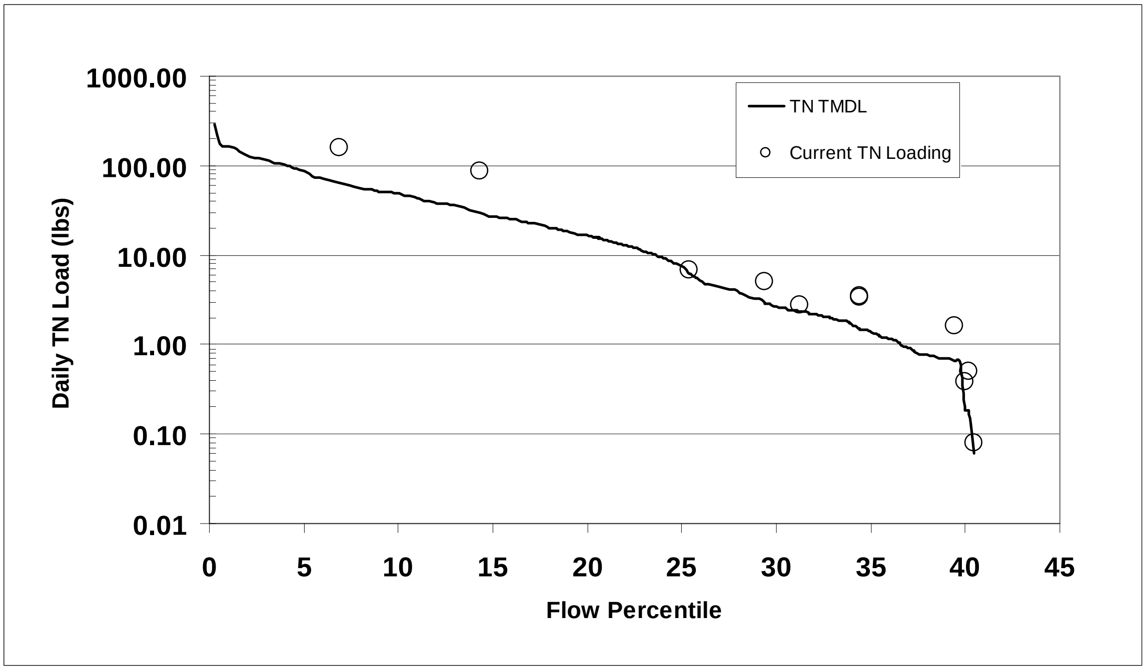

Figure 5-11. Load duration curve for the TN TMDL and current TN loading in East Redwater Creek

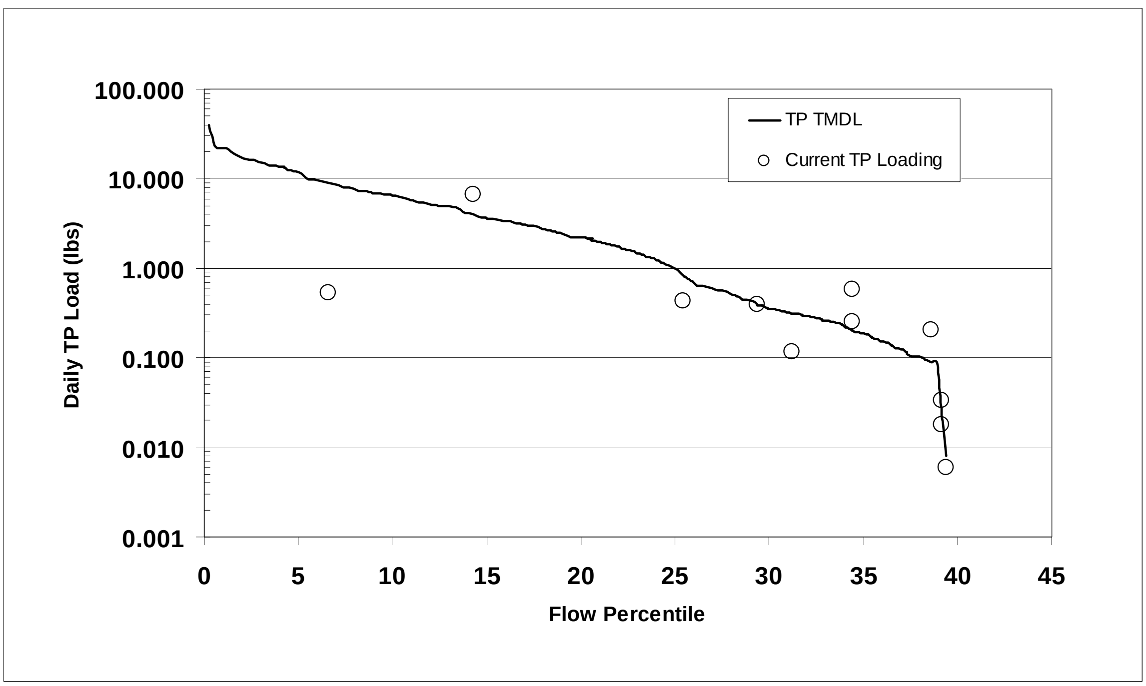

Figure 5-12. Load duration curve for the TP TMDL and current TP loading in East Redwater Creek

The solid line in the graph is the TP TMDL based on **Equation 5-2**. Although sampling occurred across a range of flow conditions, those exceeding the TMDL occurred most often during dry conditions. The mean growing season TP concentration from the existing data record is 192 µg/L.

The NO_{3+2}-N listing for East Redwater Creek stems from a single target exceedence and the timing of the listing prior to development of the higher 76 µg/L target for the unglaciated Northwestern Great Plains ecoregion. A concentration of 30 µg/L in a sample from a glaciated area (site 5288NO01), for which the target is 20 µg/L, is the single genuine target exceedence in the NO_{3+2}-N data record. A value of 70 µg/L, measured in a sample from an unglaciated area, was considered excessive until development of the higher 76 µg/L target. All analysis results for samples with a corresponding flow value contained less than detectable levels of NO_{3+2}-N (< 10 µg/L).

Figure 5-13 is a graph of the NO_{3+2}-N TMDL based on **Equation 5-3** and the targets of 20 and 76 µg/L for the two prairie ecoregions in the East Redwater Creek watershed. Points on the graph for current loading cannot be shown since all results with accompanying flows contained less than detectable amounts of NO_{3+2}-N. The growing season mean for NO_{3+2}-N in East Redwater is 17 µg/L. This concentration multiplied by mean daily flow is illustrated by the green line graph in **Figure 5-13** that lies below that for the TMDL.

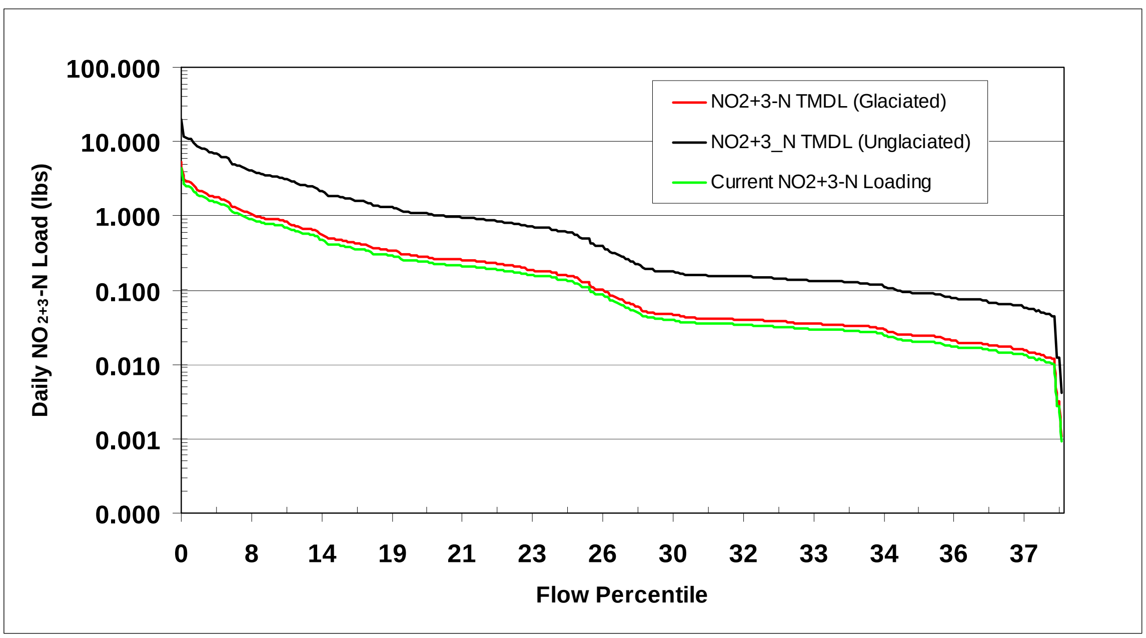

Figure 5-13. Load duration curves for the NO_{3+2}-N TMDLs (glaciated and unglaciated ecoregions) and current NO_{3+2}-N loading in East Redwater Creek

5.6.4.2 East Redwater Creek Nutrient Load Allocations

The approach to quantifying nutrient loads and allocations is to combine information from the following assessment sources:

1. Current loading as represented by growing season means for nutrient parameters calculated from the available data,

2. Allowable loading calculated from mean daily flows multiplied by nutrient target concentrations,
3. Natural background sources calculated from background nutrient parameter concentrations derived from a reference dataset of Montana prairie streams (Suplee 2007).
4. Loading from significant agricultural sources identified in the STEPL modeling exercise.

As discussed above in **Section 5.6.2**, nonpoint loading from croplands, rangelands and livestock confinements were considered sufficient to warrant load allocations. The amount of loading attributable to natural background sources is the mean daily flow multiplied by background concentrations for nutrient parameters (**Section 5.5.1**). Nutrient loads and allocations in this analysis are presented on a daily basis. However, because nonpoint agricultural production activities are by far the most significant loading sources, BMP source controls are more realistically applied annually. Vegetative filter strips on cropland, prescribed grazing on rangelands and diversion of runoff from livestock confinements are actually year-around restoration solutions. Reductions realized during spring runoff will lessen the accumulation in channel pools of sediment-bound loads that may later enter the water column during the growing season. **Table 5-23** contains example TMDLs and allocations for the 50th percentile flow in East Redwater Creek

Table 5-23. Current nutrient loads, TMDLs, allocations, and needed load reductions in East Redwater Creek.

Flow (cfs)	Nutrient Parameter	Current Load (lbs/day)	TMDL (lbs/day)	Background Load Allocation (lbs/day)	Agricultural Load Allocation (lbs/day)	Percent Reduction Needed
0.7	TN	8.63	4.2	2.50	1.70	51
	TP	0.73	0.56	0.18	0.38	23
	NO_3+$_2$-N *	0.06	0.08	0.04	0.04	0-30

* Example is for glaciated portion of the watershed.

The analysis concludes that a 51 percent reduction in current TN loading and a 22 percent reduction in current TP loading are needed to meet the corresponding TMDLs. Reductions in current NO_3+$_2$-N loading range from zero in the unglaciated portion of the watershed to 30 percent in the lower, glaciated area where a sample analysis result of 30 µg/L compared to the applicable target of 20 µg/L.

5.6.5 Horse Creek

Horse Creek is an intermittent Redwater River tributary with its mouth near the Town of Circle. Gaged flow data are not available for Horse Creek. Mean daily flows were estimated based on the hydrograph for Timber Creek at USGS station 06131120 and total annual discharge derived from basin characteristics and the regression equations of Omang and Parrett (1984).

5.6.5.1 Horse Creek Nutrient Load Analysis

The line graph in **Figure 5-14** is the TN TMDL calculated by **Equation 5-1**. Flow percentile values on the chart indicate that Horse Creek has little or no surface flow during much of the year. The data points on the chart are daily TN loads based on growing season water quality analysis with corresponding flow measurements. The measured daily TN loads consistently exceed the TMDL. The observations are clustered along the low flow portion of the curve. Little information is available on loading conditions during runoff from summer convectional storms. The mean growing season TN concentration in Horse Creek based on existing growing season data (**Appendix D**) is 3,799 µg/L.

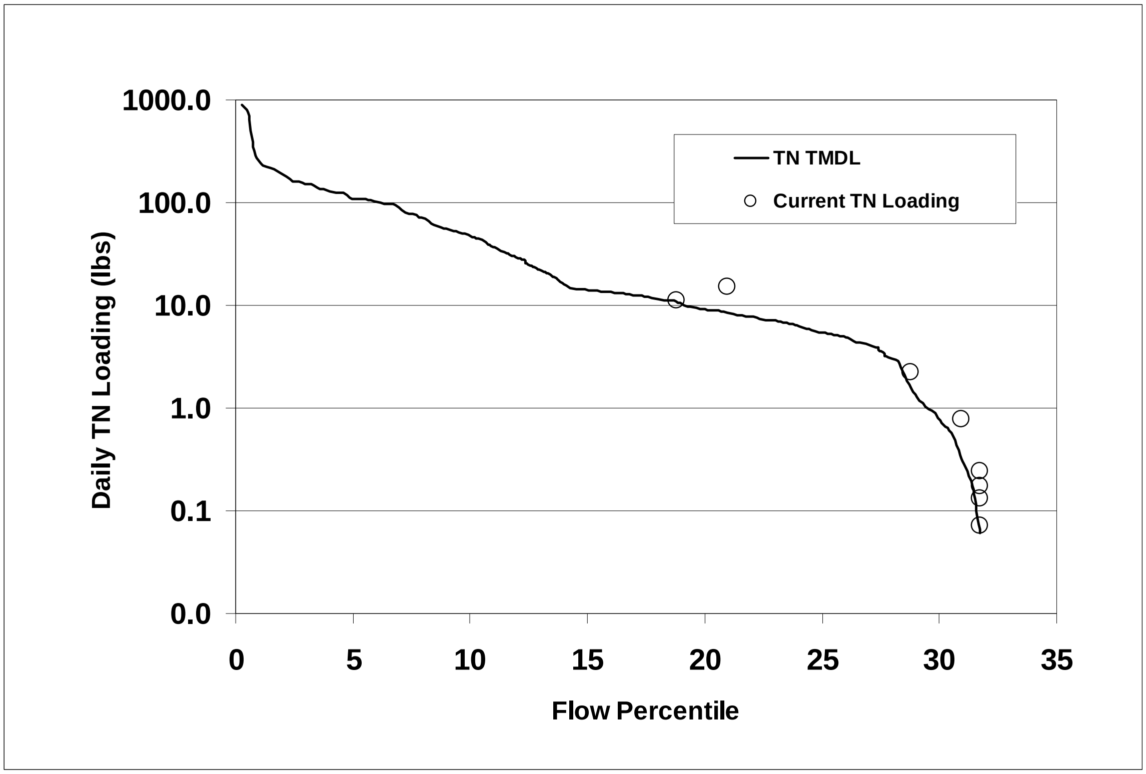

Figure 5-14. Load duration curve for the TN TMDL and current TN loading in Horse Creek

Figure 5-15 is the Horse Creek load duration curve for the TP TMDL based on **Equation 5-2** and a target of 150 µg/L. The graph also contains daily loading points from the growing season data record. Despite a mean growing season TP concentration of 238 µg/L, all growing season analysis results for TP that have coincident flow measurements are less than the target TP concentration of 150 µg/L. Therefore, all current daily loading points on the **Figure 5-15** graph are less than the corresponding TMDLs, and so fall below the TMDL line. The 10 samples collected from 2003 through 2008 (**Table 5-4**) with TP target exceedences had either no corresponding flow measurements or were collected under non-flowing conditions.

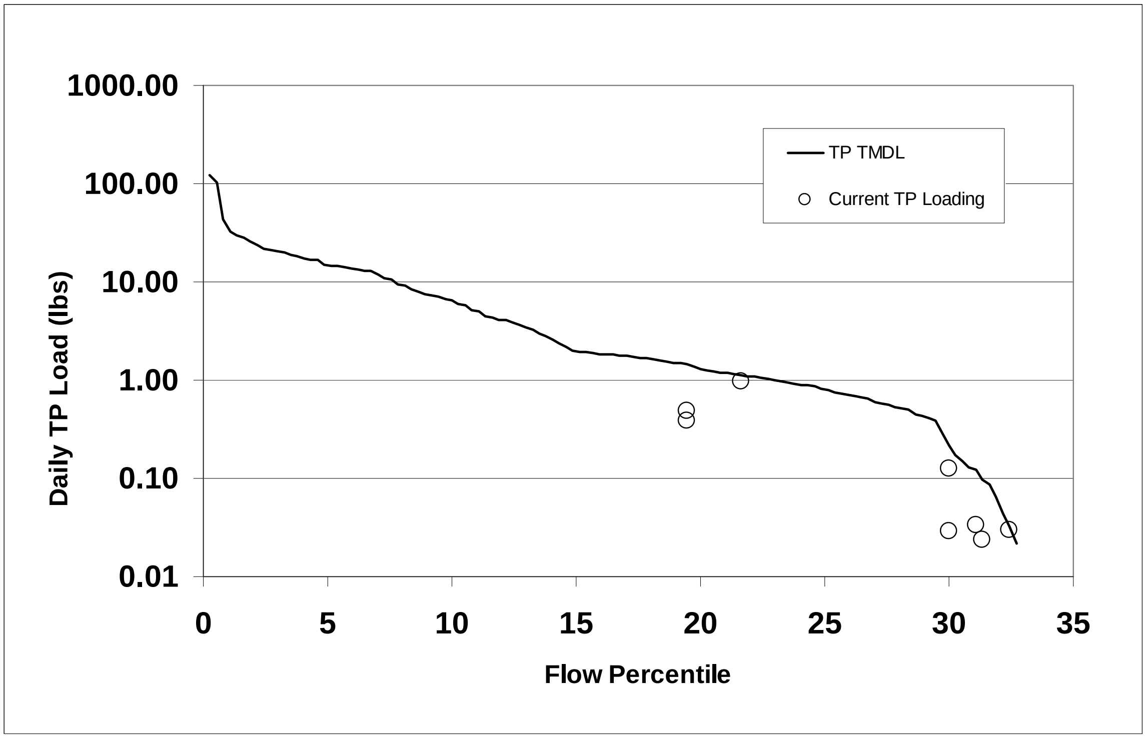

Figure 5-15. Load duration curve for the TP TMDL and current TP loading in Horse Creek

5.6.5.2 Horse Creek Nutrient Load Allocations

Using the allocation approach described above for East Redwater Creek, **Table 5-24** contains examples of current Horse Creek loading, TMDLs, allocations and needed load reductions at a flow of 0.1 cfs. The large departure of the mean growing season TN concentration (3,799 µg/L) from the TN target (1,120 µg/L) results in a large load reduction (70%) requirement. The results for diatom inferred DO in **Table 5-6** suggest that large nutrient loads are depressing DO concentrations in lower Horse Creek. A 38 percent reduction applies to Horse Creek TP loading.

Table 5-24. Example current loading, nutrient TMDLs, allocations and needed reductions in Horse Creek

Flow (cfs)	Nutrient Parameter	Current Load (lbs/day)	TMDL (lbs/day)	Background Load Allocation (lbs/day)	Agricultural Load Allocation (lbs/day)	Percent Reduction Needed
0.1	TN	2.05	0.60	0.36	0.24	70
	TP	0.13	0.08	0.03	0.05	38

5.6.6 Nelson Creek

Nelson Creek is an intermittent tributary of Fort Peck Reservoir. The load duration curves in the discussions below are based on mean daily flows for USGS station 06131200 upstream of the Highway 24 crossing.

5.6.6.1 Nelson Creek Nutrient Load Analysis

Figure 5-7, used above in **Section 5.6.1** as an example load duration curve, contains a line graph of the Nelson Creek TN TMDL calculated according to **Equation 5-1**. The graph also contains daily TN loading points based upon the growing season TN monitoring record and measured stream discharge. The mean growing season TN concentration in Nelson Creek based on existing data is 1,921 mg/L. The graphed points for current daily TN loading are distributed across a wide range of stream discharge conditions.

Figure 5-16 is the corresponding load duration curve for the NO_3+$_2$-N TMDL in Nelson Creek based on the 76 µg/L target. The current level of NO_3+$_2$-N loading based on analytical results with corresponding flow measurements shows that most target exceedences occur under high flow conditions. The growing season mean for the Nelson Creek NO_3+$_2$-N dataset is 135 µg/L.

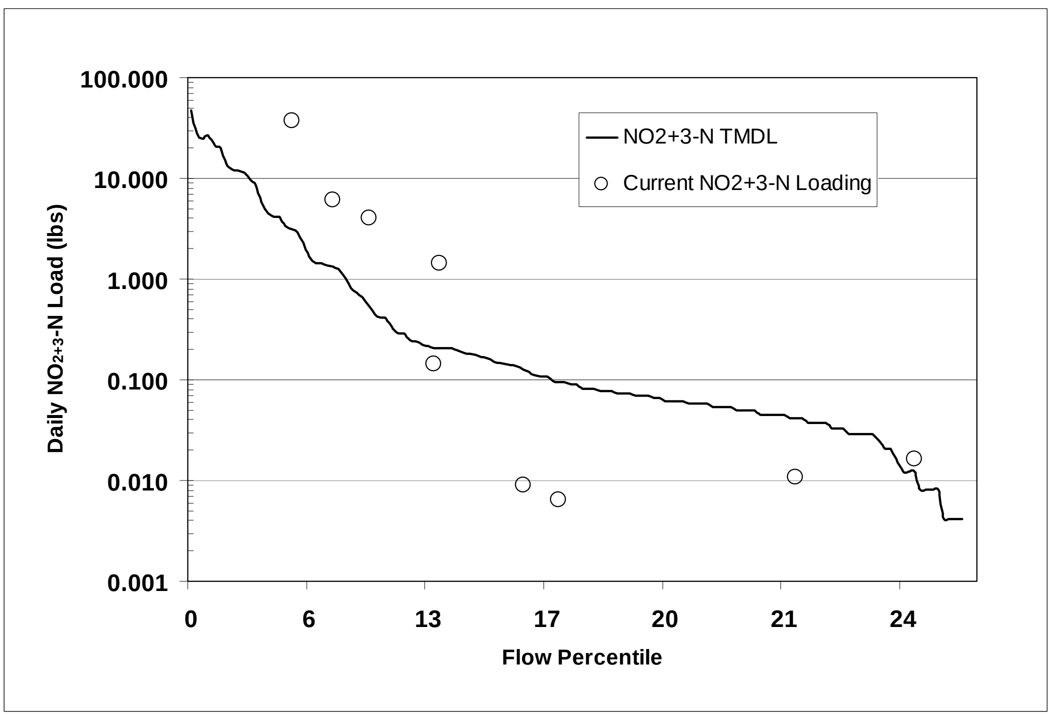

Figure 5-16. Load duration curve for the NO_3+$_2$-N TMDL and current NO_3+$_2$-N loading in Nelson Creek

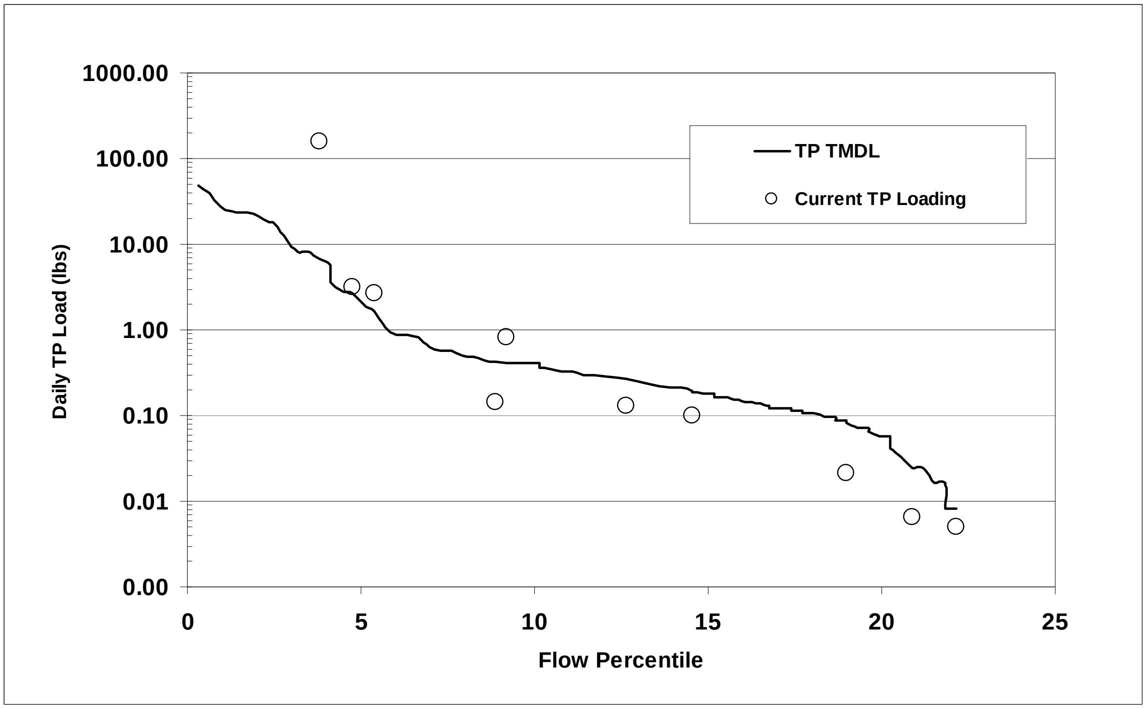

Figure 5-17. Load duration curve for the TP TMDL and current TP loading in Nelson Creek

Figure 5-17 contains the load duration curve of the TP TMDL in Nelson Creek based on **Equation 5-2**. Current TP loading points for Nelson Creek show most loading is associated with high flow events. The mean growing season TP concentration from the existing Nelson Creek data record is 380 µg/L.

5.6.6.2 Nelson Creek Nutrient Load Allocations

Table 5-25 contains the current loading, TMDLs, allocations and percent reductions in current loading needed to meet to meet TMDLs in Nelson Creek at a flow of 2.0 cfs. Current daily loads are calculated from flow multiplied by the mean growing season concentrations from the existing data record. Background loading is calculated using parameter concentrations suggested in the literature for prairie streams in Montana (Suplee 2007). Background loading subtracted from the TMDL is the allowable human-caused load. The percent needed reduction is the difference between current loading and the TMDL expressed as a percent of the current load.

Table 5-25. Current nutrient loads, TMDLs, allocations, and needed load reductions in Nelson Creek.

Flow (cfs)	Nutrient Parameter	Current Load (lbs/day)	TMDL (lbs/day)	Background Load Allocation (lbs/day)	Agricultural Load Allocation (lbs/day)	Percent Reduction Needed
2.0	TN	20.75	12.10	7.24	4.86	42
	TP	4.10	1.62	0.52	1.10	61
	NO_{3+2}-N *	1.46	0.82	0.11	0.71	44

The analysis concludes the need for a 42 percent TN reduction, a 61 percent reduction in TP loading, and a NO_{3+2}-N load reduction of 44 percent. The data record suggests that loading reductions are most needed under high flow conditions during the growing season.

5.6.7 Pasture Creek

Pasture Creek is an intermittent Redwater River tributary. Pasture Creek load duration curves were developed from the hydrograph of Timber Creek, a gaged intermittent stream in the planning area.

5.6.7.1 Pasture Creek Nutrient Load Analysis

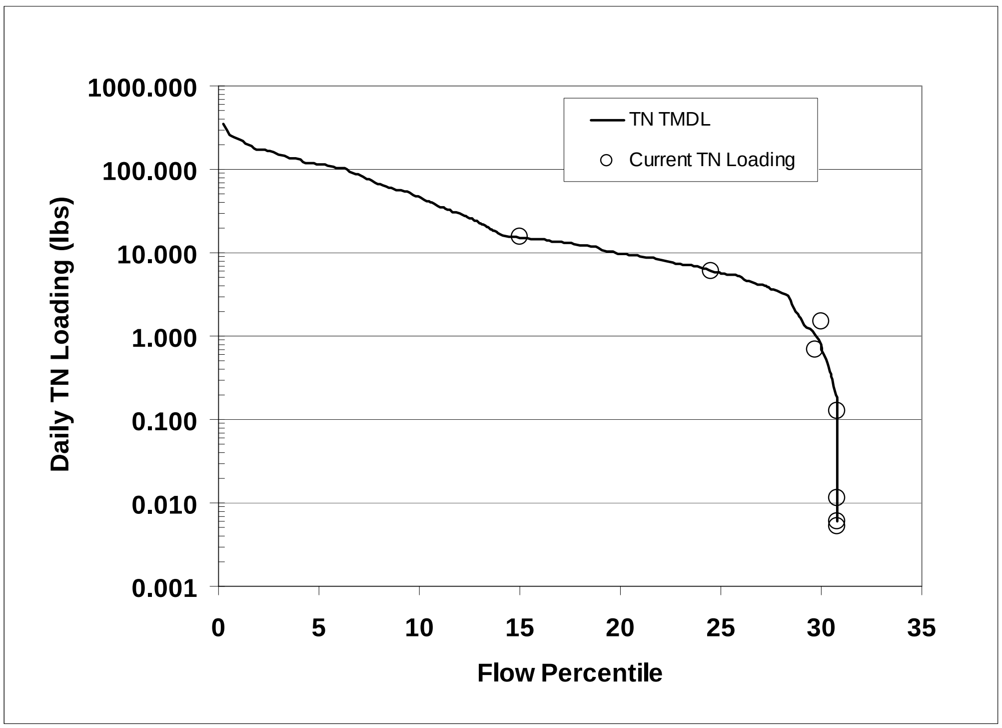

Figure 5-18. Load duration curve for the TN TMDL and current TN loading in Pasture Creek

Figure 5-18 shows the load duration curve of the TN TMDL for Pasture Creek, based on **Equation 5-1**. The mean growing season TN concentration is 1,835 µg/L. Pasture Creek is a sedimentary upland watershed lacking the river breaks topography of Nelson Creek. The flow duration curve shows a short base flow period followed by rapid evaporative dewatering. All current TN loads in the figure are based on samples collected under low flow conditions.

5.6.7.2 Pasture Creek Nutrient Load Allocations

Table 5-26 contains values for current mean daily loading, the TN TMDL, TN allocations and needed reduction for TN in Pasture Creek at a flow of two cfs.

Table 5-26. Example current daily TN load, TMDL, allocations, and needed TN load Reduction in Pasture Creek.

Flow (cfs)	Nutrient Parameter	Current Load (lbs/day)	TMDL (lbs/day)	Background Load Allocation (lbs/day)	Agricultural Load Allocation (lbs/day)	Percent Reduction Needed
2.0	TN	16.29	12.10	7.24	4.86	26

The analysis of existing data concludes the need for a 26 percent reduction to current loading. Additional monitoring is needed to characterize infrequent high flow loading conditions during the growing season.

5.6.8 Prairie Elk Creek

Prairie Elk Creek is an intermittent tributary to the Missouri River. The following load duration curves were developed from flow records for USGS station 06175540 near the mouth of Prairie Elk Creek.

5.6.8 1 Prairie Elk Creek Loading Analysis

Figure 5-19 shows the duration curve of the TN TMDL for Prairie Elk Creek, based on **Equation 5-1**. Based on existing data, the mean growing season TN concentration is 1,833 µg/L. The clustering of measured TN loads around the 32nd percentile flow (about 2.0 cfs) puts downward pressure on the growing season mean. This is offset by several extremely high loads measured during common summer storm events.

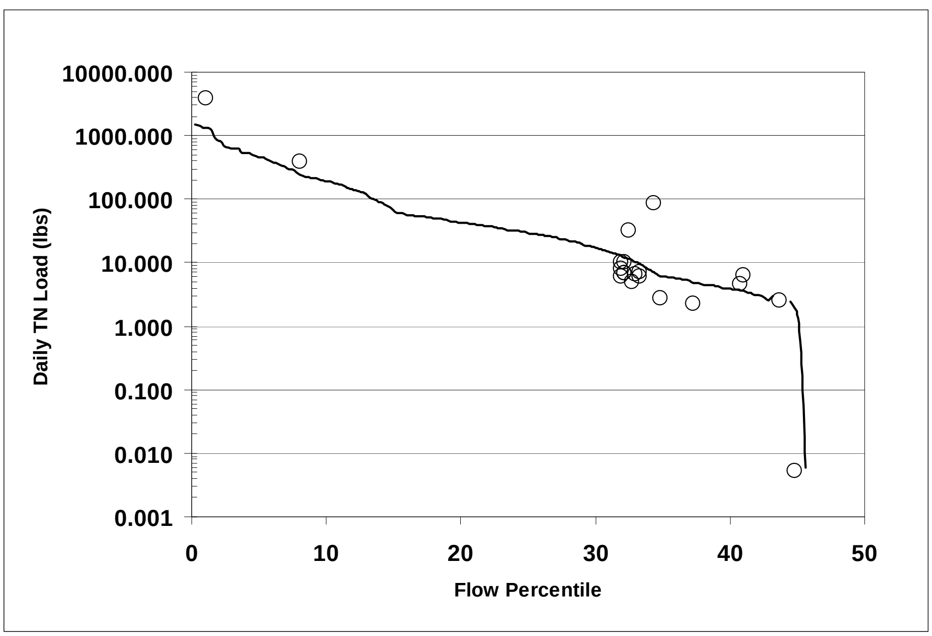

Figure 5-19. Load duration curve for the TN TMDL and current TN loading in Prairie Elk Creek

Figure 5-20 shows the load duration curve for the TP TMDL based on **Equation 5-2** and measured growing season TP loads based on existing data with corresponding flow measurements. As with TN, measured data are clustered along the dry conditions portion of the curve. All loads measured under high flow conditions are greater than the TMDL. The mean growing season TP concentration is 549 µg/L.

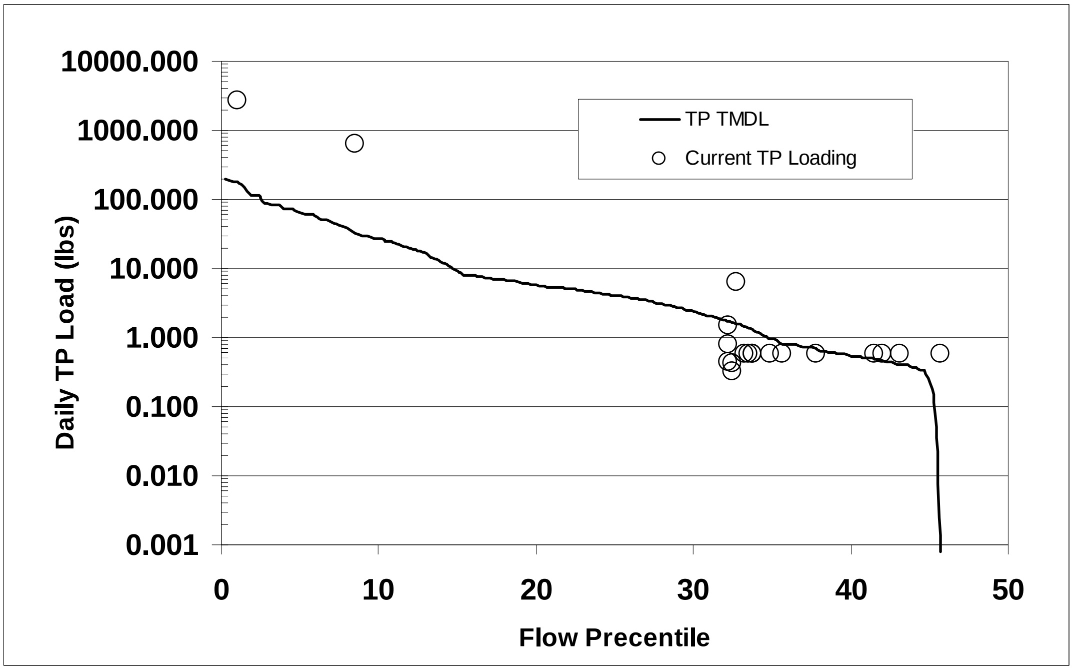

Figure 5-20. Load duration curve for the TP TMDL and current TP loading in Prairie Elk Creek

5.6.8 2 Prairie Elk Creek Load Allocations

Table 5-27 contains daily values for current TN and TP loading, the TN and TP TMDLs, allocations and needed TN and TP reductions for Prairie Elk Creek at the average daily growing season base flow of 0.8 cfs.

Table 5-27. Example Current Loads, Nutrient TMDLs, Allocations and Needed Reductions for Prairie Elk Creek

Flow (cfs)	Nutrient Parameter	Current Load (lbs/day)	TMDL (lbs/day)	Background Load Allocation (lbs/day)	Agricultural Load Allocation (lbs/day)	Percent Reduction Needed
0.8	TN	7.92	4.84	2.89	1.95	39
	TP	2.37	0.65	0.21	0.44	73

The analysis of existing data concludes the need for a 39 percent reduction in current TN loading and a 73 percent reduction in TP loading.

5.6.9 Redwater River, Hell Creek to Buffalo Springs Creek

The nutrient listed segment of the Redwater River receives loading from natural background sources, upstream agricultural sources, loading from the Circle WWTP (**Section 5.5.3**), and loading from Horse Creek. **Figure 5-21** is a box plot graph of TN concentrations for the five monitoring sites along the listed segment. The relative locations of the WWTP and the mouth of Horse Creek are shown in the figure. **Figure 5-22** is a similar graph of TP concentrations for the five sites.

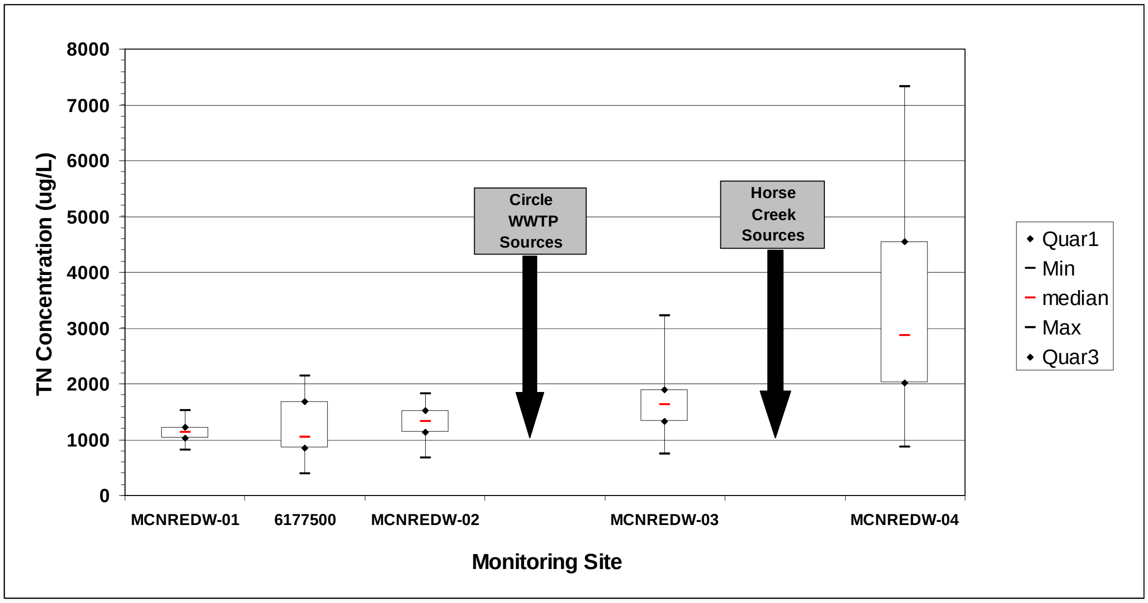

Figure 5-21. Box Plot Graph of TN Concentrations for Redwater River Monitoring Sites Showing Relative Source Locations.

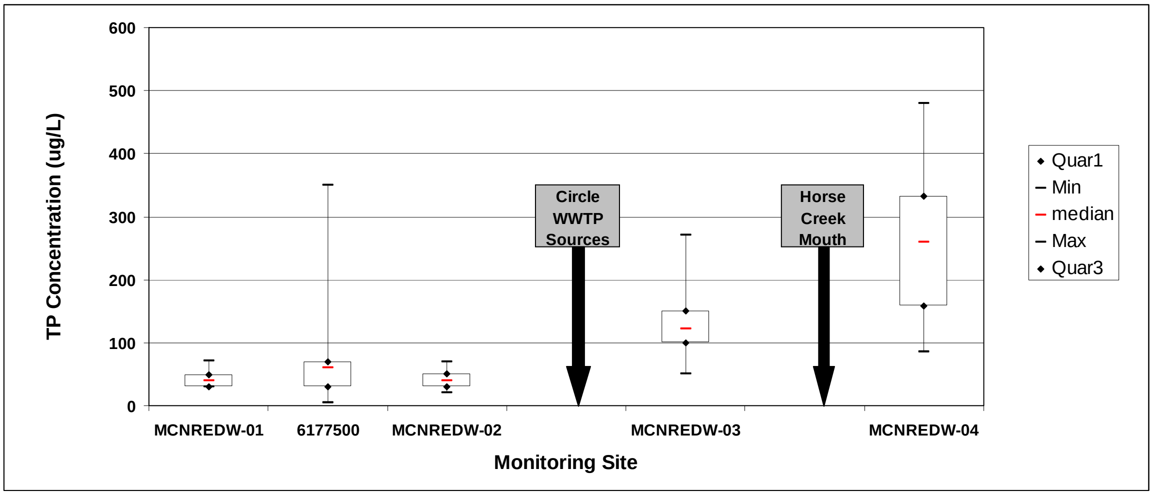

Figure 5-22. Box Plot Graph of TP Concentrations for Redwater River Monitoring Sites Showing Relative Source Locations.

Data from the three sites upstream of the WWTP are used to quantify upstream loading. Data from sites MCNREDW-03 and MCNREDW-04 are used to quantify respective loading from the Circle WWTP and Horse Creek.

5.6.9.1 Loading from Upstream Sources

Figure 5-23 shows the locations of three water quality monitoring sites used to characterize upstream nutrient loading: MCNEDW-01, MCNEDW-02 and USGS station 06177500. They are located upstream of the Circle WWTP pond system outlined in red in the figure. The growing season mean TN concentration in samples from these three stations is 1,241 µg/L.

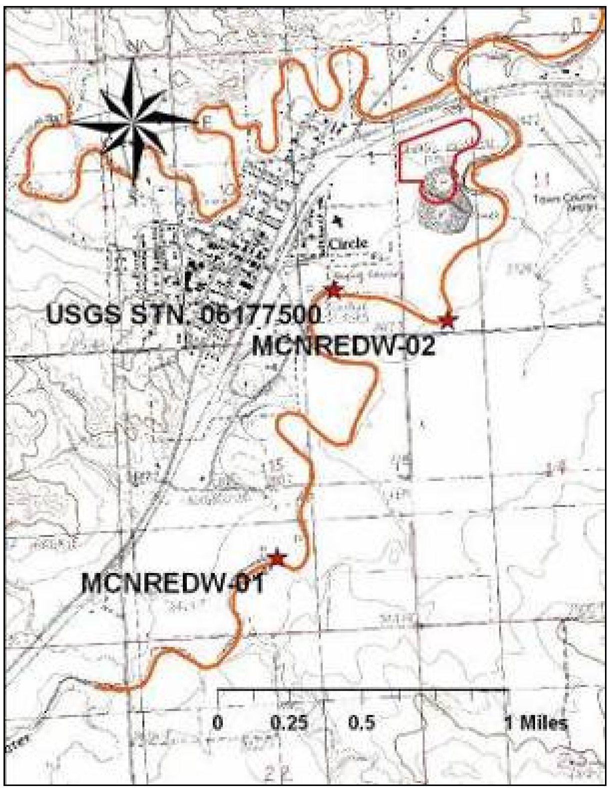

Figure 5-23. Monitoring Stations Used to Characterize Upstream Nutrient Loading to the Redwater River.

Figure 5-24 is the load duration curve for the TN TMDL according to **Equation 5-1**; using mean daily flows for the USGS station. **Figure 5-24** also shows 34 growing season loading points based on TN analysis results with corresponding flow measurements for the three monitoring sites. Fifteen TMDL exceedences have occurred over a range of flow conditions. Measured exceedences most commonly occur under low flow conditions.

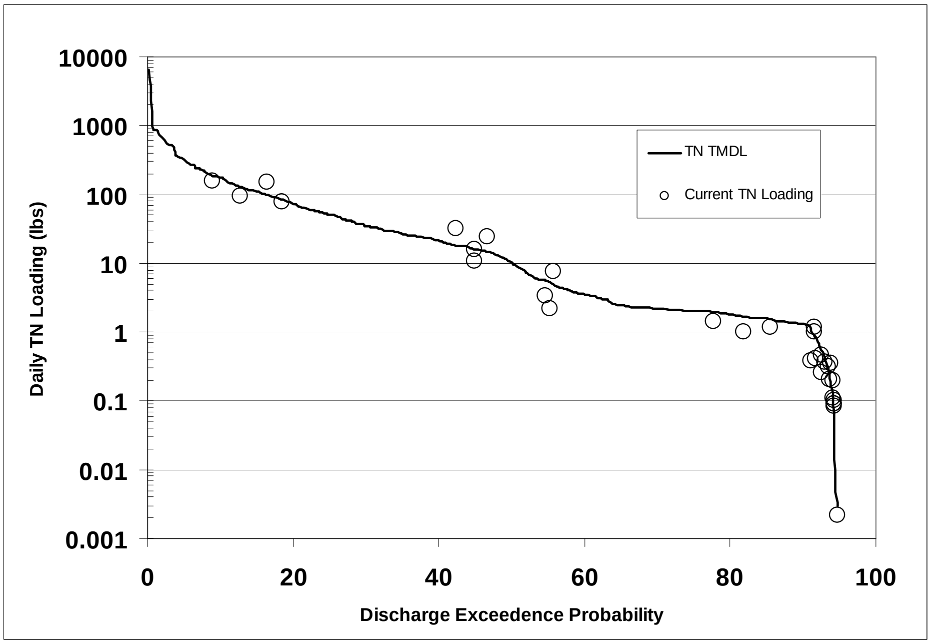

Figure 5-24. Load duration curve for the TN TMDL and current TN Loading to the Redwater River at sites MCNREDW-01, MCNREDW-02, and USGS Station 06177500

Figure 5-25 is shows the load duration curve for the TP TMDL and daily growing season TP loads based on existing data and flow measurements for the three monitoring sites in **Figure 5-23**. As with TN, measured TP data are clustered along the minimum flow portion of the curve. Only one of the illustrated daily TP loads exceeds the TMDL. The mean growing season TP concentration for the selected monitoring sites is 86 µg/L, compared to the TP target of 150 µg/L.

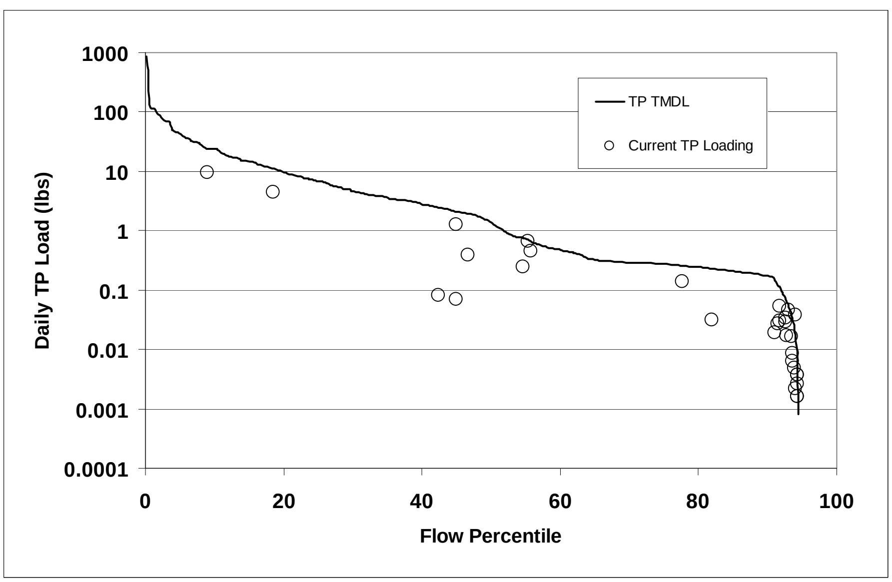

Figure 5-25. Load duration curve for the TP TMDL and current TP loading to the Redwater River at sites MCNREDW-01, MCNREDW-02, and 06177500

5.6.9.2 Loading from the Circle WWTP

Despite the total retention design of the newly constructed Circle WWTP pond system, the current MPDES permit allows for continued surface discharge to the Redwater River from Outfall 001. The permit limits (**Table 5-21**) do not include those for TN or TP. The Statement of Basis for the permit states that “Since any TP and TN impacts on the Redwater River would be extremely infrequent and of short duration, the Circle WWTP is not expected to cause or contribute to any further decline in water quality.” According to data from past surface discharges from the WWTP to the Redwater (**Section 5.5.3**), future permitted discharges from Outfall 001 would deliver 6.1 lbs/day of TN and 3.2 lbs/day of TP.

The analysis of TN loading from effluent seepage from the new pond system to local groundwater (**Section 5.5.3**, **Appendix E**) concludes that future seepage loading will be nearly eliminated by the system upgrade. The remaining seepage loading sources from the WWTP are from residual elevated nutrients in groundwater from past WWTP operations, leachate from surface disposal of approximately 3,100 tons of sewage sludge buried within the remaining footprint of the former pond system.

Nutrient water quality data from monitoring sites located down-gradient of the old pond system provides an estimate of past loading. **Figure 5-26** is a map of the Circle WWTP and two water quality monitoring sites located downstream of the facility. Site MCNREDW-03 is situated below the pond system and upstream of the mouth of Horse Creek. The difference between loading at MCNREDW-03 and that at MCNREDW-04 indicates, in part, the effects of Horse Creek loading. A portion of the difference in water quality between these two sites may also be due to loading from past operations of the Circle pond system.

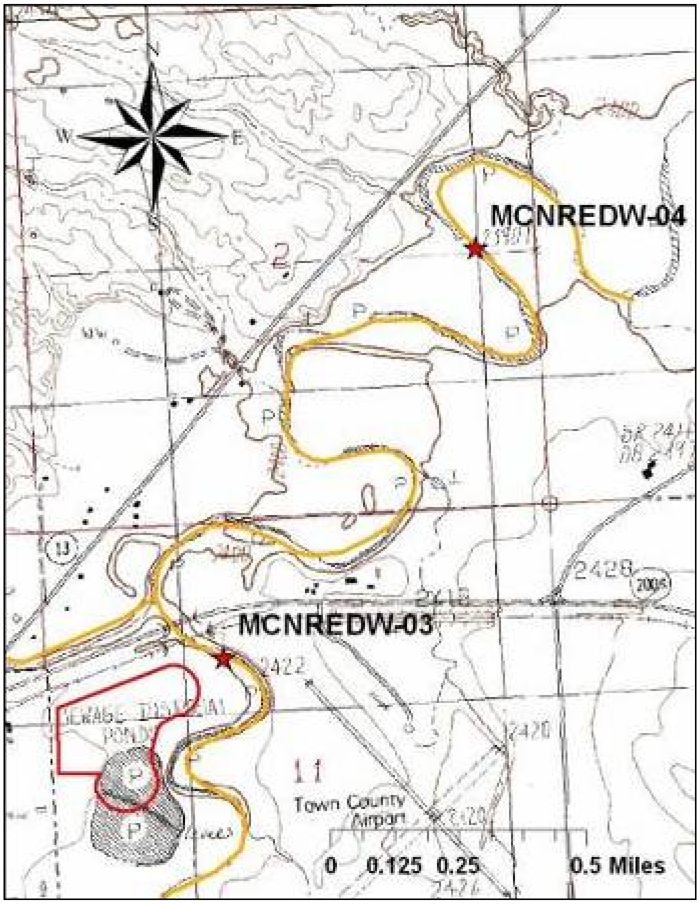

Figure 5-26. Location Map of Redwater River Monitoring Sites below the Circle WWTP and Below the Mouth of Horse Creek.

Of the 14 TN analysis results available for site MCNREDW-03, only two results have corresponding flow measurements. In order to compare daily loading down-gradient of the ponds to the TN TMDL, mean daily flows at station 06177500 that correspond to sampling dates were multiplied by TN concentration results for site MCNREDW-03. Of the 14 loading points graphed in **Figure 5-27**, 12 exceed the TN TMDL. The exceedences occur over a broad range of flow conditions. The mean growing season TN concentration at MCNREDW-03 is 1,706 µg/L, a 39 percent increase over the upstream TN mean of 1,241 µg/L.

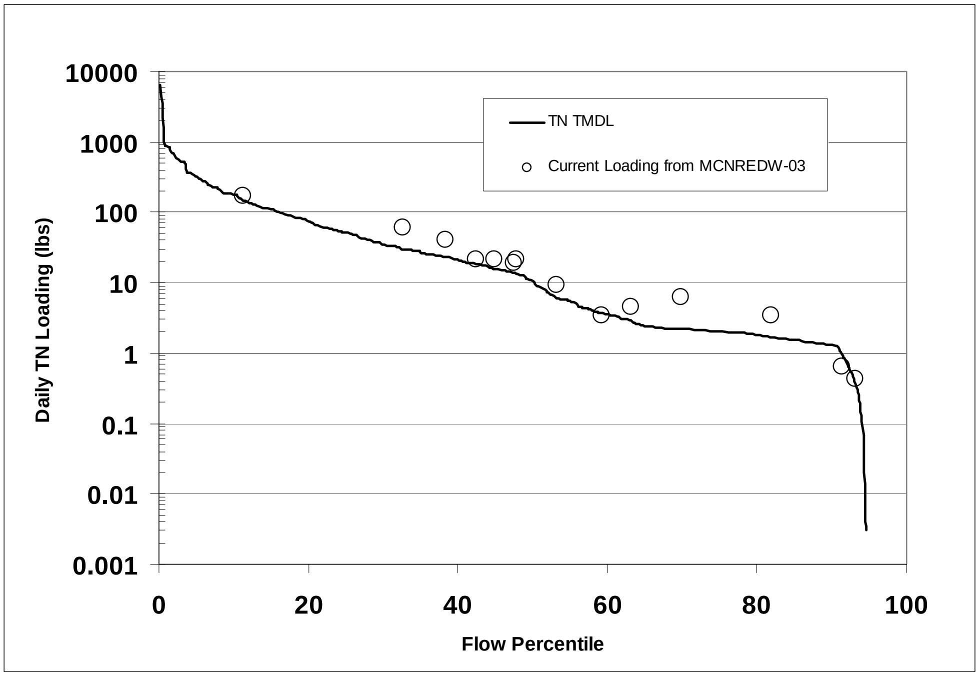

Figure 5-27. Load duration curve for the TN TMDL and current TN loading to the Redwater River at site MCNREDW-03.

Figure 5-28 is the load duration curve of the TP TMDL and the individual points for TP loading at site MCNREDW-03, based on mean daily flows at USGS station 06177500. The mean TP concentration at the site is 136 µg/L, less than the TP target of 150 µg/L but more than double the upstream TP concentration mean of 58 µg/L.

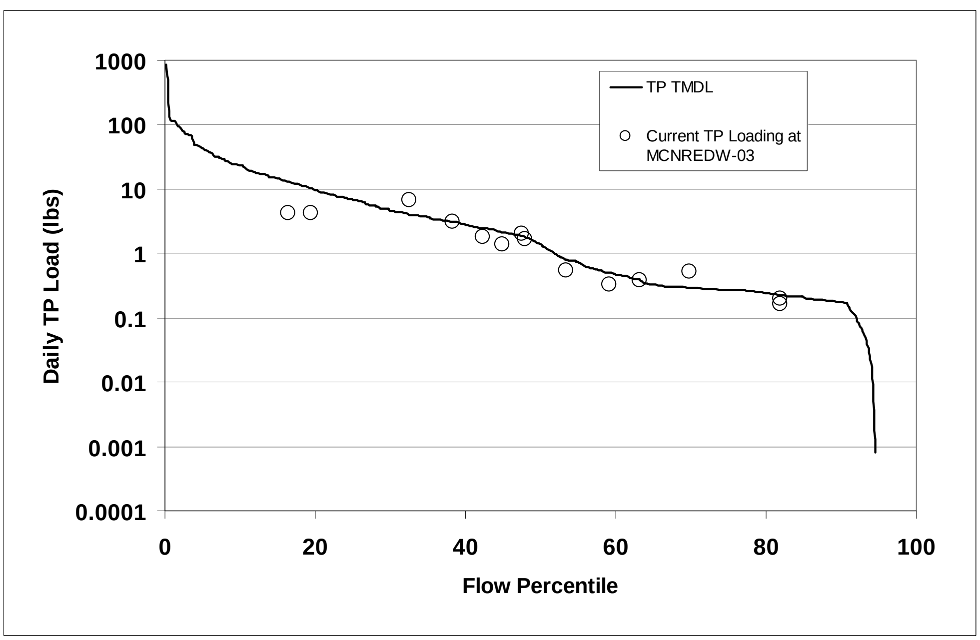

Figure 5-28. Load duration curve for the TP TMDL and current TP loading to the Redwater River at site MCNREDW-03.

Two lines of evidence point to the Circle WWTP pond system as a loading source. The first is the measured nutrient concentration increases at MCNREDW-03 compared to the three upstream monitoring sites. The TN concentration increases by 39 percent and the TP concentration more than doubles. The difference between pre- and post-upgrade nitrogen loading, shown in the **Appendix E**, also indicates significant loading prior to the system upgrade. The estimated daily TN load from the former pond system is 2.3 pounds, compared to a small fraction of a pound (0.004) after the upgrade.

Surface sludge disposal is assumed to have a seepage loading effect from precipitation infiltrating through the disposal area. **Appendix E** also contains the loading analysis for this source. Assuming a precipitation infiltration fraction of 20 percent, and an assumed nitrate concentration of 10.6 mg/L in the leachate, the disposal area would contribute about 0.2 lbs/day of nitrogen to the Redwater River.

5.6.9.3 Nutrient Loading to the Redwater River Below Horse Creek.

Monitoring site MCNREDW-04 is located about two stream miles below the mouth of Horse Creek and about one mile above the end of the listed river segment (**Figure 5-24**). There are 12 analytical results each for growing season TN and TP at MCNREDW-04. Coincident flow measurements are only available for the two 2008 sampling events. **Figure 5-29** is the load duration curve of the TN TMDL and daily TN loads at MCNREDW-04 based on **Equation 5-1**, using mean daily flows from station 06177500.

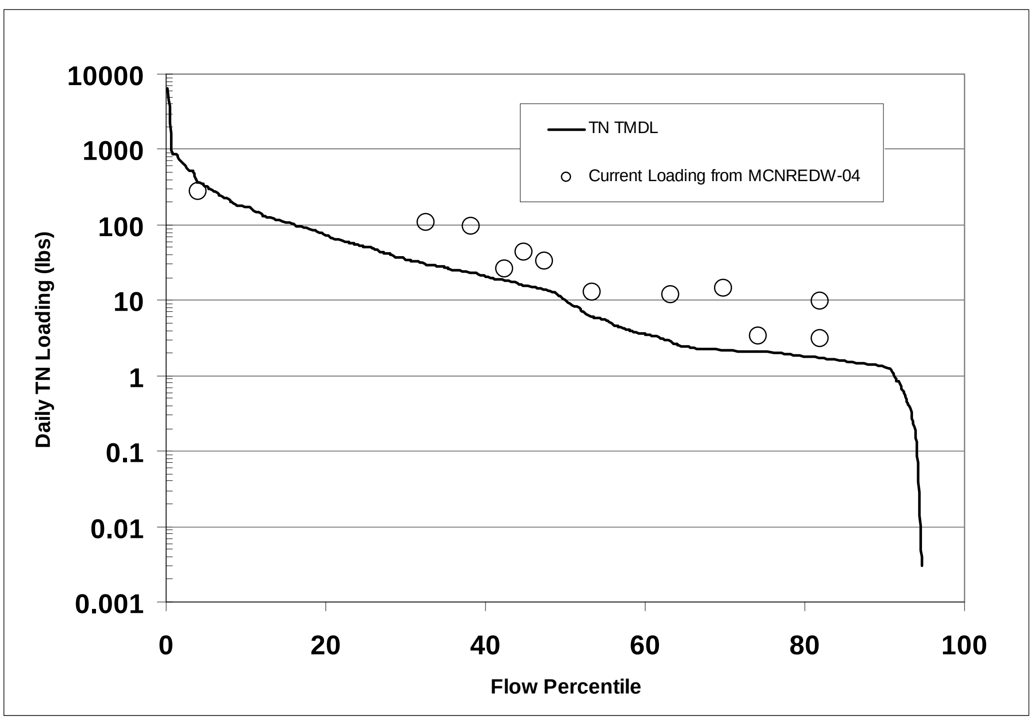

Figure 5-29. Load duration curve for the TN TMDL and current TN loading to the Redwater River at site MCNREDW-04.

Eleven of 12 measured daily loads exceed the TMDL. The mean growing season TN concentration at MCNREDW-04 is 3,472 µg/L, compared to 1,706 µg/L at site MCNREDW-03.

Figure 5-30 is the load duration curve of the TP TMDL and current daily TP loads at MCNREDW-04. Nine of 12 TP results exceeded the TMDL; the mean TP concentration is 260 µg/L. This is a 91 percent increase over the mean TP concentration at MCNREDW-03. Although Horse Creek, with its elevated TN (3,799 µg/L) and TP (238 µg/L) concentrations, has a large influence on Redwater River water quality, it does not account for the entire increase between sites MCNREDW-03 and MCNREDW-04.

At a flow rate of 0.1 cfs, the mean daily TN load from Horse Creek is 2.05 lbs/day (**Table 5-24**). This load, added to 3.09 lbs/day calculated for MCNREDW-03 at 0.335 cfs, should result in a loading rate of 5.14 lbs/day (2.05+3.09) in the Redwater River flowing at 0.435 cfs (0.1+0.335) downstream of Horse Creek. The combined TN load of 5.14 lbs/day is only 63 percent of the 8.16 lbs/day calculated from the 3,472 µg/L mean TN concentration at MCNREDW-04 multiplied by the combined flow of 0.435 cfs. Therefore, 37 percent of the TN loading at MCNREDW-04 remains unaccounted for after Horse Creek loading is added to loading from the Redwater River above Horse Creek.

A similar relationship exists with TP loading at MCNREDW-04. **Figure 5-30** is the TP load duration curve and current daily TP loads calculated from analytical results at MCNREDW-04. The TMDL is commonly exceeded across a range of moderate to low flows.

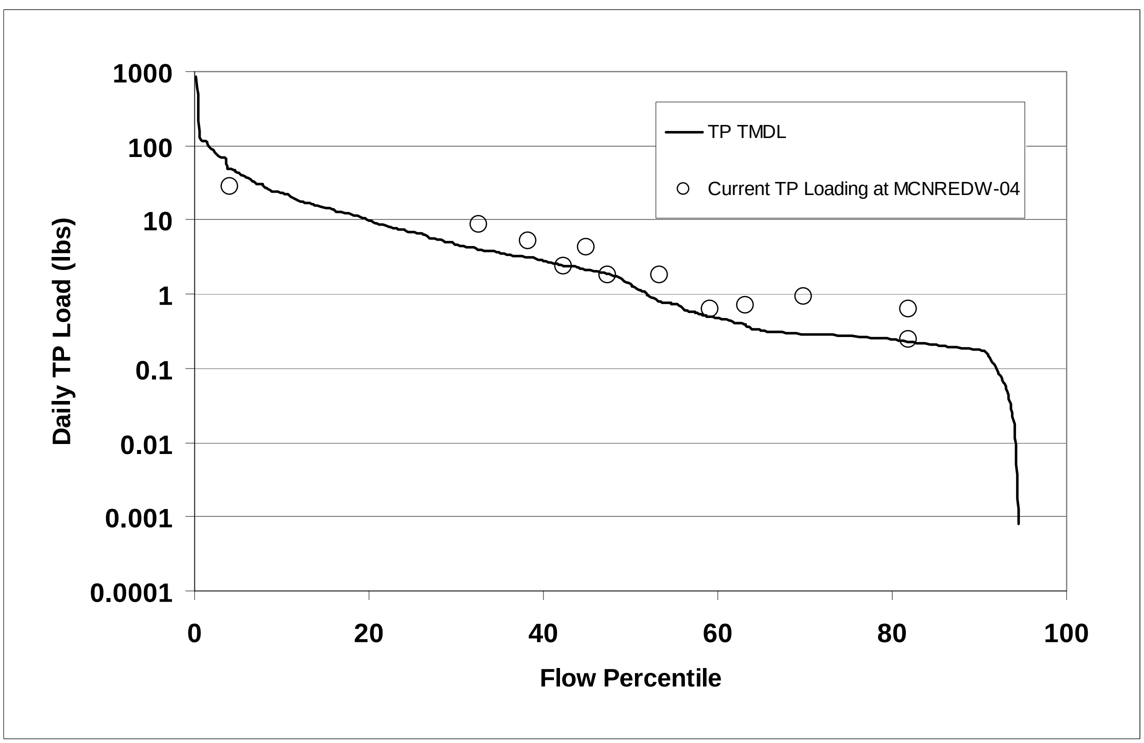

Figure 5-30. Load duration curve for the TP TMDL and current TP loading to the Redwater River at site MCNREDW-04.

The mean growing season TP concentration of 260 µg/L at site MCNREDW-04, multiplied by a stream flow rate of 0.435 cfs (and the unit conversion factor of 0.0054), gives an average daily TP load of 0.61 pounds. The daily TP load from Horse Creek at 0.1 cfs is 0.13 pounds. Loading from the Redwater River above Horse Creek at 0.335 cfs and a TP concentration of 136 µg/L is 0.25 lbs/day. The sum of upstream TP loading equals 0.38 pounds, only 62 percent of the 0.61 pounds calculated for site MCNREDW-04. There is an apparent source of both TN and TP loading to the river at MCNREDW-04 that is not accounted for by the sum of surface water loading from Horse Creek plus that from the Redwater River above Horse Creek. The magnitude of this source is shown in the difference between data distributions for sites MCNREDW-03 and MCNREDW-04 in **Figures 5-21** and **5-22** above.

5.6.9.4 Redwater River Nutrient Load Allocations

The nutrient loading analysis in **Sections 5.6.9.1-3** documents increasing downstream concentrations of both TN and TP from the upper to the lower end of the listed river segment. The magnitude of potential agricultural loading adjacent to the eight-mile length of the listed segment is assumed small compared to that from the 550 square miles of watershed area upstream of the segment. Loading from agricultural sources in the upper watershed is accounted for in the water quality monitoring records of sites MCNEDW-01, MCNEDW-02 and 06177500. There are several possible sources for the 40 percent increase in TN loading and the more than doubling of the TP loading along the 1.4 mile reach between station 06177500 and site MCNREDW-03. There are likely residual nutrient concentrations in local groundwater from past operations of the former 17-acre pond system. The preliminary engineering report (Interstate Engineering 2004) describes the possibility of leakage from aging segments of the existing sewage collection system. According to local stakeholders, a number of individual domestic septic systems are not connected to the WWTP. These systems may be affecting local groundwater and surface water near the mouth of Horse Creek.

The **Appendix E** estimate of nitrogen loading from the upgraded pond system is too small (0.004 lbs/day) to warrant a meaningful TN allocation to seepage from the new system. Total P loading from this source is likely even smaller given the tendency of phosphorus to become fixed to aquifer sediments. The remaining potential sources of loading include a combination of leachate seepage through the disposed sewage sludge, discharges from the municipal sewage collection system, unconnected individual septic systems and unspecified local agricultural sources.

Table 5-28 contains example TN and TP TMDLs, load allocations (LA) and waste load allocations (WLA) that apply May through September to the Redwater River below the mouth of Horse Creek at the mean growing season base flow of 0.435 cfs. Allocations are to:

1. Natural background sources upstream of Horse Creek,
2. Agricultural loading upstream of Horse Creek,
3. Seepage loading from surface sludge disposal,
4. Horse Creek TMDLs for TN and TP (Table 5-23),
5. Direct discharges from the Circle WWTP outfall and,

6. A composite load from past WWTP operations, unconnected septic systems and unspecified agricultural sources affecting the river between MCNREDW-03 and MCNREDW-04.

Allocations to Redwater River sources above Horse Creek assume a mean daily river discharge of 0.335 cfs. This is the mean base flow discharge rate for the Redwater River at Circle. Horse Creek TMDLs assume a mean daily discharge in Horse Creek of 0.10 cfs, the mean growing season base flow discharge for Horse Creek.

Table 5-28. Example Nutrient TMDLs and Allocations for the Redwater River below Horse Creek

Nutrient	TMDL (lbs/day)	Natural Background LA (lbs/day)	Agricultural LA (lbs/day)	Sludge Disposal LA (lbs/day)	Circle WWTP Surface Discharge WLA (lbs/day)	Horse Creek LA (lbs/day)	Combined Domestic and Agricultural LA (lbs/day)
TN	2.63	1.21	0.62	0.20	0.0	0.60	0.0
TP	0.35	0.09	0.14	0.04	0.0	0.08	0.0

The WLA to surface water discharges from the Circle WWTP (Outfall 001) is set at zero. The current treatment capabilities of the system would release effluent that would deliver 6.1 lbs/day of TN and 3.2 lbs/day of TP (**Section 5.5.3**). These loads exceed Redwater River TMDLs during the growing season of mid-June through September. The WLA applies from the beginning of May because of the potential for direct discharges from Outfall 001 to load nutrients that may not be flushed from the system by the beginning of June. The Circle WWTP can receive a WLA greater than zero should future treatment capacity improve effluent quality such that TMDLs in the Redwater River are met and the TMDL is revised to reflect the reduced loading potential.

The LA to combined domestic sewage and agricultural sources is also set at zero. Current loading from this source combination was estimated as approximately 38 percent of current loading at MCNREDW-4. Thirty-eight percent of 8.16 lbs TN/day equals 3.1 lbs/day; 38 percent of 0.61 lbs TP/day equals 0.23 lbs/day. This level of loading would also exceed TMDLs in the Redwater River.

The reductions needed to meet TMDLs are calculated by subtracting the TMDLs from current loading levels (8.16 lbs TN/day and 0.61 lbs TP/day). The required TN reduction is 5.53 pounds (68%); the required TP reduction is 0.26 pounds (43%). These reductions will partially be achieved as residual effects of past Circle WWTP seepage decrease with use of the new system. The LA to the sludge disposal is an estimate that should be revisited as groundwater monitoring of the disposal area becomes available and better estimates of the allocation to this source can be quantified. A survey of local septic and agricultural sources and a better estimate of their loading contributions can be incorporated into the allocations through adaptive management.

5.6.10 Sand Creek

Sand Creek is an intermittent Missouri River tributary. Since Sand Creek stream flow records are not available, mean daily flows were regionalized using mean daily flows at station 06175540 on adjacent Prairie Elk Creek and an annual discharge volume for Sand Creek estimated from the regression equations of Omang and Parrett (1984).

5.6.10.1 Sand Creek Loading Analysis

Figure 5-31 shows the duration curve of the TN TMDL for Sand Creek, based on **Equation 5-1** with mean daily discharge regionalized from the USGS gaging station 06175540 on Prairie Elk Creek. The mean growing season TN concentration of the exiting data is 2,864 µg/L. The points for current loading and TMDL exceedences occur across a wide range of flow conditions.

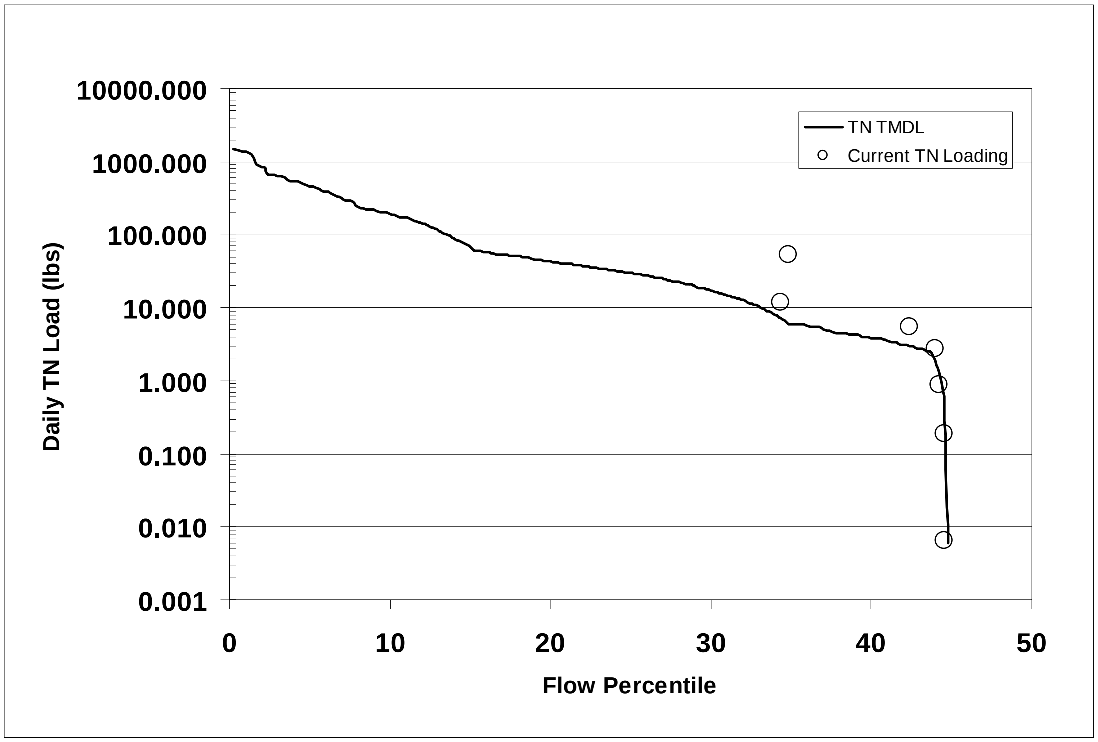

Figure 5-31. Load duration curve for the TN TMDL and growing season TN loading in Sand Creek

Figure 5-32 is the load duration curve for the TP TMDL based on **Equation 5-2** and existing growing season TP data.

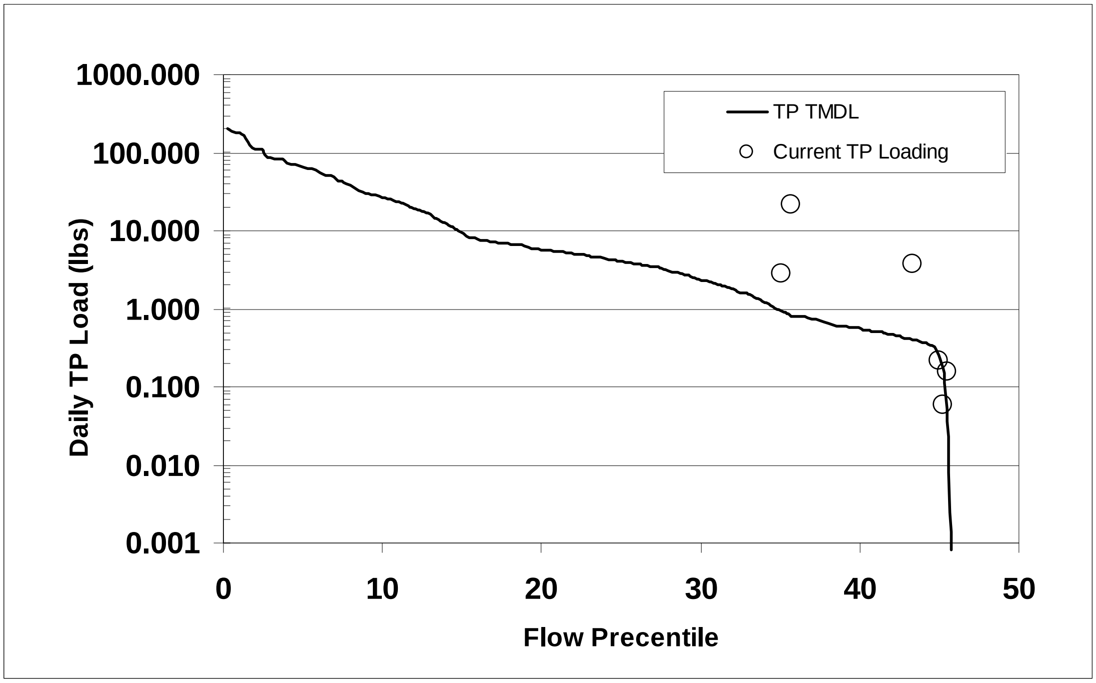

Figure 5-32. Load duration curve for the TP TMDL and current growing season TP loading to Sand Creek.

As with TN, measured data and TMDL exceedences extend across a range of flow conditions. The mean growing season TP concentration is 773 µg/L, compared to the target of 150 µg/L.

5.6.10.2 Sand Creek Nutrient Load Allocations

Table 5-29 contains daily values for current TN and TP loading, the TN and TP TMDLs, allocations, and needed TN and TP reductions for Sand Creek at a mean daily baseflow of 0.4 cfs.

Table 5-29. Example current loads, nutrient TMDLs, allocations and needed nutrient reductions in Sand Creek

Flow (cfs)	Nutrient Parameter	Current Load (lbs/day)	TMDL (lbs/day)	Background Load Allocation (lbs/day)	Agricultural Load Allocation (lbs/day)	Percent Reduction Needed
0.4	TN	6.20	2.42	1.45	0.97	61
	TP	1.67	0.32	0.10	0.22	69

The analysis of existing data concludes the need for large reductions in both TN (61%) and TP (69%) loading.

5.6.11 Timber Creek Loading Analysis

Timber Creek is an intermittent tributary to Fort Peck Reservoir listed for TN and TP. Twelve of 18 TN analysis results for Timber Creek exceed the 1,120 µg/L target. **Figure 5-33** is the load duration curve of the TN TMDL and the nine current TN loading points for which there are corresponding flow values. Exceedences have occurred over a broad range of growing season flow conditions. The mean growing season TN concentration is 2,491 µg/L, more than twice the TN target value.

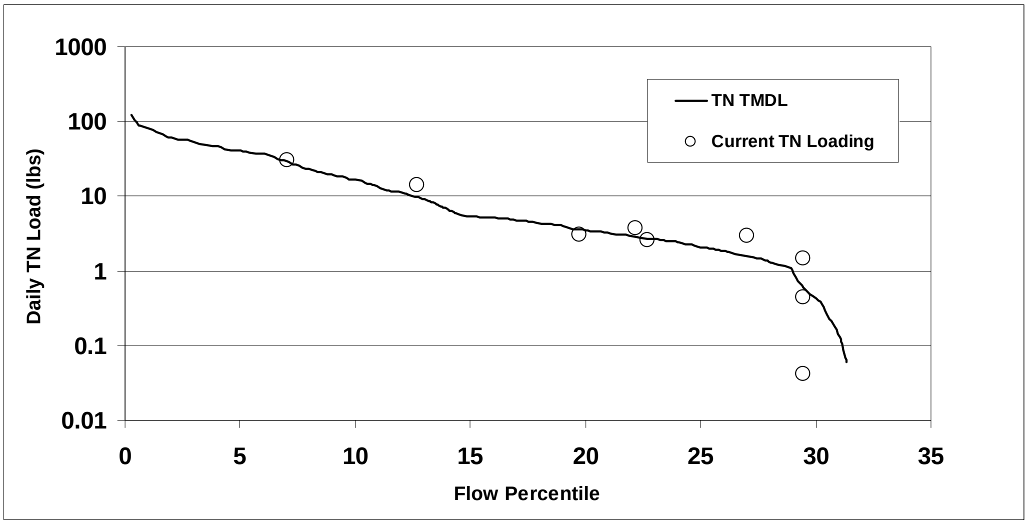

Figure 5-33. Load duration curve of the TN TMDL and current TN loading in Timber Creek

Figure 5-34 is the load duration curve of the TP TMDL in Timber Creek and graphed points for current loading. None of the TP analysis results with corresponding flow values are greater than the 150 µg/L TP target, so all points fall below the TMDL. The TP listing stems from four analysis results that exceed the TP target (**Table 5-19**). The magnitude of the exceedences ranges from 20 percent to over four times the 150 µg/L target value, with the largest departures occurring during middle to late summer when surface flow is not detectable.

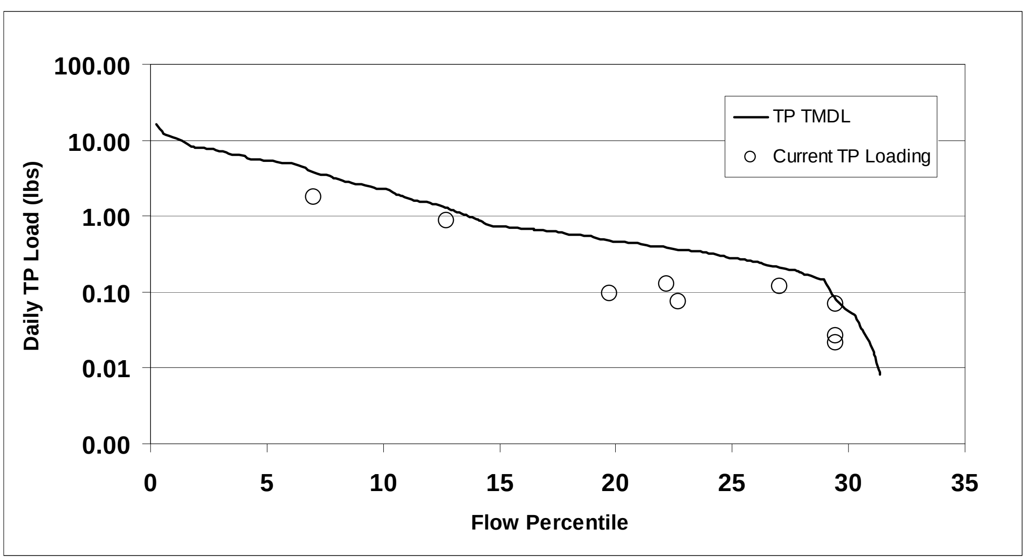

Figure 5-34. Load duration curve for the TP TMDL and current TP loading in Timber Creek

5.6.11.1 Timber Creek Nutrient Load Allocations

Table 5-30 contains daily values for current TN and TP loading, the TN and TP TMDLs, allocations, and needed reductions for Timber Creek at a mean baseflow of 0.4 cfs.

Table 5-30. Example current loads, nutrient TMDLs, allocations and needed reductions in Timber Creek

Flow (cfs)	Nutrient Parameter	Current Load (lbs/day)	TMDL (lbs/day)	Background Load Allocation (lbs/day)	Agricultural Load Allocation (lbs/day)	Percent Reduction Needed
0.4	TN	5.38	2.42	1.45	0.97	55
	TP	0.31	0.32	0.10	0.22	0-77

The nutrient data record for Timber Creek contains wide concentration ranges for both TN and TP. The TN record contains frequent, large target exceedences that consistently translate to the need for large reductions. By comparison, the growing season TP data are less than the 150 µg/L targets with the single exception of an August 2008 sample. These episodes are not clearly linked to sediment-related loading because excess TP concentrations are uncommon in Timber Creek under flowing conditions.

Approximately 87 percent of the Timber Creek watershed is native rangeland where livestock grazing is the predominant land use. The watershed contains about 19,000 acres of tilled cropland that would receive variable fertilizer rates from both commercial and livestock waste sources. The Montana Department of Transportation operates the Flowing Wells rest area that discharges 380 gallons of domestic wastewater per day from a septic drain field. The nitrogen concentration in rest area septic effluent is estimated at 180 mg/L. The system discharges about 0.6 lbs of TN/day (180mg/L*0.0006 cfs*5.39 =0.58 lbs/day), minus the amount lost through denitrification. The low water table gradient (0.002) and fine-textured sediments receiving the discharge makes for a sufficiently long travel time between the drain field and the stream channel to allow complete denitrification of the entire load. Therefore, the TN allocation for Timber Creek is to natural background sources and composite agricultural sources.

5.7 Uncertainty and Adaptive Management in Nutrient TMDLs

Uncertainties in the accuracy of field data, source assessment methods, loading calculations, and other considerations are inherent when assessing and evaluating environmental variables for TMDL development. While uncertainties are an undeniable fact of TMDL development, mitigation and reduction of uncertainties through adaptive management approaches are key components of ongoing TMDL implementation and evaluation. Uncertainties, assumptions, and considerations have been applied throughout this document. They highlight the need to refine the analysis by further monitoring to quantify loading from composite local sources and improve the understanding of nutrient impairment conditions and the loading processes that affect beneficial uses.

The process of adaptive management is predicated on the premise that TMDLs, allocations, and the analyses supporting them are not static, but subject to refinement as new information becomes available and loading conditions are better understood. Uncertainty is inherent in both the water quality-based and model-based modes of assessing nutrient sources and needed reductions. The main sources of uncertainty are summarized below with suggestions for future improvements.

Section 5.6 combined results of water quality analysis and hydrologic data to quantify current growing season nutrient loading. Confidence is higher in loading estimates for gaged streams such as the Redwater River near Circle, Nelson Creek and Prairie Elk Creek due to the larger number and more regular timing of sampling and flow measurement compared to the ungaged streams. Regularly timed water sampling was able to capture loading from infrequent but large growing season storms that are an important aspect of loading to intermittent prairie streams. Sampling of such events did not occur for East Redwater Creek, Pasture Creek, Horse Creek and Sand Creek. Sampling in these streams most often coincided with minimal or no flow conditions during the late growing season. Nutrient load duration curves for ungaged streams are based on extrapolated hydrographs from similar nearby watersheds and may not reflect actual distributions of annual flow.

There is uncertainty in the broad application of targets to areas with different channel gradients or ground cover conditions. The selected targets are those derived for the level III Northwestern Glaciated Plains and Northwestern Great Plains ecoregions. “River Breaks” is a level IV subdivision of the Northwestern Great Plains that occurs in portions of Timber Creek, Nelson Creek and Prairie Elk Creek. Such terrain may have inherently higher TP loading compared to the more subdued topography of stable uplands.

Although the dissolved oxygen targets have strong links to aquatic life use support, the Redwater dataset for field DO readings is weakened by the mid-day timing. Pre-dawn DO readings are more validly compared with daily minimums in the standards. Photosynthesis effects of daytime readings obscure the nutrient-DO relationship and weaken field DO as a target. Depressed daytime DO conditions, however, may correspond to lower DO concentrations during pre-dawn hours, giving value to a daytime reading as a supplemental indicator of nutrient impairment.

In C-3 streams, where fish and macroinvertebrate metrics are not well developed, diatom-inferred DO holds promise as a reliable indicator of aquatic life use support. However, the relationship between the inferred DO values and nutrient concentrations remains weak (**Figure 5-1**) and could benefit by additional diatom sampling paired with predawn DO measurements. The level of agreement between low inferred DO values and nutrient concentrations in the Redwater analysis was sufficient to substantiate the largest concentration target departures, such as those for the lower reaches of Horse Creek and for Pasture Creek.

As with any empirical model applied at the scale of the Redwater TPA, a number of assumptions are required to simplify the range of existing conditions that affect nutrient loading. The following are among the most notable simplifying assumptions that introduce uncertainty in the modeled loading estimates:

- Assumed uniform rainfall distribution within subbasins,

- Assumed accuracy of the National Land Cover Dataset,
- Assumed accuracy of selected USLE and other soil variables as representing existing conditions,
- The assumed number and distribution of livestock within the planning area,
- Assumed relevance and effectiveness of selected BMPs to planning area land uses and corresponding management practices,
- The assumed extent of BMP implementation as achievable.

Table 5-31 compares calculated TN and TP loading reductions based on water quality target departures with those based on BMP implementation through the STEPL model. There is an average 15 percent difference between TP reductions and an average 30 percent difference between the TN reductions. Overall, these differences represent reasonable agreement between the two assessment methods considering the fundamental difference in how the reductions are calculated. The model cannot consider concentrated TN sources such as the Circle WWTP. The large differences in TP loading reductions for Sand Creek, Nelson Creek and Prairie Elk Creek, may suggest the need for target adjustments in river breaks terrain.

Table 5-31. TN and TP Loading Reductions Based on Water Quality Target Departures and BMPs Applied Using STEPL.

Segment Name	% TN Reduction		% TP Reduction	
	Water Quality-Based	Model-Based	Water Quality-Based	Model-Based
East Redwater	51	39	23	44
Horse Creek	70	43	38	49
Nelson Creek	42	30	61	36
Pasture Creek	26	40	NA	47
Prairie Elk Creek	39	34	73	38
Redwater River	68	39	43	44
Sand Creek	61	39	69	43
Timber Creek	55	30	39	37

Although there is uncertainty in the STEPL loading values, the model provided a sound basis for the composite allocation to agricultural sources and gave reasonable assurance that nutrient target departures could largely be addressed by BMP implementation. In addition, STEPL model may function well as an adaptive management tool applied to agricultural nutrient sources at a smaller, field scale where overlapping effects of BMPs can be realistically quantified. In some instances, natural variability in nutrient loading may prevent target compliance with complete application of all reasonable land, soil and water conservation practices. Under such circumstances one or more target values would require adjustment.

Uncertainty exits in the **Appendix E** estimates of loading from past and future sources related to the Circle WWTP. The unaccounted increases in both TN and TP loading between monitoring sites MCNREDW-03 and MCNREDW-04 may be due to a broader residual groundwater effect than assumed in the pre-upgrade analysis. A potential alternate source is loading to both groundwater and Horse Creek surface water from an aging sewage collection system mentioned in the preliminary engineering report (Interstate Engineering 2004). Groundwater monitoring of the sludge disposal area may be the basis for future loading and allocation adjustments for that source.

Adaptive management requires regular nutrient and flow monitoring to improve seasonal nutrient loading estimates from all sources. As water quality analyses and flow measurements become more current, adaptive management allows for adjustments that improve understanding of actual loading conditions.

5.8 Margin of Safety and Seasonal Considerations for Nutrient TMDLs

A margin of safety (MOS) is a required TMDL component. The MOS compensates for uncertainty in estimates of current loading and uncertainty that selected targets represent water quality capable of supporting all beneficial uses. The implicit margin of safety for nutrient TMDLs has several components related to conservative assumptions in data interpretation, target setting, load calculations, allocation periods, and BMP selection.

Growing season nutrient concentration means were chosen over median concentrations when computing the degree of departure of existing data from targets. The use of growing season means provided more consideration of episodic loading from growing season convection storms that are an important characteristic of intermittent prairie streams. As and example, **Figure 5-35** is the hydrograph of Nelson Creek at USGS station 06131200 showing the effects of frequent rainstorms on stream discharge during the growing season (mid-June-September).

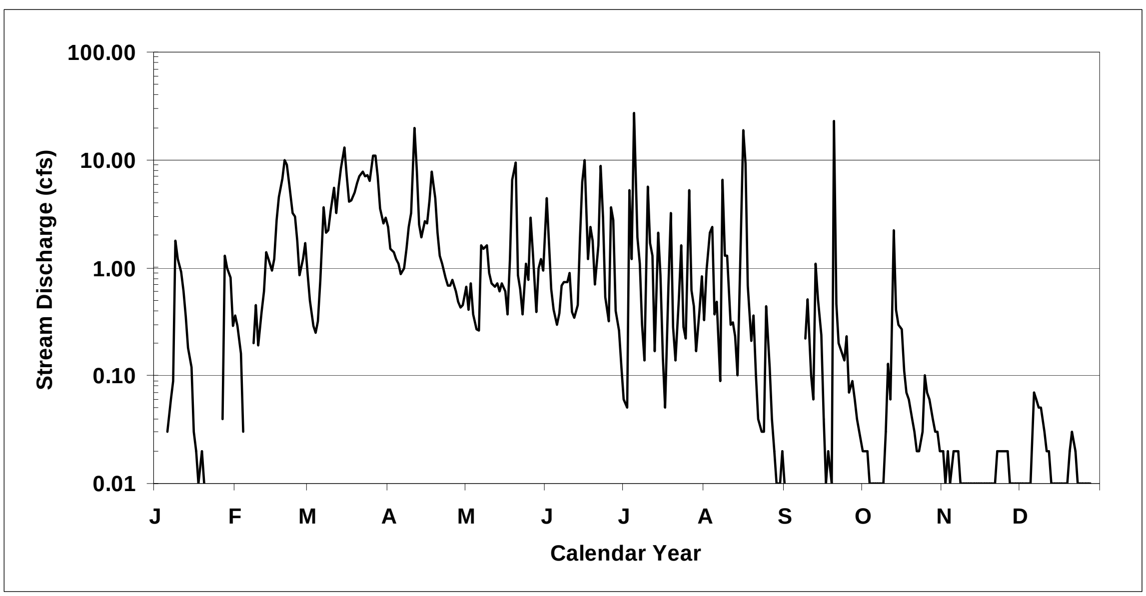

Figure 5-35. Hydrograph of Lower Nelson Creek at USGS Station 06131200

The use of mean growing season nutrient concentrations gives more consideration to concentrations measured during such storms than use of median values. More consideration of these potentially large loading events translates to larger target departures and consequent larger load reduction requirements than if departures are based on median values.

The reference condition approach to target setting (**Appendix C**) uses distributional statistics from a reference dataset to identify appropriate nutrient target values. This approach for the available set of reference prairie streams would result in TN targets of 1,310 or 1,358 µg/L respectively for the glaciated and unglaciated ecoregions. The more conservative target of 1,120 µg TN/L correlated with a significant lowering of the diatom oxygen tolerance index (Suplee 2008). Selection of the lower harm-to-use threshold as the TN target contributes a margin of safety that target compliance will support aquatic life, the most restrictive beneficial use.

The Redwater River allocations period was expanded from the mid-June through September growing season to include the month of May. This expansion provides an additional margin of safety against growing season bio-availability of accumulated nutrient loads in channel pools as flows decline late in the runoff period.

Although nutrient TMDLs and allocations apply during the growing season, an additional margin of safety is inherent in selection of BMPs that can reduce nutrient loads during the entire year. The function of diversion structures, vegetative filters and prescribed grazing systems is not restricted to the growing season. With proper maintenance, these controls on nonpoint nutrient loading help prevent excess loading from significant natural events throughout the year.

Consideration of the seasonality of nutrient TMDLs and allocations in inherent in their application during the mid-June through September growing season when nutrient-induced eutrophication is most likely to harm aquatic life. The graphing of TN and TP TMDLs in **Section 5.6** as load duration curves with inserted current loading points illustrates both the seasonal fluctuation in allowable daily loading and the timing of measured loads. This information can help land managers anticipate seasonal loading conditions and develop controls that restrict loading to the allowable maximum within a reasonable timeframe.

SECTION 6.0
SALINITY TMDL COMPONENTS

This portion of the water quality restoration plan focuses on salinity as the identified cause of water quality impairments. It describes: 1) use impairment mechanisms, 2) the specific stream segments of concern, 3) the presently available salinity data, 4) contributing sources of dissolved solids based on relevant studies, and 5) the proposed salinity TMDLs and their rationale.

6.1 Salinity Impacts to Beneficial Uses

Table 6-1. Water classification terms and corresponding TDS concentrations

Water Classification Term	TDS (ppm)
Fresh	< 1,000
Brackish	1,000 – 5,000
Highly Brackish	5,000 – 15,000
Saline	15,000 – 30,000
Sea Water	30,000 – 40,000
Brine	40,000 – 300,000+

The ultimate sources of soluble constituents entering aquatic systems are through groundwater sources and chemical weathering of primary minerals in bedrock and soils. The release of soluble constituents through solution, hydrolysis, hydration and oxidation is often accompanied by transport and accumulation of soluble solids with water movement and evaporation. The TDS concentration of water is directly proportional to its specific conductance (SC) measured in units of micosiemens per centimeter (µS/cm). The strong relationship between TDS and SC has led to the use of conductance as a surrogate parameter for assessing the dissolved solids concentration of waters.

A principal effect of increasing salinity on aquatic biota is alteration of internal osmotic pressure. An increased ionic concentration in the water column causes tissue cell desiccation and loss of function as water diffuses toward the higher concentration in the surrounding environment. Salinity tolerance is dependent on the ability of organisms to self-regulate internal osmotic pressure. Other salinity effects are related to specific ionic composition, interactions of various water contaminants, and exposure duration (Dunlop et al. 2005).

A literature review of the effects of sodium salts on aquatic life (Skaar 2003) summarized both laboratory and field studies on the effects of increasing SC on mortality of zooplankton and fish found in Montana. **Table 6-2** summarizes the laboratory toxicity studies.

Table 6-2. Summary LC50 statistics for 48-hour exposure of zooplankton and 96-hour exposure of fathead minnows to increasing SC.

LC50	Daphnia magna	Ceriodaphnia dubia	Fathead minnow
Mean (uS/cm)	5,499	3,246	6,080
Minimum (uS/cm)	1,560	1,797	413
Maximum (uS/cm)	11,466	5,130	20,266
Geometric mean (uS/cm)	4,843	3,128	4,204
Number of Trials	14	20	18

Bauder and others (2007) calculated a maximum EC criterion of 1,564 µS/cm for Ceriodaphnia, the most sensitive of the three species used in the studies. Bauder and others (2007) summarized the research literature on fish tolerance to varying TDS concentrations in saline lakes from work by Rawson and Moore (1944). **Table 6-3** gives TDS tolerance ranges for a number of fish species assessed in the Saskatchewan surveys. The bolded common names in the table are species occurring in the Redwater TPA. The species present are indicative of a broad TDS range in the planning area.

Table 6-3. TDS tolerance ranges for fish species in saline Saskatchewan lakes

Fish Species	TDS Tolerance Range (mg/L)
Lake Whitefish (Coregonus clupeaformis)	100 – 3,000
Bigmouth Buffalo (Ictiobus cyprinellus)	900 – 3,000
White Sucker (Catostomus commersoni)	200 – 8,000
Longnose Sucker (Catostomus catostomus)	200
Longnose Dace (Rhinichthys cataractae)	200 – 600
Pearl Dace (Margariscus margarita)	200
Emerald Shiner (Notropis atherinoides)	200 – 3,000
Fathead Minnow (Pimephales promelas)	200 – 15,000
Spotted Shiner (Notropis hudsoniscus)	200 – 4,000
Northern Pike (Esox lucius)	200 – 3,500
Yellow Perch (Perca flavescens)	200 – 8,000
Walleye (Stizostedion vitreum)	200 – 8,000
Iowa Darter (Etheostoma exile)	200 – 12,000
Brook Stickleback (Culaea inconstans)*	200 – 17,000
Burbot (Lota lota)	200 – 3,000

Skarr (2003) also reviewed the available research of salinity effects on hatch success and growth rates of warm water species. Hatch success declines for Northern Pike occurred over an EC range of from 450 to 4,000 µS/cm. Slight growth and survival reductions were observed in Fathead Minnows as SC values changed from 480 to 2,750 µS/cm

Salinity affects the suitability of water for livestock consumption. High TDS concentrations change the electrolyte balance and intracellular osmotic pressure, producing a form of dehydration. High TDS concentrations can also damage kidney function. The suitability of highly mineralized waters is more often limited by specific ion concentrations than dissolved solids concentrations generally. A sulfate concentration of 1,000 mg/L may cause scours in calves and reduce copper availability in the diet. The sulfate recommendation for calves is less than 500 mg/L or 167 mg/L sulfur as sulfate (Lardy et al 2008). For adult cattle, the recommendation is less than 1,000 mg/L (333 mg/L sulfur as sulfate). **Table 6-4** contains TDS recommendations for livestock water quality published by the USDA (2008).

Table 6-4. Recommendations for livestock water use based on TDS (USDA 2008)

TDS (mg/L)	Limitation
< 1,000	Relatively low level of salinity. Excellent for all classes of livestock and poultry.
1,000-3,000	Very satisfactory for all classes of livestock and poultry. May cause temporary and mild diarrhea in livestock not accustomed to saline water. Poultry may exhibit watery droppings.

Table 6-4. Recommendations for livestock water use based on TDS (USDA 2008)

TDS (mg/L)	Limitation
3,000-5,000	Satisfactory for livestock, but may cause temporary diarrhea or be refused at first by animals not accustomed to them. Poor waters for poultry, often causing watery feces, increasing mortality, and decreased growth, especially in turkeys.
5,000-7,000	Can be used with reasonable safety for dairy and beef cattle, sheep, swine, and horses. Avoid use for pregnant or lactating animals. Not acceptable for poultry.
7,000-10,000	Unfit for poultry and probably for swine. Considerable risk in using for pregnant or lactating cows, horses, or sheep, or for the young of these species. In general, use should be avoided although older ruminants, horses, or swine may subsist on them under certain conditions.
> 10,000	Risks with these highly saline waters are so great that they cannot be recommended for use under any condition.

Waters that have conductivity values less than 750 µS/cm are generally satisfactory for irrigation of non-sensitive crops. Sensitive crops may be adversely affected by waters with a conductivity range of from 250 to 750 µS/cm. Waters having conductivity values up to 2,250 µS/cm have been used successfully for irrigation under good management with adequate soil drainage (USDA 1954). Surface waters in the Redwater TPA are not extensively used for irrigation due to both salinity and alkalinity. Water spreading systems have been installed to divert snowmelt runoff that is typically low in dissolved solids. Diverted water is applied to forage and small grain crops. Approximately 10 percent of forage and grain crop acreage in McCone County receives some irrigation (USDA 2010). Most if this irrigation water is diverted from the Missouri River.

6.2 Stream Segments of Concern

Three tributaries in the Redwater River TPA have appeared on Montana 303(d) Lists due to salinity related impairments (**Table 6-5**). These include East Redwater Creek, Horse Creek, and Nelson Creek. Salinity impaired beneficial uses for all three streams include aquatic life and warm water fishery.

Table 6-5. Salinity Listed Waters within the Redwater TPA (2008 303(d) List).

Waterbody Segment ID	Waterbody Name, Location Description	2008 Probable Causes of Impairment
MT40P002_010	**EAST REDWATER CREEK**, headwaters to mouth (Redwater River)	Specific Conductance Total Dissolved Solids Sulfates
MT40P002_020	**HORSE CREEK**, headwaters to mouth (Redwater River)	Salinity
MT40E003_020	**NELSON CREEK**, headwaters to mouth (Fort. Peck Reservoir)	Sulfates

6.3 Information Sources and Assessment Methods

There is a negative relationship between the concentration of dissolved solids in surface water and stream discharge. This relationship supports the hypothesis that in stream dissolved solids concentrations that are likely to limit aquatic life uses are controlled by loading from groundwater sources. The deep percolation of precipitation, beneath cropland where the crop-fallow rotation system of soil moisture harvesting is used, is assumed as the principal human source of dissolved solids loading to groundwater. Therefore, the salinity source assessment is focused on quantifying this source of loading.

Estimates of dissolved solids loading to surface waters during low flow conditions are based on a simple loading model of concentration times flow. Dissolved solids concentration is derived from groundwater chemistry data. Flow is estimated by applying Darcy's Law:

$$Q = K*dh/dl*A$$

Where: Q = Groundwater discharge rate in cfs
K = Effective hydraulic conductivity (ft/day)
dh/dl = Hydraulic gradient
A = the area (ft2) through which groundwater discharges to surface water.

The groundwater concentration of dissolved solids, multiplied by the volume of groundwater discharging to stream channels (and a unit conversion factor), gives a value for the mass of dissolved solids entering the channel per unit time. The principal sources of information for target development and quantifying dissolved solids loading include:

- Salinity-related surface water chemistry,
- Salinity-related groundwater chemistry,
- Groundwater gradient and flow direction information,
- Stream flow data, and
- Aerial Imagery depicting channel width.

6.3.1 Salinity-Related Surface Water Chemistry data

The available salinity-related surface water chemistry data was compiled into an MS Access database by a DEQ contractor in 2005. Records for individual samples were entered into an MS Excel spreadsheet. The principal data sources include flow and biological and chemical water quality data from the USGS, planning area stakeholders, and DEQ.

Surface and groundwater quality data, stream gage data, and groundwater table elevations were obtained for Nelson Creek during the period from September 2006 to October 2008 as part of an environmental baseline characterization of the drainage for proposed coal mine development. Stream gage rating curves and well construction data are not currently available for the project. The gage rating curves are required to calculate flow volumes and TDS loading from the dataset. The analytical water quality data were used to quantify the relationship between SC and TDS in Nelson Creek surface water and characterize dissolved solids concentrations in local groundwater.

The salinity database (Appendix B) contains 1,082 records collected from 45 different streams from 1975 through 2008. Similar to the nutrient database, the number of salinity results varies widely by waterbody. About 70 percent of the records were collected by the USGS at both gaged and ungaged sites. The remaining 30 percent were recorded by DEQ and a combination of agency and local stakeholders and a private sector consultant. About 60 percent of the USGS gage data is from two stations on the unlisted Redwater River, one near Circle (06177500) and the second near Vida (06177875).

On the three salinity-listed streams there are 156 records: 70 records from Horse, 122 from Nelson Creek, and 21 from East Redwater Creek. The USGS records occurred on varying monthly, quarterly, and seasonal schedules from 1975 through 1985. The most recent data for listed segments were gathered by DEQ monitoring and assessment crews during 2003 and 2004, by a private consultants gathering baseline data during 2006-2008 related to a proposed coal development project, and by a DEQ contractor working during the 2008 growing season. In addition to the sampling site, date, and location identifiers, the records include results for the following parameters:

1. Instantaneous Discharge (cfs)
2. SC (µS/cm)
3. TDS (mg/L)
4. Sodium Adsorption Ratio
5. Sulfate Concentration (mg/L).

The database for all tributary streams (streams other than the Redwater River) contains 487 results for SC, 119 for TDS, and 76 for sulfate.

6.3.2 Groundwater Chemistry and Well Construction Data

Groundwater chemistry and well construction data available from the Groundwater Information Center (GWIC) database were compiled and edited to include results for shallow wells within the Redwater TPA. Wells 150 feet deep or shallower are assumed to characterize the aquifer recharging stream channels. Groundwater quality data used to characterize the shallow aquifers within the three salinity-listed watersheds are contained in **Appendix B**.

Well construction data from the GWIC database (**Appendix B**) were used to construct a potentiometric surface map in each of the three listed watersheds. Database values for static water level below ground surface were subtracted from the ground surface elevation at each well obtained from topographic maps. Groundwater flow direction and aquifer gradient were determined from the potentiometric surface maps.

6.3.3 Stream Flow Data

Mean daily stream flow data for Nelson Creek are derived from USGS gaging records at station 06131200 located immediately downstream of the Highway 24 crossing. Stream flows in East Redwater are extrapolated from mean daily proportions of annual discharge in the Redwater River at Vida (USGS station 06177825) multiplied by an annual discharge volume in East Redwater Creek estimated from the regression equations of Omang and Parrett (1984). Mean daily discharge in Horse Creek was similarly estimated based on the hydrograph of Timber Creek at station 06131120. Gaged and estimated mean daily discharge data are in **Appendix B**.

6.3.4 Aerial Imagery

Stream channel width was assessed through interpretation of 2005 and 2009 National Agricultural Imagery Program (NAIP) aerial photography.

6.4 Salinity Target Development

The salinity impairment causes in the Redwater TPA include SC, sulfate, TDS, and "Salinity" (**Table 6-4**). The SC data for both the mainstem Redwater River and planning area tributaries indicate that the dissolved solids concentration in surface water generally increases with decreasing flow. **Figure 6-1** shows this relationship between SC and discharge for the Redwater River at Circle. A similar relationship exists for tributary streams. **Figure 6-2** shows the SC relationship to discharge for tributaries.

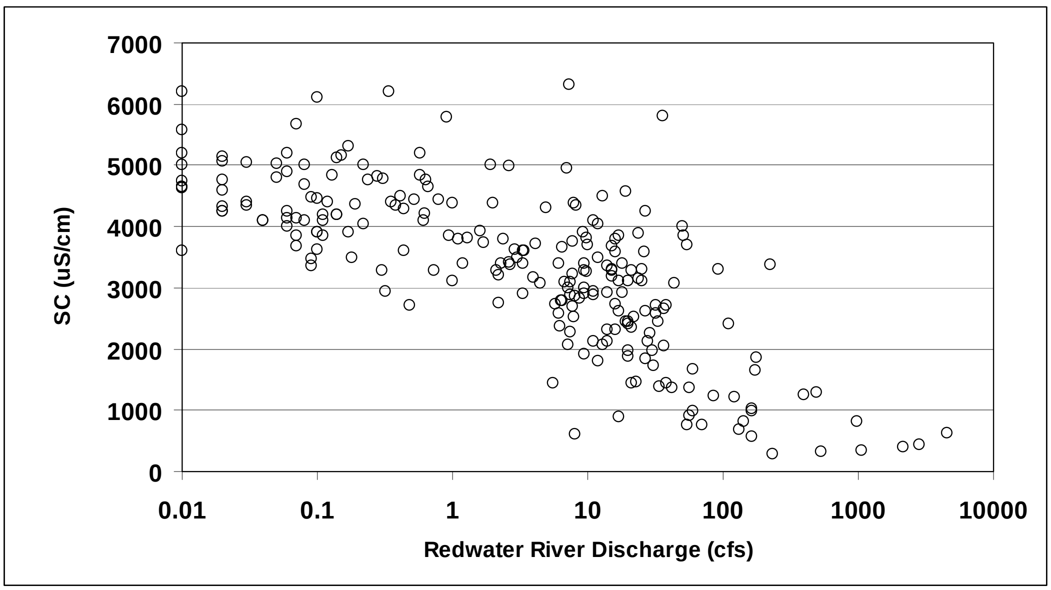

Figure 6-1. Graph of specific conductance and measured flow of the Redwater River at Circle

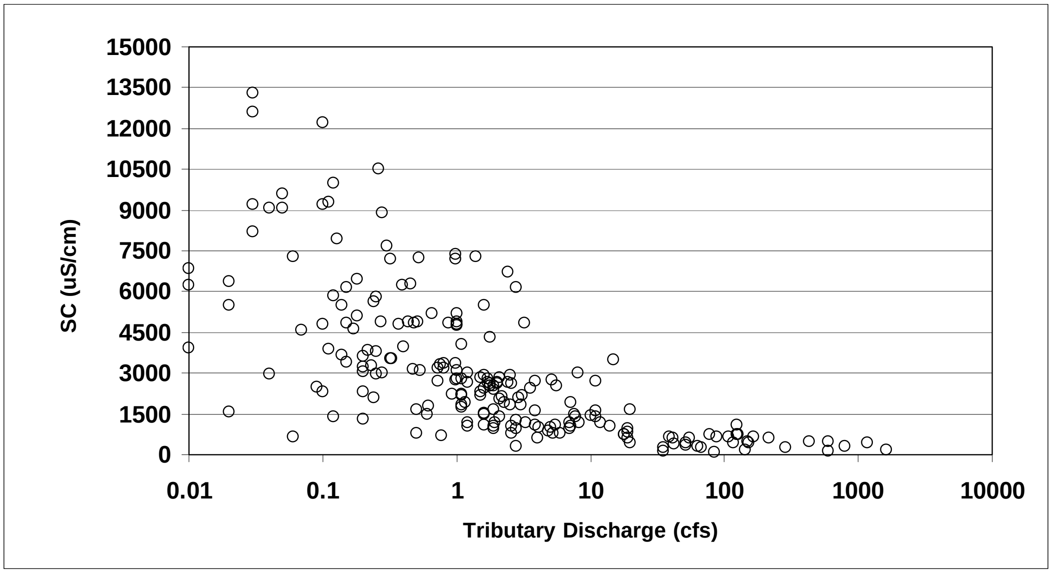

Figure 6-2. Graph of specific conductance and tributary stream flow.

High stream flows resulting from snowmelt or precipitation runoff that is low in dissolved solids contrast with late summer and winter base flows more influenced by groundwater. Note the concentration (y-axis) scale difference between the Redwater River mainstem in **Figure 6-1** and that for tributary streams in **Figure 6-2**. Most tributary streams have intermittent flows and the graph reflects the influence of evaporative concentration under minimal or no flow conditions. **Figure 6-3** shows this relationship between TDS and flows on a flow duration curve for Horse Creek.

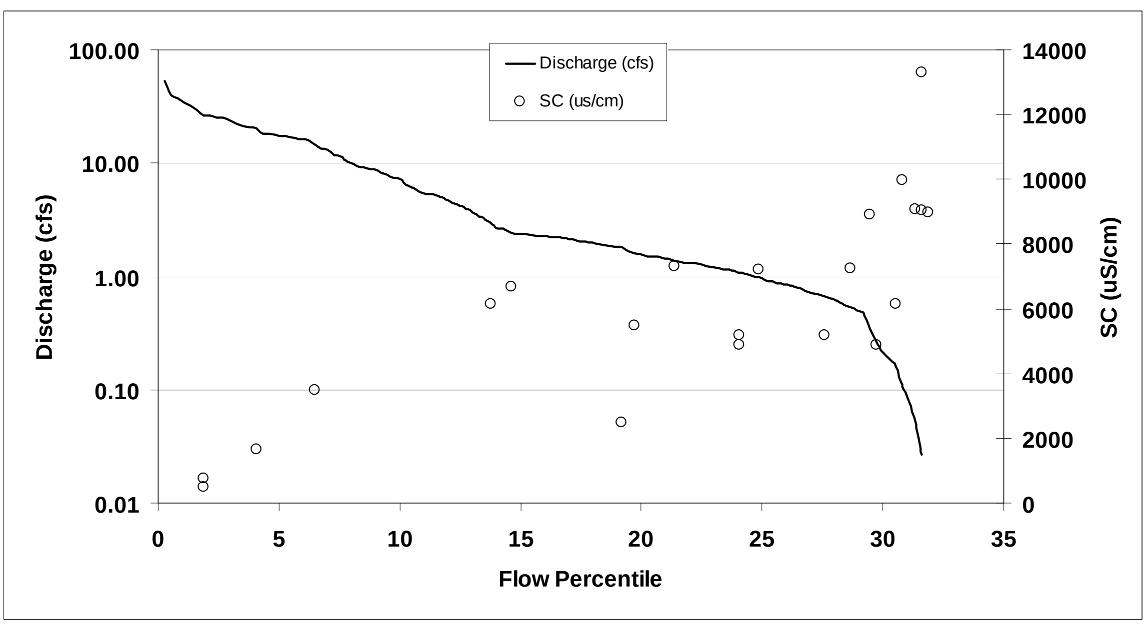

Figure 6-3. Flow duration curve for Horse Creek with measured SC values.

The average tributary SC measured for flows greater than the 50th percentile (1.5 cfs) is 1,462 µS/cm; for flows less than the 50th percentile the mean tributary SC value is 4550 µS/cm. This common pattern in the Redwater TPA streams and the upper range of aquatic life salinity tolerances in **Table 6-3** suggests that a salinity target is more appropriate for low flow conditions when dissolved solids concentrations are more likely to harm the aquatic life uses for C-3 streams.

Among the salinity pollutant causes, TDS and sulfate have units of mass per unit volume that can be expressed as loads when multiplied by discharge. There is a strong correlation among TDS, SC, and sulfate. **Figure 6-4** illustrates the relationship between TDS and SC for wadeable tributaries. The strength of these relationships suggests that TDS is the most useful target parameter for addressing salinity impairment causes.

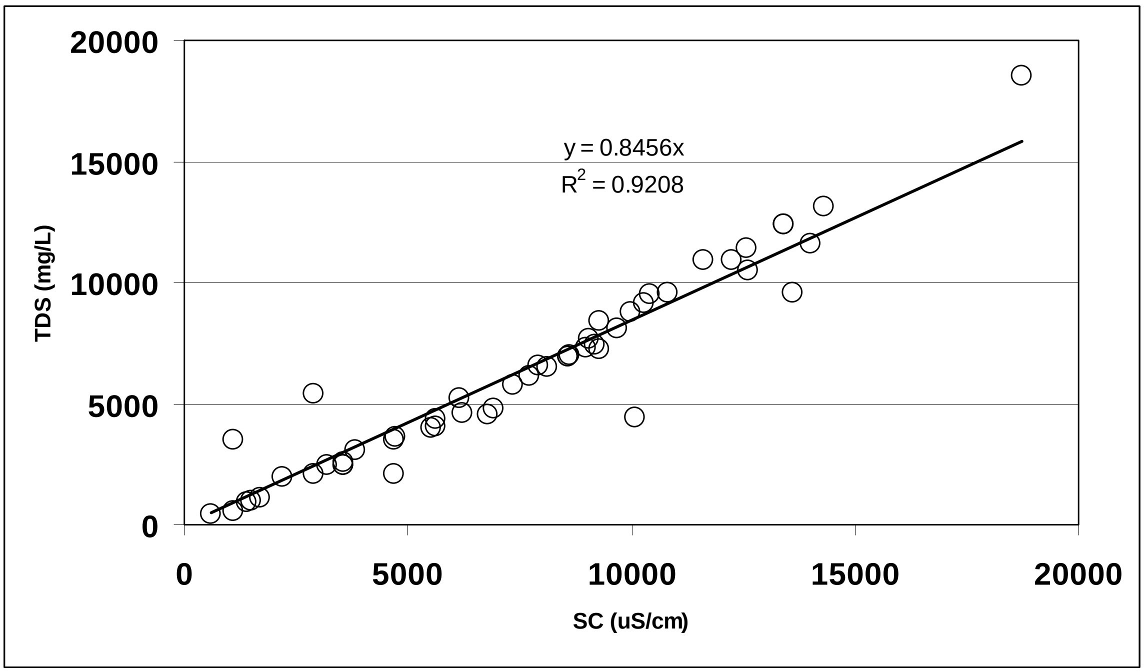

Figure 6-4. Graph of the linear relationship between TDS and SC for wadeable streams in the Redwater TPA.

Figure 6-5 is a graph of the relationship between TDS and sulfate for tributaries. The development of sulfate standards has been limited to use classification categories that support the drinking water use. In Montana, these are the B-1 through B-3 categories. Streams classified as C-3 are naturally marginal for drinking water, agricultural, and industrial purposes. Drinking water standards for sulfate, therefore, are not appropriately applied to C-3 streams. Due to a lack of sulfate criteria developed for aquatic life use support in C-3 streams, salinity impairment in this document is assessed using TDS and SC targets.

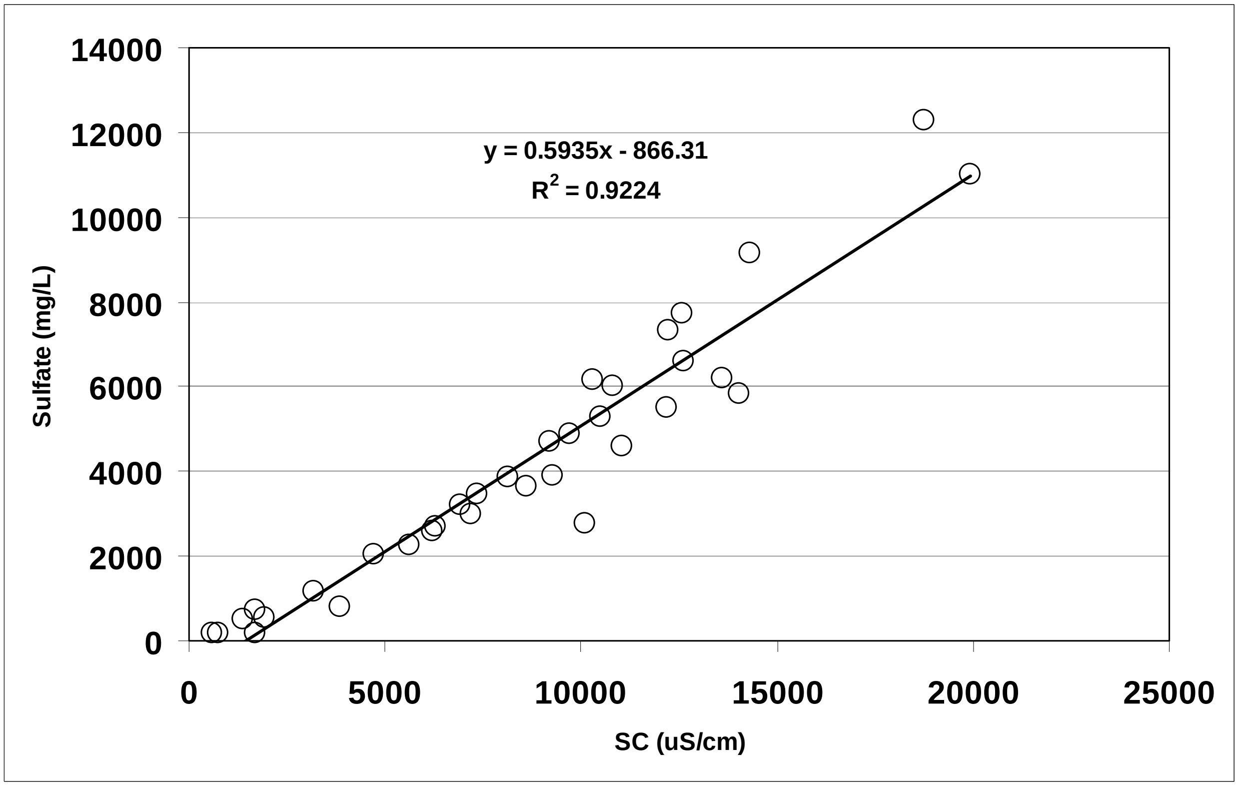

Figure 6-5. Graph of the linear relationship between TDS and sulfate for Redwater TPA tributaries.

Water quality standards for salinity include the narrative general prohibition against toxicity or harm to human, animal, plant, or aquatic life (**Section 3.3.2**). Established numeric standards for electrical conductivity (EC) are in effect for the tributaries and mainstems of Rosebud Creek, and the Tongue, Powder, and Little Powder rivers (ARM 17.30.670). en 1,000 and 2,500 µS/cm applied seasonally. For Tongue-Powder-Rosebud tributaries, the EC standard is a year-round maximum of 500 µS/cm for any sample. The tributary standard is intended to protect water quality for irrigation of salt sensitive crops (alfalfa).

Past salinity TMDL target development has focused on protecting agricultural and aquatic life uses. Seasonal average and instantaneous maximum TDS targets of 820 mg/L and 1,145 mg/L were established for the Middle and Lower Teton River (Class B-2 and B-3 waters) to protect irrigation use. A seasonal TDS average of 660 mg/L, and a year-round average of 960 mg/L, were used as targets for TMDLs in the Sun River and Muddy Creek to protect irrigation water quality for field corn.

The standards and targets described above are considerably lower than SC values in the C-3 classified streams of the Redwater TPA. High salinity has historically limited irrigation use to runoff water spreading during high flows and some pumping from runoff-fed reservoirs. About one percent of the wheat crop and 12 percent of the hay crop receive some irrigation (USDA 2010). The impracticality of supporting irrigated agriculture with inherently saline and often sodic water shifts the focus of target development to use support for aquatic life under the most limiting flow conditions.

A toxicity model was used to derive an aquatic life support target of 1,600 µS/cm for Sage Creek and Big Sandy Creek TMDLs in north-central Montana. The model predicted six percent mortality in water fleas (Daphnia magna) at 1,600 µS/cm. The corresponding TDS target is 1,250 mg/L. The Sun River TMDL document included a maximum aquatic life support target of 2,264 mg/L TDS in Freeze-out Lake for waterfowl propagation. Bauder and others (2007) described a range of aquatic life support SC and TDS values in a review of the salt mitigation plan for discharges to the Milk River from Lake Bowdoin. Effects thresholds (LC50) for zooplankton species and fathead minnows ranged from 3,000 to 5,000 µS/cm. The recommended protective maximum conductivity criterion was 1,564 µS/cm (Skarr 2003).

Like the irrigation criteria, the aquatic life targets above are considerably lower than dissolved solids conditions encountered during low flow periods for Redwater TPA tributaries. **Table 6-6** gives median low flow SC and percent cropland values for seven planning area watersheds. Salt loading during low flow comes mainly from groundwater. The human caused loading from groundwater is assumed to be deep percolation of excess soil water from beneath crop-fallow acreage. The data indicate that high salinity occurs in several watersheds having minimal human sources. Nelson Creek, with only six percent tilled cropland, has a median low flow SC of 4,628 µS/cm. Timber Creek represents an extreme case with just nine percent tilled cropland and a median low flow SC of 10,000 µS/cm.

Table 6-6. Cropland Percentages and Median Low Flow SC Values for Several Redwater TPA Tributaries.

Watershed	Cultivated Cropland Percent	Median Low Flow SC (µS/cm)
Nelson Creek	6	4,628
Prairie Elk Creek	7	2,480
Timber Creek	9	9,557
Sand Creek	19	3,230
East Redwater Creek	24	5,688
Pasture Creek	33	4,310
Horse Creek	37	8,988

The inherently high salinity conditions of the Redwater TPA justify a reference condition approach to developing a low flow aquatic life salinity target for intermittent streams. **Figure 6-6** is a box plot graph of SC values from 22 intermittent and perennial tributaries (n=219) stratified by flow condition. Low and high flow conditions are those less than and greater than the median discharge of 1.5 cfs calculated from measured tributary flows. The median SC value during low flow is 3,940 µS/cm. The **Figure 6-4** formula for the SC-TDS relationship gives a corresponding TDS value of 3,332 mg/L. This is the proposed low flow TDS target.

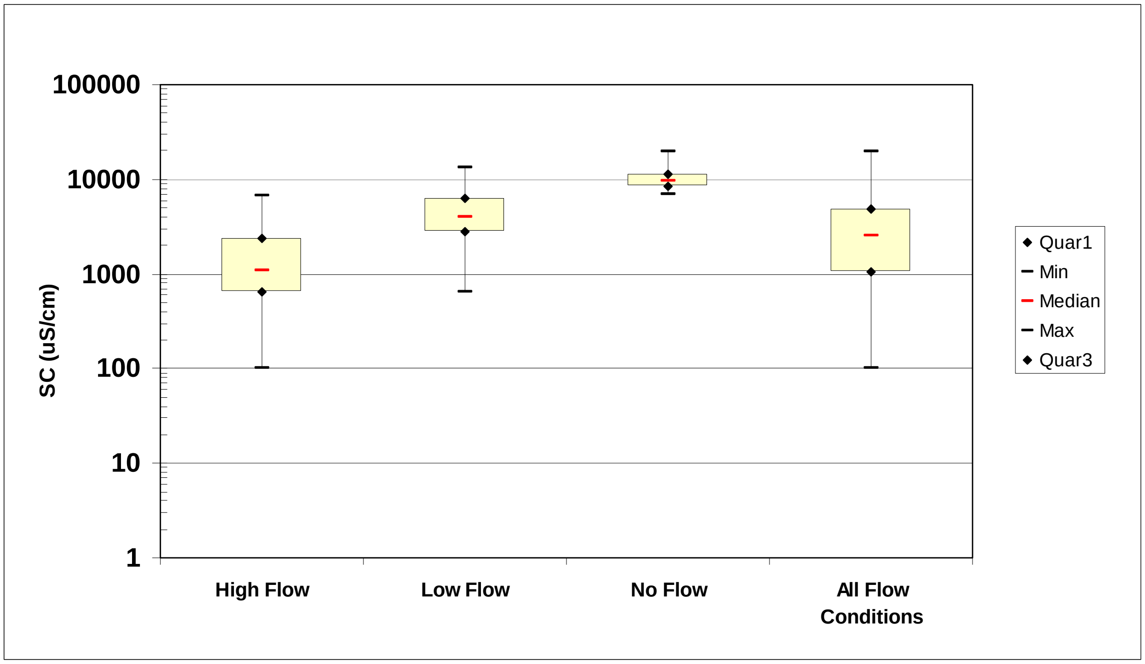

Figure 6-6. Box plot graph of specific conductance of tributary streams in the Redwater TPA stratified by flow condition.

The rationale for selecting the median TDS value as the target is that, despite the remoteness of the planning area, confidence is low that the tributary dataset represents a true reference condition reflecting minimal human influence. Distributional statistics from an "all data" versus a reference dataset can be used as a target setting tool (**Appendix C**). The 25th percentile value (2,368 mg/L) is considered too restrictive in settings such as Nelson and Timber creeks where salinity is high and human sources are few and dispersed.

The proposed targets reflect conditions in watersheds with the lowest extent of cropland loading sources. Nelson Creek, with six percent cropland cover, has a low flow TDS median of 3,661 mg/L; that for Prairie Elk Creek, with nine percent cropland, is 1,975 mg/L. The proposed TDS target of 3,332 mg/L reflects the low flow water quality of samples from throughout the planning area with land cover dominated by native rangeland with a generally discontinuous extent of cropland loading sources. The target is derived from a dataset that includes values from a number of perennial tributaries that may have aquatic life assemblages adapted to lower salt concentrations than those of the listed streams, all three of which are intermittent. This provides an implicit bias toward a more restrictive and protective target set.

6.5 Comparison of Listed Waters to Salinity Targets

The evaluation of salinity target departures is based on comparisons of current water quality conditions, as described in the data record, to the SC target of 3,940 µs/cm and the TDS concentration target of 3,332 mg/L under low flow conditions. Low flows in this analysis are those less than the median value among calculated values of mean daily flows. Mean daily flows for Nelson Creek are those developed by the USGS for station 06131200. Mean daily flows for

East Redwater Creek and Horse Creek are developed from hydrographs of similar streams as described in **Section 5.6.4**. and **Section 5.6.5**.

Compliance with targets is evaluated on the number and degree of target exceedences. After a review of statistical methods for testing compliance with numeric water quality standards, an allowable exceedence rate of 25 percent was recommended for nutrient data from wadeable Montana Streams (Suplee and Sada de Suplee 2010). The 25 percent allowance is used here as a guideline in judging salinity target departures. The degree of target departure is assessed using a one-sample t-test of TDS and SC dataset means. The test is a simple means of detecting a real difference between the dataset means and targets.

Target compliance also considers the extent of tilled cropland in the watersheds of listed streams. Dissolved solids loading to surface water from groundwater being recharged from areas of tilled cropland is the assumed source of human caused loading. Without significant sources, loading may be from naturally mineralized waters that are locally quite variable in the Tongue River Member of the Fort Union Formation (Lee 1981), predominant surface geology in the planning area.

6.5.1 East Redwater Creek

The target departures for TDS in East Redwater Creek are illustrated in **Figure 6-7** for both high flow and low flow conditions and all flows combined. High and low flow values are those measured at flows greater than or less than the estimated median flow of 0.7 cfs. The median low flow TDS concentration is 4,565 mg/L. A 27 percent reduction in low flow TDS concentration is required to meet the proposed target.

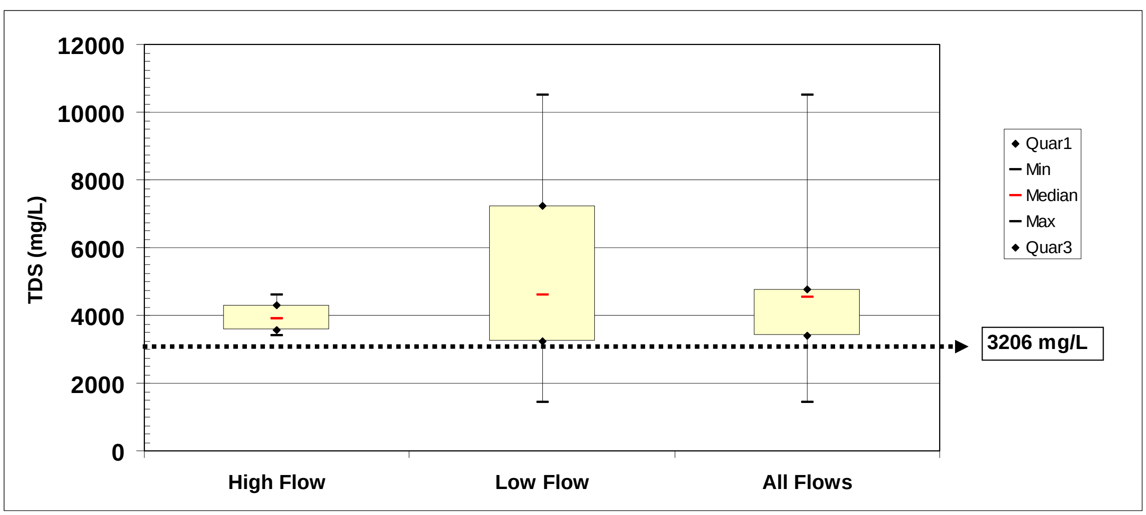

Figure 6-7. Target departures for TDS data collected on East Redwater Creek.

Table 6-7 contains the TDS and SC data records for East Redwater Creek. About a quarter of the watershed area is used for small grain production. Six of eight low flow TDS values and four of five low flow SC values exceeded the targets. Among results with no corresponding flow measurements, the table contains four SC exceedences. There are two exceedences of the low flow SC target that occurred under high flow conditions, and three low flow TDS target exceedences that occurred under high flow conditions. The results suggest the need for a dissolved solids TMDL.

Table 6-7. TDS and SC data records and low flow target exceedences (bolded) for East Redwater Creek

Station ID	Sample Date	Discharge (cfs)	TDS (mg/L)	SC (µS/cm)
474859105033100	10/07/75			2,250
474516104494500	10/17/75			600
5288NO01	06/01/76			4,469
G020002	06/01/76			8,210
5288NO01	06/15/76	1	3,629	4,735
G020001	06/15/76			8,210
474910104472501	09/01/78			2,820
5385EA01	06/23/82	1		4,780
5385EA01	10/19/82	0.14		3,680
G020007	06/03/03			4,200
M48RDWEC02	06/19/03	10.5	3,400	
M48RDWEC01	06/19/03	10.8	4,590	
M48RDWEC03	06/19/03	0.25	**4,540**	
M48RWENF01	06/19/03	0.25	1,450	
M48RDWEC04	06/19/03	0.5	1,690	
5385EA01	06/17/08	0.39	**4,590**	**6,217**
M48RDWEC03	06/17/08	0.11	**7,230**	**9,280**
M48RDWEC05	06/17/08	0.03	**10,500**	**12,600**
M48RWENF01	06/17/08	0.03	**7,450**	**9,201**
5385EA01	08/28/08	0	**4,760**	**6,906**

6.5.2 Horse Creek

Figure 6-8 illustrates the target departures for Horse Creek TDS data stratified by flow condition. High and low flow values are those measured at flows greater than or less than 0.19 cfs. Horse Creek is an intermittent stream without long-term flow monitoring records. Approximately 20 percent of the results for TDS and 30 percent of SC readings have accompanying flow measurements. The remaining data records for these parameters have either no corresponding flow measurements, or were obtained under non-flowing conditions. The median low flow TDS concentration, for results with coincident flow measurements, is 7,495 mg/L. A 56 percent reduction in low flow TDS concentration would be required to meet the proposed low flow target of 3,332 mg/L.

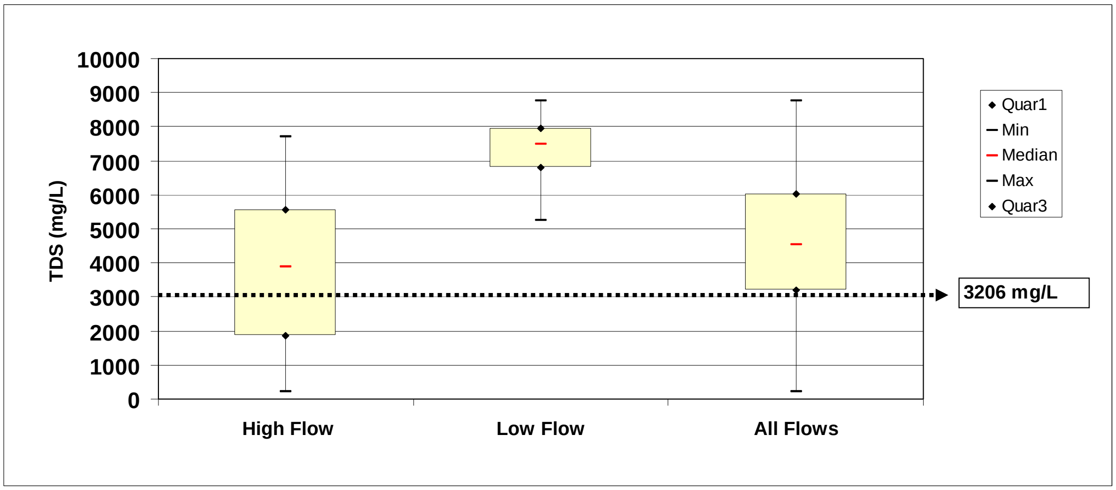

Figure 6-8. Target departures for Horse Creek TDS data distributions for high and low flow conditions

Table 6-8 contains the TDS and SC results from Horse Creek that have corresponding flow measurements. The data are arranged in order of decreasing flow and show the general trend of increasing salinity with decreasing flow. The TDS and SC targets are exceeded under all low flow conditions. The targets are also exceeded by nearly 70 percent of the high flow results. The t-test results confirm that the low flow means from the dataset exceed both targets. Approximately 37 percent of the Horse Creek watershed area is used for small grain production. The results indicate the need for a dissolved solids TMDL.

Table 6-8. Horse Creek results for TDS and SC with corresponding flow measurements and low flow target exceedences (bolded).

Site ID	Date	Discharge (cfs)	TDS (mg/L)	SC (uS/cm)
6177520	03/22/78	150	193	489
6177520	04/11/79	126	420	749
6177520	03/19/79	20	1224	1670
6177520	05/09/79	15	2805	3480
6177520	06/05/79	2.8	5136	6150
6177520	05/09/78	2.4	5617	6700
6177520	07/12/78	1.8	1958	2510
6177520	06/08/78	1.6	4569	5500
6177520	07/10/79	1.4	6141	7300
6177520	04/01/77	1	4307	5200
6177520	04/25/78	1	4045	4900
6177520	11/14/78	0.99	6053	7200
6177520	10/11/78	0.66	4307	5200
6177520	06/22/82	0.52	6097	7250
6177520	10/19/82	0.28	7538	8900
6177520	08/09/78	0.27	4045	4900
MCNHORC-03	06/17/08	0.15	**5240**	**6160**
MCNHORC-04	06/18/08	0.12	**8770**	**9980**
6177520	08/21/79	0.05		**9080**
MCNHORC-05	06/17/08	0.04	**7680**	**9050**
6177520	10/19/77	0.03		**13300**
MCNHORC-03	08/27/08	0.01	**7310**	**8988**

6.5.3 Nelson Creek

The TDS data record for Nelson Creek contains 28 results for measured valuesTDS. All were obtained during sampling events of 2003 through 2008. The results are arranged in upstream to downstream order in **Table 6-9**. Note the much lower values for the three samples and measurements taken during March. The annual peak flow period for Nelson Creek extends from late February through early May. The table contains several values from intermittent stream reaches such as the South Fork of Nelson Creek (SFUS-01) that shows a marked increase in dissolved solids from spring to mid-summer. The site labeled “Pond-25” has two very different measurements that probably reflect flowing versus non-flowing conditions in a large channel pool in the central part of the watershed. Frequent rainfall occurred during May of 2008, prior to sampling in June. This is reflected in the lower dissolved solids data from widely scattered monitoring locations.

Corresponding flow rates are unavailable for all but three of the **Table 6-9** measurements. Flows measured on June 17, 2008 were zero for the headwaters site M31NLSNC01, 0.24 cfs for site M31NLSNC02, located 13 miles downstream, and 0.33 cfs for site 6131200, another five miles downstream. These flows at the three sites coincide with respective TDS values of 6,150, 4,040 and 2,550 mg/L. Targets for TDS and SC were met only at the downstream-most site.

Table 6-9. TDS and SC values measured for Nelson Creek sites arranged from upstream to downstream.

Site ID	Activity Start Date	TDS (mg/L)	SC (µS/cm)
NCUS-02	03/08/07	1,200	1,700
NCUS-02	04/17/07	13,100	14,300
NCUS-02	05/10/07	11,400	12,580
NCUS-02	06/14/07	9,140	10,280
NCUS-02	07/11/07	6,980	8,627
NCDS-01	09/26/06	4,400	10,090
SFUS-01	09/26/06	55,300	7,062
SFUS-01	10/22/06	60,000	275,700
SFUS-01	03/08/07	935	1,394
SFUS-01	04/17/07	9,540	10,820
SFUS-01	05/09/07	9,560	13,620
SFUS-01	06/13/07	10,900	12,240
SFUS-01	07/11/07	18,500	18,750
M31NLSNC01	06/17/08	**6,150**	**7,720**
POND-25	06/13/07	1,110	1,704
POND-25	07/10/07	11,600	14,020
MCNNLSN-01	07/09/03	6,920	8,600
MCNNLSN-01	07/14/03	6,670	
NCDS-01	10/22/06	2,720	31,030
NCDS-01	11/11/06	2,460	3,200
NCDS-01	03/08/07	438	605
NCDS-01	04/16/07	5,780	7,370
NCDS-01	05/09/07	6,500	8,122
NCDS-01	06/12/07	4,330	5,629
NCDS-01	07/09/07	8,100	9,697

Table 6-9. TDS and SC values measured for Nelson Creek sites arranged from upstream to downstream.

Site ID	Activity Start Date	TDS (mg/L)	SC (µS/cm)
M31NLSNC02	06/17/08	**4,040**	**5,630**
6131200	06/17/08	2,550	3,550
MCNNLSN-03	07/10/03	2,700	

Figure 6-9 illustrates the data distributions of calculated TDS values for Nelson Creek. Calculated TDS values were derived from a regression equation of the relationship between paired measurements of SC and TDS. Over 80 percent of the high flow values meet the proposed TDS target. High flow TDS loading is generally not a problem in Nelson Creek. For flows less than the 50th percentile (0.32 cfs), when aquatic life use in C-3 streams is most vulnerable, 70 percent of the calculated TDS values exceed the proposed target. The low flow median TDS concentration is 3,661; a nine percent reduction in the low flow median would be required to meet the target TDS concentration. Over all flow conditions, the median TDS value (1,616 mg/L) meets the proposed target.

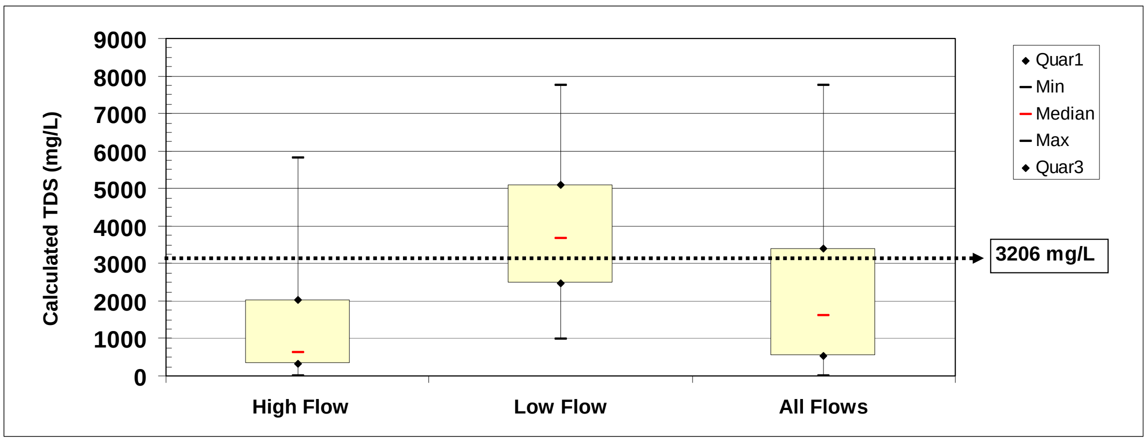

Figure 6-9. Target departures for calculated TDS data distributions for high and low flow conditions in Nelson Creek

Among the fifth code hydrologic unit watersheds in the Redwater TPA, Nelson Creek has the smallest cropland extent with six percent. Given the smaller target departures compared to East Redwater Creek and Horse Creek, and lack of human-caused sources in Nelson Creek, the sulfate impairment cause should be reassessed before development of dissolved solids TMDL. Nelson Creek, with its small cropland area, could represent a minimally impacted condition with regard to salt loading from tilled cropland. A similar situation exists in adjacent Timber Creek.

Timber Creek has the highest median low flow SC value of any stream in the planning area, with only nine percent of its watershed area as tilled cropland. The evidence suggests that natural geologic sources of salinity, or other unknown human sources of salinity, may be affecting surface water quality in the southwestern extent of the planning area. The anomalous relationship between cropland extent and surface water salinity in this area should be better understood prior to TMDL development.

6.6 Dissolved Solids Source Quantification

The assumed human caused source of dissolved solids loading to surface water is from groundwater affected by precipitation recharge within tilled cropland under a crop-fallow rotation system of moisture harvesting. A conceptual model of this source is illustrated in **Figure 6-10**. Excess precipitation recharge to the water table delivers dissolved solids to down-gradient discharge areas that can include stream channels.

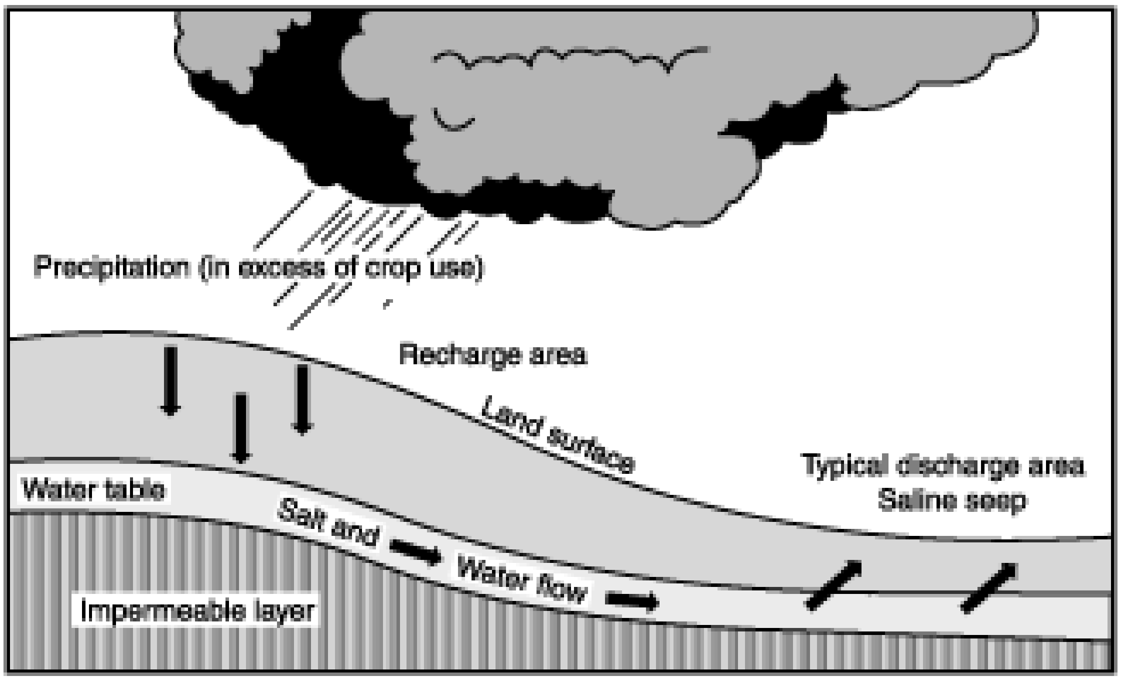

Figure 6-10 Conceptual model of dissolved solids loading from excess precipitation recharge of shallow aquifers beneath croplands.

Under perennial vegetation cover, most plant-available soil water is consumed by transpiration, allowing little to percolate to the local water table. The purpose of cropping in alternate years is to increase soil water in the root zone for a 21-month fallow period for subsequent use by the crop the following growing season. When the water holding capacity of root zone soils is reached, additional water moving through the root zone percolates to the local groundwater carrying a dissolved solids load from soil and aquifer materials. Percolating groundwater that discharges to streams in this setting delivers an increased salt load compared to settings where sub-root zone percolation is minimized by evapotranspiration from perennial plant cover

The TMDL is intended to reflect the application of all reasonable land, soil, and water conservation practices to control human caused pollutant loading. Control of dissolved solids loading from the crop-fallow production system is accomplished by scheduling crop seeding and production according to soil moisture supply rather than by including a regular, alternating fallow cycle in each two-year production cycle irrespective of root zone moisture supply. Researchers working on salinity control in Montana concluded that 7-15 percent of annual precipitation percolates below the root zone under crop-fallow rotation acreage, compared to 1-4 percent under native sod (Holzer et al 1995). Thus, the ratio of long-term percolation from beneath crop-fallow acreage to that from beneath native sod is about 4:1. This ratio, combined with acreage figures for tilled cropland and perennial vegetation cover can be used to partition the volume of deep percolation between these to cover types. The result is an estimate of deep percolation from beneath native rangeland (plus CRP acreage), and an estimate of current percolation from crop-fallow acreage.

The bedrock geology beneath the Redwater TPA consists mainly of the Fort Union Formation (**Appendix A**, **Figure 4**). The formation was deposited in deltaic and marine estuarine environments resulting in a heterogeneous sequence of shales, siltstones and sandstones with numerous coal beds (Lee 1981). **Table 6-10** contains means and ranges of dissolved cations and anions concentrations in water from shallow (< 150 ft) Fort Union wells. Although quite variable, the groundwater is generally brackish with its chemistry dominated by sodium sulfate

Table 6-10. Dissolve cation and anion concentrations (mg/L) in shallow Fort Union Formation wells (Lee 1981).

Statistic (n=375)	Ca	Mg	Na	K	HCO3	SO4	Cl	TDS
Minimum	1.7	0.3	3.2	1	20	0	0.4	110
Mean	120	120	410	8	650	1,100	13	2,100
Maximum	460	680	1,900	48	2,000	4,400	120	6,300

In this analysis, dissolved solids loading to stream channels from groundwater discharge is calculated as the product of discharge volume and dissolved solids concentration. Groundwater discharge is calculated using Darcy's law, as described above in **Section 6.3**, where the groundwater discharge rate is a function of aquifer hydraulic conductivity, water table gradient, and size of the area across which the discharge to surface water occurs. The groundwater concentration of dissolved solids is determined from analytical results for samples of shallow groundwater.

Expectations for TDS load reductions from cropland sources vary greatly with local climate, soil, geologic conditions and crop management options (Brown et al 1982). Reductions are often stated in term of declines in water table elevations within seep recharge and discharge areas. Holzer and others (1995) described a 22 percent decline in discharge area water table elevations over a nine-year period for a seep reclamation project in Montana. Beke and others (1993) reported long-term reductions in seepage volume from a continuous wheat cropping system, compared to two different wheat-fallow rotations. They reported a 20 percent reduction in the volume of water percolating beneath a continuously cropped area, compared to the fallow treatments for sites with cropping histories dating from 1911 and 1951. Adopting evidence from this long-term study, a 20 percent reduction in the volume of sub-root zone percolation is assumed possible in the Redwater River TPA setting with intensive soil moisture management within dryland cropping systems. In this analysis, a 20 percent reduction in cropland discharge is assumed to represent all reasonable land, soil and water conservation practices on the cropland salinity source. The current condition discharge from native rangeland is assumed to represents the natural background TDS loading to surface water from shallow groundwater.

The TDS concentration of shallow groundwater that ultimately discharges to streams is not expected to change significantly with changes in crop cover management. Percolating water from both cropland and rangeland source passes through a large reservoir of soluble salts in the unsaturated zone and shallow aquifer. Therefore, loading reductions result from a reduction in the rate of deep percolation beneath cropland with more efficient uptake of root zone moisture. With this assumption, TDS loading from native rangeland is not expected to change, while loading from cropland sources would be reduced in proportion to the reduction in soil water beneath the root zone.

6.6.1 Dissolved Solids Loading to East Redwater Creek.

East Redwater Creek is an intermittent fourth order tributary of the Redwater River. Salinity related impairment listings for SC, TDS, and sulfates were first posted in 1992.

The GIS layer of construction information for shallow (< 150 ft) wells was extracted from the GWIC database for the East Redwater Creek watershed boundary. Attribute data for static water level were subtracted from the ground surface elevation determined from topographic maps. The difference is the elevation of the water table surface. The array of points for water table elevation was interpreted to produce water table contours. **Figure 6-11** is the resulting water table map of East Redwater Creek with 100-foot contours.

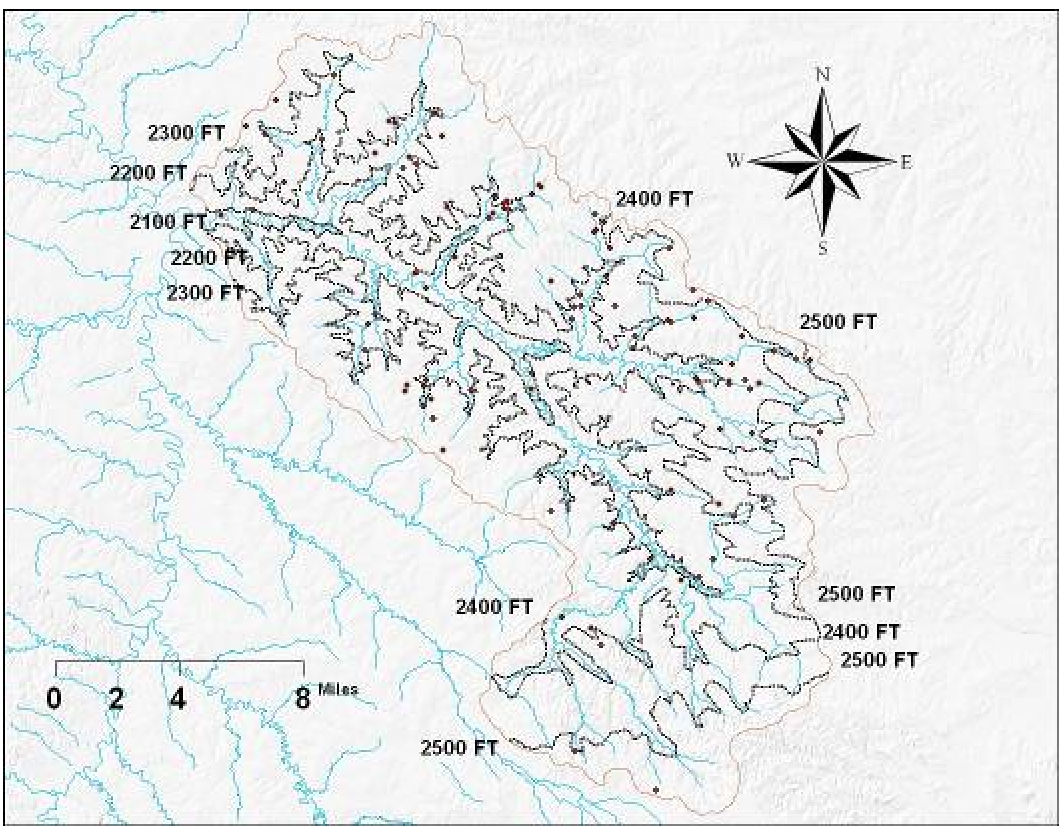

Figure 6-11. Approximate water table contour map of East Redwater Creek with locations of GWIC well construction data

A water table gradient was estimated using GIS tools to measure distances perpendicular to the contours along the axes of major drainages in the watershed. The cross-sectional area of groundwater discharging to the channel was estimated by multiplying channel length by a mean channel width determined from aerial photography. Hydraulic conductivity was estimated from pump test results for 10 Fort Union Formation wells in the area **Appendix B**. The parameters and values used to estimate the rate groundwater discharge to East Redwater Creek are the following:

- Water table gradient – 0.0065,
- Hydraulic conductivity – 13 ft/day,
- Stream length – 257,582 ft
- Mean stream width – 8 ft

The estimated discharge rate of the aquifer is:

(Qa) = (13 ft/day)(2,060,656 ft2)(0.0065)
= 174,125 ft3.day or (2.0 cfs)

The flow of two cfs is the estimated groundwater discharge rate to East Redwater Creek over the entire 48-mile length of the channel. Evaporation and transpiration by aquatic and riparian vegetation increase with shrinking channel width during low flow conditions. These losses, combined with incidental livestock and wildlife consumption, prevent the instream accumulation of groundwater flows that would equal the total discharge estimate. Evaporative and transpiration losses may partially explain the difference between the mean of measured surface water TDS concentrations (4,413 mg/L) and the calculated mean TDS concentration in shallow wells (1,482 mg/L) explained below.

The GWIC database contains water quality data on nine wells with a total depth of 150 feet or less in the East Redwater Creek drainage. The database contains values for laboratory SC from each well. The groundwater concentration of TDS was estimated from the TDS:SC ratio of 0.77 calculated for surface water samples from East Redwater Creek that have measured values for both TDS and SC. The mean SC value for the shallow East Redwater wells is 1,925 µS/cm. This value multiplied by 0.77 gives an estimate of 1,482 mg/L TDS for shallow groundwater in the drainage. This concentration, times the estimated groundwater discharge rate of two cfs, gives a daily TDS loading rate according to the following equation:

(2.0 cfs)(1,482 mg/L)(5.4) = 16,006 lbs TDS/day

Where: 2. cfs = estimated rate of aquifer discharge to the channel,
1,482 mg/L = TDS concentration in groundwater,
5.4 = unit conversion factor

An average loading rate of 16,006 pounds of dissolved solids per day equates to 5,842,190 pounds per year. The annual loading rate per mile for the 48-mile length of the channel is 121,712 pounds.

6.6.2 Dissolved Solids Loading to Horse Creek.

Horse Creek is an intermittent fourth order tributary of the Redwater River. The stream was listed in 2000 as being impaired due to salinity.

The GIS layer of construction information for shallow (< 150 ft) wells was extracted from the GWIC database for the Horse Creek watershed boundary. Attribute data for static water level were subtracted from the ground surface elevation determined from topographic maps. The difference is the elevation of the water table surface. The array of points for water table elevation was interpreted to produce approximate water table contours. **Figure 6-12** is the resulting water table contour map of Horse Creek with 100-foot contours.

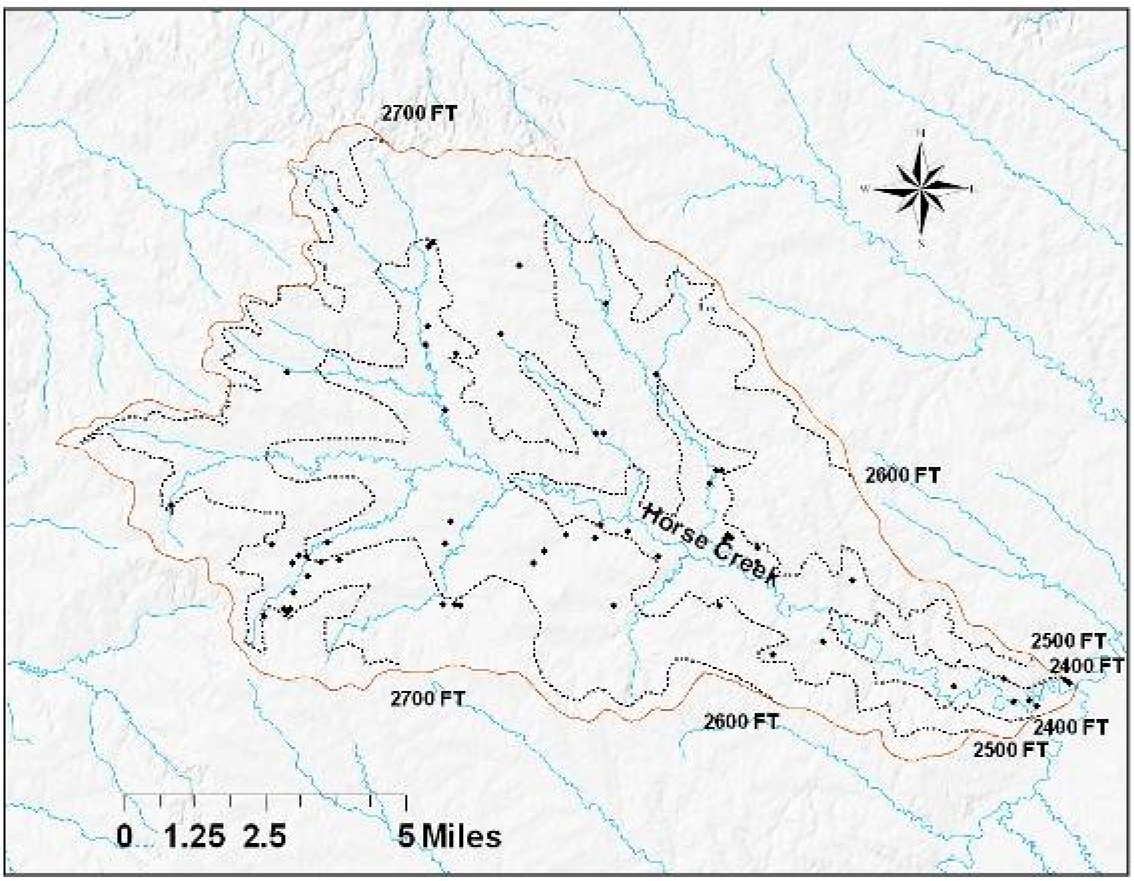

Figure 6-12. Approximate water table contour map of Horse Creek with locations of GWIC well construction data

A water table gradient was estimated using GIS tools to measure distances perpendicular to the contours along the axes of major drainages in the watershed. The cross-sectional area of groundwater discharging to the channel was estimated by multiplying channel length by a mean channel width determined from aerial photography. Hydraulic conductivity was estimated from pump test results for seven Fort Union Formation wells in the area Appendix B. The parameters and values used to estimate the rate groundwater discharge to Horse Creek are:

- Water table gradient – 0.004

- Hydraulic conductivity – 3.3 ft/day
- Stream length – 158,429 ft
- Mean stream width – 15 ft

The estimated discharge rate of the aquifer is:

(Qa) = (3.3 ft/day)(2,376,435 ft2)(0.004)
= 31,369 ft3.day or (0.36 cfs)

The flow of 0.36 cfs is the estimated groundwater discharge rate to Horse Creek over the 30-mile length of the channel. Evapotranspiration losses increase under low flow conditions as the channel width shrinks through the course of the growing season. As with East Redwater Creek, evaporative and transpiration losses have a large influence on Horse Creek water quality. The mean surface water TDS concentration measured in Horse Creek is 6,172 mg /L. The estimated average TDS concentration of shallow groundwater is 1,792 mg/L.

Water quality data is available for five shallow (≤150 ft) wells in the Horse Creek drainage. The database contains values for laboratory SC from each well. The groundwater concentration of TDS was estimated from the TDS:SC ratio of 0.81 calculated for Horse Creek surface water samples having measured values for both TDS and SC. The mean SC value for the shallow wells is 2,059 µS/cm. This value multiplied by 0.81 gives an estimate of 1,668 mg/L TDS for shallow groundwater in the drainage. This concentration, times the estimated groundwater discharge rate of 0.36 cfs, gives the daily TDS loading rate calculated below:

(0.36 cfs)(1,668 mg/L)(5.4) = 3,243 lbs TDS/day

Where: 0.36 cfs = estimated rate of aquifer discharge to the channel,
1,668 mg/L = TDS concentration in groundwater,
5.4 = unit conversion factor

An average loading rate of 3,243 pounds of dissolved solids per day equates to 1,183,695 pounds per year. The average annual loading rate per mile for the 30-mile length of the channel is 39,457 pounds.

6.6.3 Dissolved Solids Loading to Nelson Creek

Nelson Creek is an intermittent tributary to the Dry Creek arm of Fort Peck Reservoir. The stream was listed in 2006 as being impaired by sulfates. As with East Redwater and Horse creeks, well construction data from the GWIC database was used to construct an approximate groundwater contour map for Nelson Creek. **Figure 6-13** is the resulting water table contour map of Nelson Creek with 100-foot contours. Construction data are not available for wells installed and sampled as part of a proposed coal development project in Nelson Creek. Therefore, these wells were not used to construct the map in **Figure 6-13**.

GIS measuring tools were used to estimate the table gradient. The cross-sectional area of the groundwater discharge zone was estimated by multiplying channel length by a mean channel width determined from aerial photography. Hydraulic conductivity was estimated from pump test results for five Fort Union Formation wells in the area **Appendix B**.

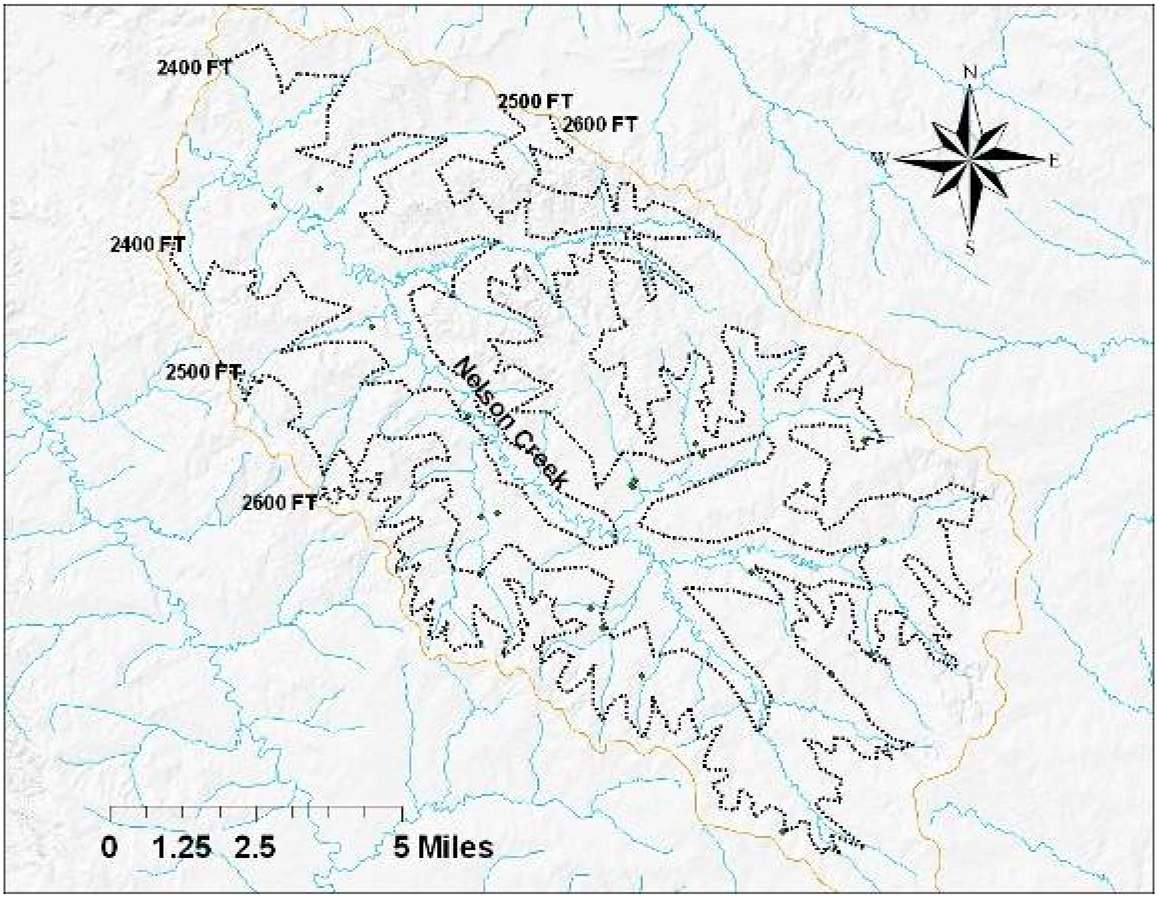

Figure 6-13. Approximate water table contour map of Nelson Creek with locations of GWIC well construction data

The parameters and values used to estimate the rate groundwater discharge to Nelson Creek are the following:

- Water table gradient – 0.0063
- Hydraulic conductivity – 1.5 ft/day
- Stream length – 172,031 ft
- Mean stream width – 8 ft

The estimated discharge rate of the aquifer is:

(Qa) = (1.5 ft/day)(1,376,248 ft2)(0.0063)
= 13,006 ft3/day or (0.15 cfs)

The flow of 0.15 cfs is the estimated groundwater discharge rate to Nelson Creek over the 33-mile length of the channel. Results for surface water TDS concentration with corresponding flow data are limited for Nelson Creek. The median calculated TDS value, based on a regression equation derived from the limited number of paired SC and TDS measurements, is 3,661 mg/L.

Groundwater quality data available from the GWIC database is for four shallow (≤150 ft) wells in the Nelson Creek drainage that have values for laboratory SC. The groundwater TDS concentration of was estimated for these wells from the TDS:SC ratio of 0.73 calculated for Nelson Creek surface waters samples having measured values for both TDS and SC. The mean SC value for the shallow wells is 2,622 µS/cm. This value multiplied by 0.73 gives an estimate of 1,914 mg/L TDS for shallow groundwater in the drainage. This concentration, times the estimated groundwater discharge rate of 0.15 cfs, gives the daily TDS loading rate calculated below:

(0.15 cfs)(1,914 mg/L)(5.4) = 1,550 lbs TDS/day

Where: 0.15 cfs = estimated rate of aquifer discharge to the channel,
1914 mg/L = TDS concentration in groundwater,
5.4 = unit conversion factor

An average loading rate of 1,550 pounds of dissolved solids per day equates to 565,750 pounds per year. The average annual loading rate per mile for the 33-mile length of the channel is 17,144 pounds.

6.7 Dissolved Solids TMDLs and Allocations

The TMDLs for TDS are expressed as daily loading equations where the combined daily groundwater discharges from tilled cropland and native rangeland, multiplied by the TDS concentration in groundwater, and a unit conversion factor, equal the allowable human-caused loading, plus loading from naturally occurring sources. Loading from the cropland is assumed to be controllable through a combination of soil moisture augmentation and increased consumption of soil moisture by growing crops. Loading to groundwater from native rangeland and CRP acres is assumed to be naturally occurring.

The allocations to controllable sources are based on an assumed achievable loading reduction of 20 percent realized through an increase in the efficiency of soil water consumption by crops. **Table 6-11** contains acreage figures and deep percolation estimates for each land cover category for the three salinity-listed waterbodies. In each watershed, the percolation rates from crop-fallow versus perennial cover conform to the 4:1 ratio observed by Montana saline seep researchers (Holzer et al 1995). The total seepage discharge rate for each stream equals that estimated for each watershed from aquifer characteristics and stream geometry.

Table 6-11. Existing condition estimates of shallow aquifer recharge rates from crop-fallow acreage and perennial vegetation cover for salinity listed streams

Stream Name	Cover Condition	Acreage	Percolation Rates	
			ft3/ac/yr	cfs
East Redwater Creek	Crop-Fallow	40,676	880	1.1
	Perennial	126,410	220	0.9
			Total	**2.0**
Horse Creek	Crop-Fallow	24,610	327	0.25
	Perennial	41,620	82	0.11
			Total	**0.36**

Table 6-11. Existing condition estimates of shallow aquifer recharge rates from crop-fallow acreage and perennial vegetation cover for salinity listed streams

Stream Name	Cover Condition	Acreage	Percolation Rates	
			ft3/ac/yr	cfs
Nelson Creek	Crop-Fallow	4,767	200	0.03
	Perennial	76,191	50	0.12
			Total	**0.15**

The acreage figures for the two cover categories sum to 98 percent or more of the watershed area for each drainage. The remaining identified cover categories of "urban" land and woodland are assumed to have minimal percolation discharge. Other assumptions in the analysis include:

- Percolation beneath the root zone flows through the shallow aquifer and ultimately discharges to streams,
- Pump test hydraulic conductivity values reflect the shallow aquifer conditions,
- Most tilled cropland is managed in a crop-fallow rotation, and
- The volume of percolation beneath native sod and CRP acreage are similar.

The percolation rates in **Table 6-11** can be used to calculate daily TDS loading rates for each cover type using the following equation:

(Percolation (cfs)) x (TDS (mg /L)) x (5.4 (unit conversion)) = TDS Load (lbs/day).

Table 6-12 gives the estimated daily TDS loads to listed streams from cropland and rangeland sources in each watershed.

Table 6-12. Estimated current daily TDS loading to East Redwater Creek from cropland and rangeland

Stream Name	Cover Condition	Percolation Rate (cfs)	Groundwater TDS (mg/L)	Daily TDS Load (lbs/day)
East Redwater Creek	Tilled Cropland	1.1	1,482	8,803
	Perennial Vegetation	0.9		7,203
	Total	2.0		16,006
Horse Creek	Tilled Cropland	0.25	1,668	2,252
	Perennial Vegetation	0.11		991
	Total	0.36		3,343
Nelson Creek	Tilled Cropland	0.03	2,045	310
	Perennial Vegetation	0.12		1,240
	Total	0.15		1,550

The abundance of dissolved solids in soil and geologic materials and the mixing of seepage from different land cover areas along the flow path are assumed to prevent significant differences in the TDS concentration of shallow groundwater that ultimately discharges to streams. Load reductions result from improved efficiency in crop consumption of root zone moisture. Therefore, TDS loading from native rangeland is not expected to change from current estimates in **Table 6-12**. Loading from cropland would be reduced in proportion to the reduction in soil water movement beneath the root zone. Expected reductions in this analysis are adopted from those measured by Beke and others (1993) from long-term saline seep research in southern

Alberta. They measured an average 20 percent reduction in percolation volume beneath continuously cropped areas compared crop-fallow systems.

Table 6-13 gives the current TDS loads, load allocations and TMDL for natural background and cropland sources in East Redwater Creek. The TMDL reflects a 20 percent reduction in current cropland loading from 8,803 to 7,203 pounds per day. The estimated discharge rate and loading from naturally occurring sources is that from combined native rangeland and CRP acreage managed for perennial plant cover. The figures in the table show no change in current loading for natural background sources. The estimated reduction in deep percolation beneath cropland translates to an overall loading reduction of 10 percent (100 x (16,003 lbs – 14,406 lbs)/16,003 lbs = 10).The daily allocations of 7,203 pounds from each source category sum to the low flow TMDL of 14, 406 pounds.

Table 6-13. Current low flow TDS loads, load allocations and TMDL for East Redwater Creek

Source	TDS (mg/L)	Current Percolation Rate (cfs)	Current Loading (lbs/day)	Modified Percolation Rate (cfs)	TDS Allocations (lbs/day	TDS TMDL (lbs/day)
Cropland	1,482	1.1	8,803	0.9	7,203	14,406
Natural Background	1,482	0.9	7,203	0.9	7,203	

Table 6-14 gives the current TDS loads, load reduction, and TMDL for Horse Creek sources. A 20 percent reduction in deep percolation beneath cropland translates to an overall loading reduction of 19 percent (100 x (3,343 lbs – 2,712 lbs)/3,343 lbs = 19). The daily allocations of 1,801 pounds from cropland and 911 pounds from natural background sources sum to the low flow TMDL of 2, 712 pounds.

Table 6-14. Current low flow TDS loads, load allocations and TMDL for Horse Creek

Source	TDS (mg/L)	Current Percolation Rate (cfs)	Current Loading (lbs/day)	Modified Percolation Rate (cfs)	TDS Allocations (lbs/day	TDS TMDL (lbs/day)
Cropland	1,668	0.25	2,252	0.20	1,801	2,712
Natural Background	1,668	0.11	991	0.11	911	

Applying the same process to Nelson Creek, **Table 6-15** gives the current TDS loads, load reduction, and TMDL. A 20 percent reduction in deep percolation beneath the estimated 4,800 acres of cropland in Nelson Creek translates to an overall loading reduction of only four percent (100 x (1,550 lbs – 1,488 lbs)/1,550 lbs = 4).

Table 6-15. Current low flow TDS loads, load allocations and TMDL for Nelson Creek

Source	TDS (mg/L)	Current Percolation Rate (cfs)	Current Loading (lbs/day)	Modified Percolation Rate (cfs)	TDS Allocations (lbs/day	TDS TMDL (lbs/day)
Cropland	1,914	0.03	310	0.024	248	1,488
Natural Background	1,914	0.12	1,240	0.12	1,240	

The degree of uncertainty in the loading estimates (discussed below in **Section 6-8**), the inherent lack of precision in quantifying soil water percolation, and the limited extent of human-caused loading sources in Nelson Creek suggest that a TDS TMDL may not be appropriate at this time.

6.8 Sources of Uncertainty and Margin of Safety for TDS TMDLs

The impairment determinations and TDS loading analysis for the three salinity listed streams are based on an array of data sources and process assumptions. Each information source and loading assumption introduces an accumulating level of uncertainty into impairment conclusions, the magnitude of current loading and the achievability of needed reductions. The following sections describe the uncertainty sources and discuss their contribution to an implicit margin of safety for the dissolved solids TMDLs.

6.8.1 Water Chemistry Data Quality

A distinctive characteristic of the water quality database in the Redwater TPA for salinity related parameters is the high proportion of results obtained under low or non-flowing conditions. Over half of the samples from East Redwater Creek and 70 percent of Horse Creek samples do not have flow measurements that correspond to water chemistry results. A similar situation would exist in Nelson Creek if not for the USGS gage at the Highway 24 crossing. The uniform distribution of loading points along the Nelson Creek flow duration curve in **Figure 5-7**, and the ability to construct a duration curve, is due to the presence of this stream gage. Gage height data collected by private consultants as part of Nelson Creek baseline studies have no corresponding rating curves for gaged sites, thus the gage height data could not be converted to flow rates. Except for the 2008 field sampling, little recent flow information is available that corresponds with TDS results for Nelson Creek. The mid- to late summer distribution of sampling dates and the lack of measured flow during sampling explains the lack of data.

50 percent of the salinity parameter results for Horse Creek, 50 percent for East Redwater Creek and two thirds of the Nelson Creek results, not collected at the gage location, were collected or measured from mid-June through August when flow is minimal or non-existent in intermittent prairie streams. This pattern of sample timing introduces a bias in favor high TDS and SC results. The bias translates to high loading reductions needed to meet targets, such as the 60 percent reduction needed for Horse Creek TDS loading.

Other data quality related sources of uncertainty include the inconsistency in parameter selection. The development of the TDS target depended up on TDS values generated from SC-TDS regression analysis, as opposed to a database of direct TDS measurements. The age of the salinity dataset is another source of uncertainty. From 40 to 50 percent of the readings and measurements for each of the three streams are 25 years or older. This reflects the more intense data gathering efforts of the 1970s and 1980s to document backgroundwater quality conditions in areas of potential coal development. 60 percent of the dataset used to characterize groundwater salinity consist of samples collected in 1975. This predates CRP enrollment and may reflect aquifer conditions under a larger extent of tilled cropland that could include higher SC values in recharge areas. Although the spatial distribution of sampling and measurement sites with each watershed is generally adequate, some overlap exists in the lower reaches of Horse Creek and

East Redwater Creek. Future site selection to better characterize land cover related sources would be helpful in these two watersheds.

In a general consideration of water chemistry data quality, the bias toward hot weather sampling in Horse Creek and East Redwater Creek contributes to an implicit margin of safety for these two TDS TMDLs. Samples from streams with minimal flows or from isolated channel pools reflect the effects of evaporative concentration that inflates target departures and load reduction requirements compared to a more seasonally balanced dataset.

6.8.2 Source Assessment Assumptions

Several sources of uncertainty exist in the estimates of TDS loading from groundwater discharge. The estimates, based on Darcy's law, are sensitive to the value in the flow equation for hydraulic conductivity (K). The K values used were calculated from pump test data for local water supply wells. The likely well development objective was to maximize water yield rather than to characterize aquifer discharge to local streams. This introduces a bias in favor of higher aquifer discharge rates that, in turn, increase the TDS loading estimates. A higher loading estimate introduces a margin of safety against underestimating dissolve solids loading from both natural background and agricultural loading.

The cropland acreage estimates in each of the three watersheds are based on 2001 USGS land cover and agricultural census data that may not reflect the most current conditions. The acreage figures for CRP enrollment in Richland County were extrapolated from McCone County and may not accurately reflect cropland patterns in the East Redwater Creek watershed. The discrepancy would affect the accuracy of percolation volume estimates for the two land cover categories.

The groundwater quality data is sparse and widely spaced across the planning area. Groundwater TDS concentrations were estimated from 27 shallow wells. The broad spacing among the wells does not reflect the more immediate spatial relationship between recharge and discharge areas reported by soil salinity researchers. Although field scale conditions are likely more variable, the groundwater TDS values in **Table 6-14** reflect the trend of increasing dissolved solids from northeast to southwest that corresponds to deeper and finer textured Fort Union sediments in this direction. Most of the SC values are from the mid-1970s and may reflect more extensive crop-fallow acres that have since been replaced by CRP enrollment or annual cropping. Higher than actual estimates of cropland extent increase the loading estimates and provide an additional margin of safety in the analysis.

The source assessment does not directly account for dissolved solids that accumulate within shallow stock water impoundments that are common in the planning area. Although the loading ultimately comes from the same groundwater source, reservoir accumulations cause episodes of higher initial loading from flushing flows following extended dry periods. A water quality sampling program focused during the late growing season could conceivably include more of such high salinity episodes that lead to higher loading estimates based on statistical summaries. The resulting higher estimates of needed load reductions contribute to a margin of safety against underestimating salinity loading.

6.9 Seasonality of TDS TMDLs

The selected SC and TDS targets are based on a seasonal stratification of the dissolved solids database. Elevated salt loading most commonly occurs during low flow or non-flowing conditions on intermittent prairie streams. The targets are intended to apply under flowing conditions rather than to the condition of evaporative solute concentration in a non-flowing channel. **Figure 6-14** illustrates the relationship between flow and measured SC in Horse Creek. Target exceedences in this stream appear to occur after the stream has transitioned from flow conditions caused by runoff to those of a base flow conditions more influence by groundwater discharge to the channel. The brackets in the figure illustrate the range of flow conditions over which targets would apply.

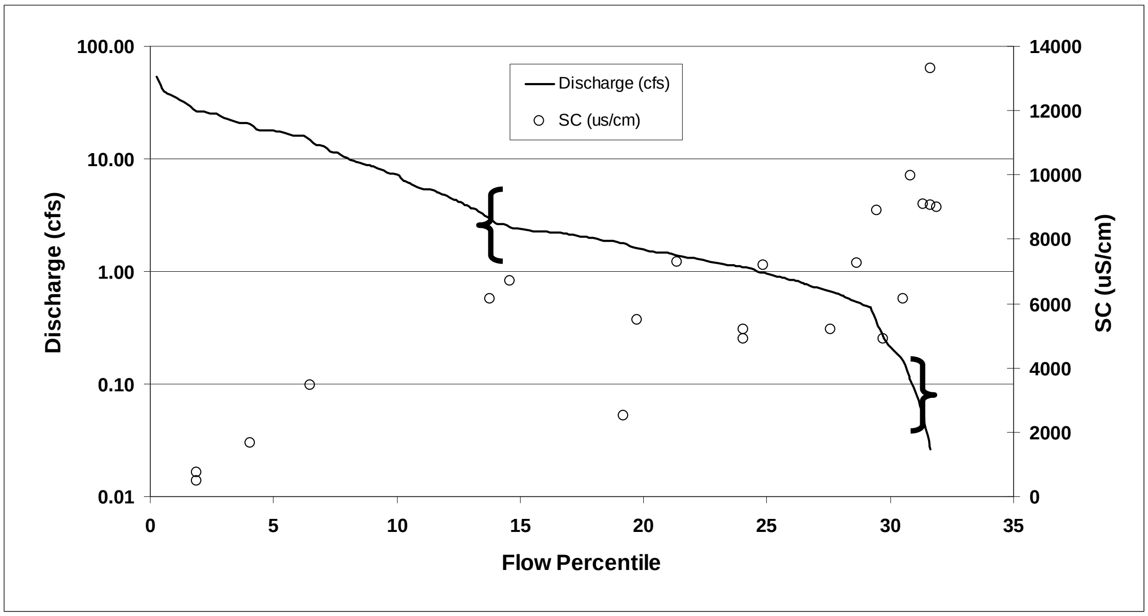

Figure 6-14. Graphed relationship between flow and measured SC in Horse Creek bracketing the flow conditions when targets would apply

Targets are intended to apply under base flow conditions dominated by groundwater discharges to the channel. Targets are not intended to apply when the flows and water chemistry from groundwater discharges are masked by runoff effects, or when evaporation is the only factor affecting solute concentration.

6.10 Adaptive Management for TDS TMDLs

The lack of a recent and comprehensive database on which to quantify the TDS TMDLs for East Redwater Creek and Horse Creek requires an adaptive management approach to water quality improvement for these streams. The sources of uncertainty described above in Section 6.8 may require future adjustments to both targets and loading assumptions that are based on the following:

1. A more accurate representation of land cover conditions,

2. A more detailed characterization of surface water TDS concentration as influenced by flow rate,
3. A better understanding of local groundwater flow dynamics,
4. A more current characterization of groundwater quality, and
5. Watershed-specific information on proportional TDS loading to groundwater from crop-fallow acreage versus that from native rangeland.

The loading analysis presented here is intended as a reasonable approximation of existing conditions. The disparity between the magnitude of reductions reported in the literature for cropland related salinity sources, and the larger reductions suggested by existing surface water quality data will need to be resolved through water quality monitoring and accurate surveying of the shallow aquifer in each watershed. Until more current information is available the specified loading reductions are intended as requirements to restore support for aquatic life use.

SECTION 7.0
FRAMEWORK WATER QUALITY IMPROVEMENT PLAN

7.1 Summary of Improvement Plan

This section provides a framework plan for water quality restoration in the Redwater River TPA, focusing on how to meet conditions that will likely achieve the TMDLs presented in this document. This section identifies which activities will contribute the most reduction in pollutants for each TMDL. Limited information about spatial application of each restoration activity will be provided.

This section should assist stakeholders in developing a more detailed adaptive Watershed Restoration Plan (WRP) in the future. The locally-developed WRP will likely provide more detailed information about restoration goals and spatial considerations within the watershed. The WRP may also encompass broader goals than the focused water quality restoration strategy outlined in this document. The intent of the WRP is to serve as a locally organized "road map" for watershed activities, sequences of projects, prioritizing types of projects, and funding sources towards achieving local watershed goals, including water quality improvements. Within this plan, the local stakeholders would identify and prioritize streams, tasks, resources, and schedules for applying Best Management Practices (BMPs). As restoration experiences and results are assessed through watershed monitoring, this strategy could be adapted and revised by stakeholders based on new information and ongoing improvements.

7.2 Role of DEQ, Other Agencies, and Stakeholders

The DEQ can provide technical and financial assistance for stakeholders interested in improving water quality. The DEQ will work with participants to use the TMDLs as a basis for developing locally-driven restoration plans and administer project funding, and assist in identifying future funding sources.

Because most nonpoint source reductions rely on voluntary measures, it is important that local landowners, conservation district personnel, and agency resource technicians collaborate to achieve water quality restoration which will progress toward meeting water TMDL targets and load reductions. Specific stakeholders and agencies that have been, and will likely be involved in restoration efforts include the conservation districts of the five counties with jurisdiction in the planning area: Dawson, Garfield, McCone, Prairie and Richland. Agency stakeholders include the NRCS, Region 6 office of Montana FWP, EPA and DEQ. Other organizations and non-profits that may provide assistance through technical expertise, funding, educational outreach, or other means include Montana Salinity Control Association, Montana Bureau of Mines and Geology, of Montana State University (MSU) Agricultural Extension Service, and MSU Extension Water Quality Program.

7.3 Watershed Restoration Goals

The following are general water quality goals:

- Extension of technical guidance toward recovery of aquatic life beneficial uses to impaired stream segments,
- Technical guidance provided in this documents' TMDL components including:
  - water quality targets,
  - pollutant source assessments, and
  - general restoration guidance toward meeting TMDL allocations.
- Prescribe restoration activities that address significant pollutant sources.

Restoration goals are addressed through preparation and implementation of a Watershed Restoration Plan (WRP), a locally-derived plan that is more geared to watershed conditions and constraints than the TMDL document. Its development and refinement occur as activities progress and goals are adopted to a broader spectrum of concerns than those included in this document. The following elements may be included in a stakeholder-derived WRP:

- Documented support for restoration projects to improve and maintain water quality for streams addressed by completed TMDLs,
- Technical assistance needs for plan completion,
- Cost and spatial considerations for water quality improvement projects,
- Developed approach for BMP implementation,
- Information and education components to assist with stakeholder outreach regarding restoration approaches, benefits and funding assistance,
- A tentative and flexible schedule for implementing restoration goals,
- Identified measures and milestones toward plan completion,
- Developed approach for monitoring restoration outcomes and making adjustments.

Specific water quality goals or targets for each pollutant are detailed in the sections pertaining to each pollutant (**Sections 5 and 6**). These targets serve as the basis for long-term effectiveness monitoring for achieving the above water quality goals. These targets specify satisfactory conditions to ensure protection and/or recovery of beneficial uses. **Section 8** identifies a general monitoring strategy and recommendations designed to track water quality conditions and restoration successes.

7.4 Overview of Management Recommendations

Nutrient TMDLs were completed for eight waterbody segments and TDS TMDLs were completed for East Redwater and Horse Creeks. Other streams in the watershed may be in need of TMDLs, but insufficient information about them precludes TMDL development at this time. In general nutrient and TDS loading can be reduced by focusing restoration efforts on cropland, rangeland and livestock confinement source areas. Installment and reestablishment of vegetative filters on cropped acreage and diversions structures for livestock confinements may be needed where sediment routing and filter capacity has been lost due to high flow erosion episodes or equipment traffic.

7.4.1 Nutrient Restoration Approach

Cropland filter strip extension, vegetative restoration, and long-term filter area maintenance are vital BMPs for achieving nutrient TMDLs in predominantly agricultural watersheds. Vigorous filter strip vegetation, of either native or introduced varieties, provides the level of sediment removal needed to reduce sediment related loading of TN and TP.

Grazing systems with the explicit goal of increased vegetative post-grazing ground cover are needed to address the same nutrient loading from rangelands. Grazing prescriptions that enhance the filtering capacity of riparian filter areas offer a second tier of controls on the sediment content of upland runoff. Grazing and pasture management adjustments should consider:

1. The timing and duration of grazing on the shallow soils of river breaks terrain,
2. The spacing and exposure duration of on-stream watering locations,
3. Provision of off-stream site watering areas to minimize near-stream damage and allow impoundment operations that minimize salt accumulations,
4. Active reseeding and rest rotation of locally damaged vegetation stands.

In general, these are sustainable grazing and cropping practices that can reduce sediment bound nutrient loads while meeting production goals. The appropriate combination of BMPs will differ according to landowner preferences and equipment but are recommended as components of comprehensive plan for farm and ranch operators. The BMPs aim to prevent availability, transport, and delivery of sediment-bound nutrients by a combination of reducing runoff rates and minimizing delivery to areas of concentrated flow.

Seasonal livestock confinement areas have an historic precedent for placement near or adjacent to flowing streams. Stream channels were the only available livestock water sources prior to the extension of rural electicity. Although limited in size, their repeated use generates high nutrient concentrations in close proximity to surface waters. Episodic runoff with high nutrient concentrations generates large loads that can settle in pools of intermittent streams and remain bio-available through the growing season. Diversion and routing of confinement runoff to harvestable nutrient uptake areas outside of active water courses are effective controls.

Sound planning combined with effective conservation BMPs should be sought whenever possible and applied to croplands, pastures and livestock handling facilities. Assistance from resource professionals from various local, state, and federal agencies or non-profit groups is widely available in Montana. The local USDA Service Center and county conservation district offices are geared to offer both planning and implementation assistance.

7.4.2 Salinity Restoration Approach

This section outlines strategies for addressing TDS loading sources in need of restoration activities within the Redwater River TPA. The restoration strategy focuses on mechanisms to control cropland sources within the East Redwater Creek and Horse Creek watersheds. The most extensive loading source is the crop-fallow rotation system used for small grain production. A grain production cycle is followed by a 19-21 month fallow period intended to allow soil moisture replenishment and storage for the subsequent crop cycle. Once the root zone water holding capacity is reached, addition precipitation infiltration causes soil water to percolate beneath the root zone and into the shallow aquifer. The concentration of dissolve solids increases along this flow path to a variety of discharge areas controlled by surface topography and subsurface stratigraphy. Brown and others (1983) identified seven different saline seep types based on combinations of source area topography and stratigraphic controls on water movement. The flow scenarios affecting surface water are those with shallow groundwater discharging TDS loads to ephemeral, intermittent and perennial drainages. Dissolved solids loads either accumulate to be periodically washed downstream or enter flowing surface water directly.

The established solution to sub-root zone percolation of soil water can be summarized in three general steps:

1. Location of expanding shallow aquifer discharge areas,
2. Delineation of shallow aquifer recharge areas, and
3. Increased agronomic use of soil moisture that minimizes sub-root zone percolation and discharge area expansion.

Early detection of expanding discharge areas is important since delay of reclamation frequently leads to an expanding problem. Detection can be accomplished by property owner surveys of typical symptoms such as vegetation shifts toward salt tolerant plants, expanding areas of surface salt crystal formation, and evidence of frequent and prolonged surface soil moisture retention affecting soil aggregate stability, crop stand density or equipment use. Two organizations providing technical assistance to property owners are the Montana Salinity Control Association (MSCA) and county conservation districts. Opportunities for technical and financial assistance with salinity diagnosis and control can be coordinated at land owner request with the USDA, NRCS and other agencies.

Remediation begins with recharge area delineation. This is accomplished with diagnostic tools ranging from interpretation of published soil surveys, aerial photos and topographic maps to use of various soil moisture and electrical resistivity probes. Local groundwater flux between recharge and discharge areas is proportional the corresponding difference in hydraulic head. This difference is measured as the water table elevations in shallow observation wells placed in both the recharge and discharge areas. With observation wells in place, reduction in TDS loading to local groundwater movement begins with a plan for increased crop consumption of available water within the recharge zone.

Published soil surveys contain tables quantifying the inches of plant-available water in each inch of root zone soil. Information on rooting depth and annual water consumption is available for a selection of potential crop plants. Salinity control then becomes an unending process of balancing water consumption, by an economically viable cropping system, with water supply. Water supply can be manipulated by selecting tillage and cropping patterns that maximize the capture and infiltration of winter snowfall. Surplus moisture can be consumed by temporary cover crops that can either be harvested or incorporated to improve fertility and soil water holding capacity. Adequate crop nutrition helps deliver both a viable economic return and a robust means of harvesting soil moisture. Ultimately, salinity control is a focused application of precision agriculture. Many of the recent advances in crop variety development, weed control, and real time yield monitoring can be focused on improving not only soil quality and crop yields, but groundwater and down-gradient surface water quality as well.

Soil water management is a complex undertaking that cannot succeed without a system of effectiveness and trends monitoring to guide future target adjustments or to determine if additional measures are needed to meet the TMDLs.

SECTION 8.0
MONITORING STRATEGY AND ADAPTIVE MANAGEMENT

8.1 Introduction

The monitoring strategies discussed in this section are a required component of watershed restoration and TMDL development under Montana's TMDL law. Water quality monitoring guides water quality management adjustments by providing current resource response and trend information. The water quality targets and allocations presented in this document are based on data reductions, process assumptions, and extrapolations made under temporal and resource constraints. The outcome of these constraints is a level of uncertainty that, despite a margin of safety, requires a concerted monitoring effort to guide future efforts to sufficiently control nutrient and dissolved solids loading to restore support of beneficial uses.

An effective monitoring strategy provides feedback to resource managers on the feasibility of target attainment, the effectiveness of water quality restoration, and the need for target or restoration strategy adjustments. The monitoring approach described here is intended as a point of departure for stakeholders toward a better understanding of current conditions and pollutant source contributions. Long-term monitoring priorities will depend on locally driven restoration priorities and available funding.

8.2 Adaptive Management Approach

Information generated by water quality and restoration monitoring is processed in an adaptive management framework to allow adjustments in the frequency and location of data gathering and adjustments to remediation methods. New information can suggest appropriate target and allocation, or guide rethinking of restoration goals.

8.3 Future Monitoring Guidance

The principal objectives for future monitoring in the Redwater River planning area include:

- Gathering additional, paired water quality and stream discharge data to better characterize existing seasonal flow and loading conditions, supplement the available data used in target development, and strengthen the linkage between in-stream pollutant concentrations and support for aquatic life in C-3 streams,
- Better characterizing the timing and magnitude of nutrient loading from croplands,
- Providing improved estimates of the nutrient content of runoff from livestock confinement areas,
- Updating the available data describing local groundwater quality,
- Investigating the difference in deep percolation volumes beneath perennial vegetation cover versus crop-fallow acreage,
- Monitoring the performance of the Circle wastewater collection and treatment facilities,
- Investigating the reference stream potential of remote watersheds, and

- Documenting the water quality effects of vegetated filter strips in croplands and prescribed grazing systems on rangelands.

8.3.1 Improve the Existing Water Quality Database for Estimating Loading Conditions for Prairie Streams

A significant hurdle in the nutrient loading analysis was the lack of paired stream discharge and water chemistry data on listed streams that lack gage stations. Staff gages with established stage-discharge curves are needed for all listed segments lacking uninterrupted flow data from gage stations. These include East Redwater Creek, Horse Creek, Pasture Creek, Sand Creek and Timber Creek. .

Regularly timed growing season water sampling was also limited on ungaged streams. Sampling on East Redwater Creek, Horse Creek, Pasture Creek, and Sand Creek rarely captured loading during large, storm-driven flow events. The records for these streams are weighted toward very low flow or non-flowing conditions. This introduces a bias toward high parameter concentrations that occur as evaporation dewaters the channels. A schedule of regular sampling, whether monthly or more frequent, should be replaced by one designed to characterize loading over the range of growing season flow conditions. This will require a local effort to obtain access clearance prior to sampling and to read gages and collect samples on short notice.

Portions of the Nelson Creek and Prairie Elk Creek watersheds occur in the “River Breaks” level IV ecoregion. The sample size for nutrient parameters from this ecoregion was not sufficient to develop nutrient targets based on reference condition. The river breaks have typically higher stream gradients and larger percentage of exposed bedrock, compared to other Northwestern Great Plains sub-regions. Thus, river breaks may have inherently higher nutrient loading potentials. Additional nutrient sampling and nutrient target development specific to river breaks may be needed to avoid unjustified impairment listings.

The **Figure 5-1** relationship between diatom-inferred DO and TN indicates a weak correlation between the biological index and water column nitrogen levels. Additional algae samples, paired with TN sampling and pre-dawn DO readings, would clarify whether inferred DO is a useful nutrient target for prairie streams.

8.3.2 Improve the Accuracy of Event Mean Nutrient Concentrations for Croplands and Livestock Confinements

The estimates of nutrient loading from croplands, obtained through the STEPL modeling exercise, largely depended upon literature-based estimates of cropland erosion characteristics and broad regional values for soil nutrient content. A limited surface soil sampling program would help to verify whether the assumed soil nutrient fractions of 0.08 percent nitrogen and 0.03 percent phosphorus are valid for planning area croplands.

The STEPL results indicate that the largest fraction of nutrients delivered to streams is that adsorbed to sediment. The sediment load is determined by USLE parameters and the delivery ratio of detached sediment to sediment actually reaching stream channels. This ratio is calculated as a fraction of watershed area. The accuracy of the model results can always be improved by customizing the USLE parameters and delivery ratios to measured erosion and delivery. Establishing small-scale erosion plots on common cropland cover conditions would be helpful in customizing STEPL or other empirical models to actual field conditions.

The STEPL estimates of nutrient loading from livestock confinements are largely dependent on the assumed concentration of nutrients in runoff from these areas. The concentration values in the model area are based on livestock numbers, livestock type, and an assumed duration of use. These assumptions may not reflect the annual schedule of livestock handling and facility use practiced in the planning area. The modeled estimates of loading from these facilities can be improved by replacing the calculated values in the spreadsheet program by actual values measured in the field. Thus, the loading calculation can be "hardwired" with real runoff nutrient concentration data. The monitoring strategy should include a plan to collect this information for storm events that generate runoff from a number of facilities.

8.3.3 Updating the Groundwater Quality Database

Groundwater concentrations of nitrogen and dissolved solids were used in the assessment of nutrient loading from the Circle wastewater treatment facility and in assessing TDS loading from two land cover categories in salinity listed watersheds. The groundwater quality database for the planning area is dominated by analytical results from the 1970s and 1980s. Cropping patterns and pollutant sources have likely changed over this period. The monitoring strategy should include an effort to update water quality for the shallow aquifers in the watersheds of listed streams.

8.3.4 Effects of Land Cover on Percolation Volumes

The TDS loading analysis for East Redwater Creek, Horse Creek, and Nelson Creek included a broad assumption regarding the difference between deep percolation of soil water beneath acreage in a crop-fallow small grain rotation, compared to that in perennial plant cover. The assumption is that the percolation ratio is about 4:1. The conclusions on the magnitude of needed TDS loading reductions are based on the validity of this ratio.

The monitoring strategy for the planning area should include an effort to check this assumption against local conditions. Direct measurement of percolation volumes can be an expensive undertaking. What is recommended is a soil sampling approach that determines plant available moisture and water holding capacity of soils at the base of the root zone for each cover category. With both of these parameters known, inches of available moist can be determined, and better percolation volume estimates can be obtained for known areas of cropland and native rangeland/CRP.

8.3.5 Monitoring Associated with the Circle Wastewater Treatment Facility

The nutrient loading analysis to the eight-mile reach of the Redwater River near Circle contains a number of assumptions about the system performance and the quality of local groundwater beneath the pond system. In addition, the large increase in water column nutrient concentrations in the Redwater River across the mouth of Horse Creek is not totally accounted for by estimates of past loading from the pond system. The monitoring strategy should include the following:

1. Placement of shallow monitoring wells and quarterly groundwater sampling both up-gradient and down-gradient of the reconstructed pond system,
2. Shallow monitoring well placement and quarterly groundwater monitoring both up-gradient and down-gradient of the surface sludge disposal area, and
3. Corresponding quarterly surface water monitoring at the following stations:
   - MCNREDW-01
   - MCNREDW-03
   - MCNHORC-04
   - MCNHORC-05
   - MCNREDW-04

The nutrient parameters of interest are TN, NO_{3+2}-N and TP.

The Preliminary Engineering Report (Interstate Engineering 2004) mentioned the possibility of an aging wastewater collection system that consisted, in part, of clay piping. The possibility that collapsed or damaged collection piping could be contributing to the high nutrient concentrations in lower Horse Creek should be assessed. Quarterly nutrient monitoring of Horse Creek upstream of Circle and at the Horse Creek mouth (the Horse Creek stations in Item 3 above) may provide information on the persistence of the nutrient problem.

Monitoring of groundwater above and below the potential sources associated with the pond system and sludge disposal area will improve knowledge of background nutrient concentrations in local groundwater, verify that the pond liners are functioning properly, and document the effects of sludge disposal on local groundwater. The monitoring results can be used to reevaluate the loading analysis and related allocations.

8.3.6 Grazing BMP Effectiveness

Nutrient and sediment removal efficiency factors are specified for the prescribed grazing BMP (Best Management Practices) applied to rangelands through the STEPL model. These factors are 43 percent for TN, 34 percent for TP and 13 percent for sediment. These factors do not represent prescriptions that are tailored to rangeland conditions in the Redwater TPA. Therefore, effectiveness monitoring for the grazing BMP should be planned on a limited scale, such a third order tributary to a nutrient listed waterbody. The project should be conducted over several years to clearly document the water quality effects of current grazing season, duration, and stocking rate. Grazing effects on water column nutrient concentrations may be a function of livestock access duration to riparian corridors. Where grazing system management includes adjustment of riparian livestock use levels, it is important to monitor growing season changes, as well as runoff water quality effects that may better document changes in sediment loading than exclusively low flow monitoring.

8.4 Effectiveness Monitoring for Restoration Activities

Should restoration activities occur that address pollutants addressed in this document, field-scale monitoring would be needed to document pre-existing conditions and improvements in water quality resulting from specific projects. Water quality in the planning area is geographically variable and real trend changes will be difficult to detect and associate with a specific management change. Monitoring methods and locations will largely depend on the project type, the local landscape setting, and the duration and timing of flow in the receiving stream.

8.5 Watershed Wide Analyses

The BMPs prescribed in this document are but a few of those available for improving water quality. Recommendations for monitoring need not to be restricted to these practices or to streams addressed within this document. The water quality targets presented herein are applicable to all streams in the watershed. A stream that does not appear on the 303(d) may not necessarily be supporting the applicable beneficial uses.

As ownership patterns and land management methods evolve, monitoring adjustments should be made that will continue to produce relevant feedback to land managers looking for cost effective pollution controls and stakeholders and resource professionals looking for workable remediation solutions downstream or in other prairie settings.

SECTION 9.0
STAKEHOLDER AND PUBLIC INVOLVEMENT

9.1 TMDL Program and Public Participation Requirements

Development of TMDLs in the Redwater River TPA involved waterbody assessments, data compilation, stakeholder information gathering, and periodic exchange between DEQ and stakeholders regarding analysis approaches and water quality conclusions. Stakeholder and public involvement is a component of TMDL planning supported by EPA guidelines and Montana State Law (MCA 75-5-703, 75-5-704), which directs the DEQ to consult with watershed advisory groups and local conservation districts during the TMDL development process. Technical advisors, stakeholders and interested parties, state and federal agencies, interest groups, advisory committees, and the public were solicited to participate.

9.2 Description of Participants and Roles

9.2.1 Montana Department of Environmental Quality (DEQ)

The Montana Department of Environmental Quality is a state agency whose mission is to '*protect, sustain, and improve a clean and healthful environment to benefit present and future generations'*. State law (MCA 75-5-703) directs the DEQ to develop all necessary TMDLs. The DEQ has sole responsibility and accountability for developing TMDLs within the legislatively mandated timeframe. The Department has committed staff and funding toward this effort. The DEQ has contacted other state and federal agencies, and local conservation districts to participate in TMDL data gathering technical discussions regarding TMDL development.

9.2.2 United States Environmental Protection Agency (EPA)

The EPA is the federal agency responsible implementing the Clean Water Act (CWA). Section 303(d) of the CWA directs States to develop TMDLs. The EPA has developed guidance and technical assistance programs to promote TMDL development. In Montana, EPA has been the principal funding source in support of the TMDL program. The EPA has also committed staff time for review and consultation with DEQ staff on technical issues related to development of nutrient and salinity TMDLs. The completion of the TMDL process in the Redwater TPA is contingent on final EPA approval.

9.2.3 Planning Area Conservation Districts

The Redwater River TPA occurs within the jurisdictions of five county conservation districts that include those for Dawson, Garfield, McCone, Prairie and Richland counties. The remoteness of the planning area, the expense of time and travel, and the work schedules of a predominantly private, agricultural community have prevented formation of general or technical watershed advisory groups. McCone and Richland counties comprise about 78 percent of the planning area, and so have been most actively involved in the planning process. The conservation district offices, together with local landowners and NRCS staff, were instrumental in completing a field assessment of the Redwater River mainstem in support of TMDL development during the spring of 1999. The assessment included water quality and biological sampling, riparian area assessments and an aerial survey of the river corridor.

The DEQ has informed the five districts of their consultation role during TMDL development consistent with State Law (75-5-703). The districts have participated in review and comment on assessment findings and analytical approaches to quantifying pollutant loading. These opportunities have included technical meetings attended by CD representatives, interested landowners and NRCS technical support staff. The meetings have been a valuable forum for gathering information on land cover and stream characteristics, crop production practices, and the carrying capacity of planning area grazing lands.

9.2.4 Natural Resource Agency Involvement

Although unable to attend local planning and discussion meetings, resource staff from several agencies expressed an interest in being informed of the Redwater TMDL planning process. These include the Bureau of Land Management (BLM) office in Miles City and the Region 6 office of the Montana Department of Fish, Wildlife and Parks in Glasgow, Montana.

9.2.5 Area Landowners

Since 85 percent of the planning area is in private ownership, local landowner cooperation in the TMDL process has been critical. Their contribution has included access for stream sampling and field assessments, advice in navigating remote watersheds, and personal descriptions of seasonal water quality and stream flow characteristics. The DEQ sincerely thanks the planning area landowners for their logistical support and informative participation in impromptu water resource and land management discussions with our field staff and consultants.

9.2.6 Stakeholders & General Public

DEQ solicited stakeholder involvement early in the TMDL process through informal means, and has maintained contact with stakeholders during the planning process through a variety methods. General members of the public have expressed interest in the TMDL process or specific aspects of the project. Communication with stakeholders typically occurs through telephone and email correspondence. Though not often directly involved in TMDL development, the general public plays a vital role with regard to eventual implementation of water quality improvement projects. It is important that the general public be aware of the process and given opportunities to participate. The general public has the opportunity for review and comment on the TMDL document during the formal Public Comment Period.

9.3 Public Comment Period

Upon completion of the draft TMDL document, and prior to EPA submittal, the DEQ issues a press release and enters into a Public Comment Period. During this time frame, the draft TMDL document is made available for general public comment, and DEQ addresses and responds to all formal public comments.

The formal public comment period for the Redwater River Nutrient and Salinity TMDLs and Framework Water Quality Improvement Plan was initiated on October 26, 2010 and extended to November 26, 2010. There was a public meeting on November 3, 2010 at the Circle Senior Center in Circle, MT. DEQ provided an overview of the Redwater River Nutrient and Salinity TMDLs and Framework Water Quality Improvement Plan, made copies of the document available to the public, solicited public input and comment on the plan. The announcement for that meeting was distributed among the technical advisors, stakeholders and interested parties, state and federal agencies, interest groups, advisory committees, and the public, and advertised in the following newspapers: The Circle Banner, The Billing Gazette, and The Roundup/AG Roundup. **Appendix F** includes DEQ's response to all official public comments received during the public comment period.

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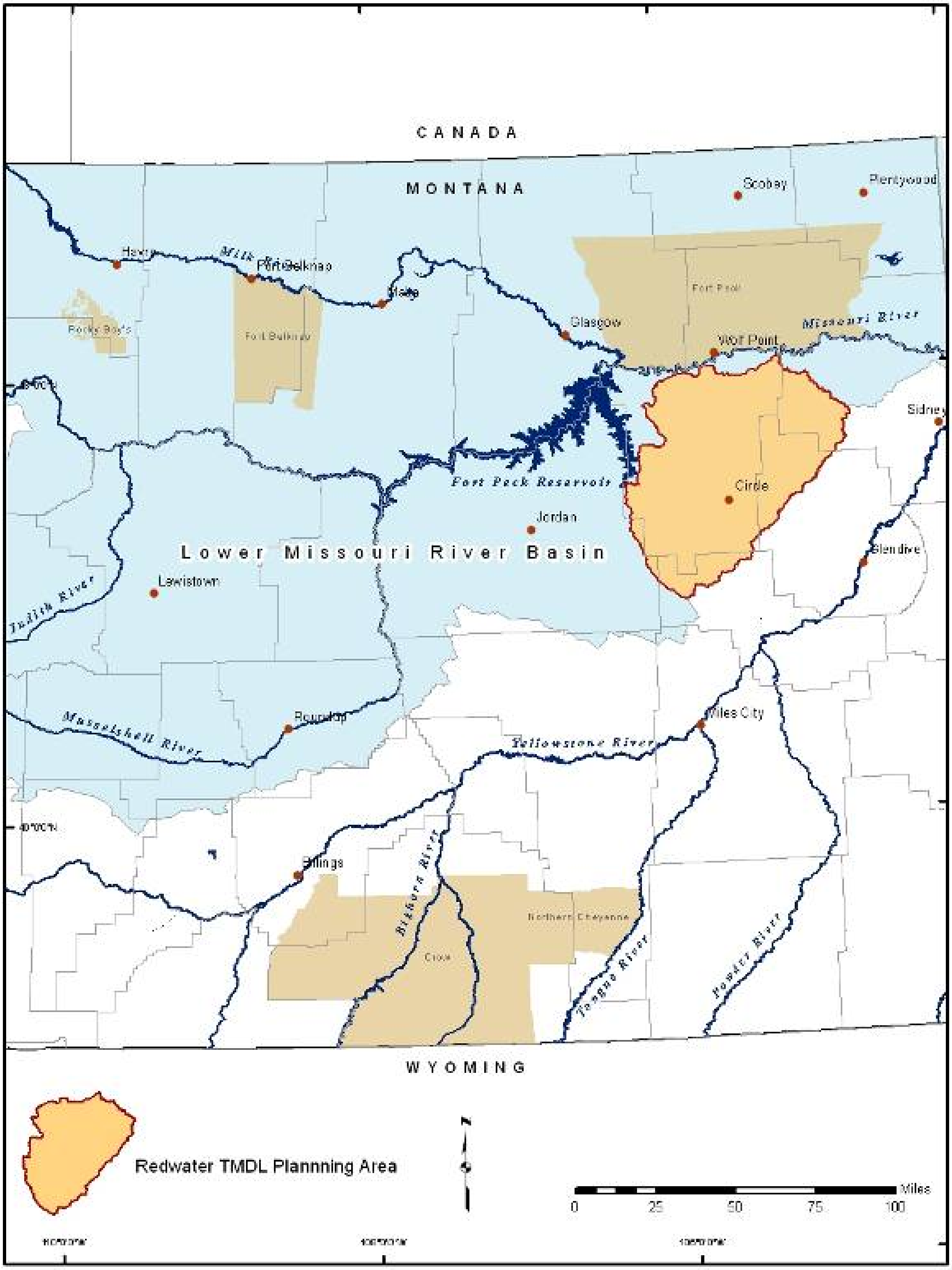
APPENDIX A
MAPS AND DATA



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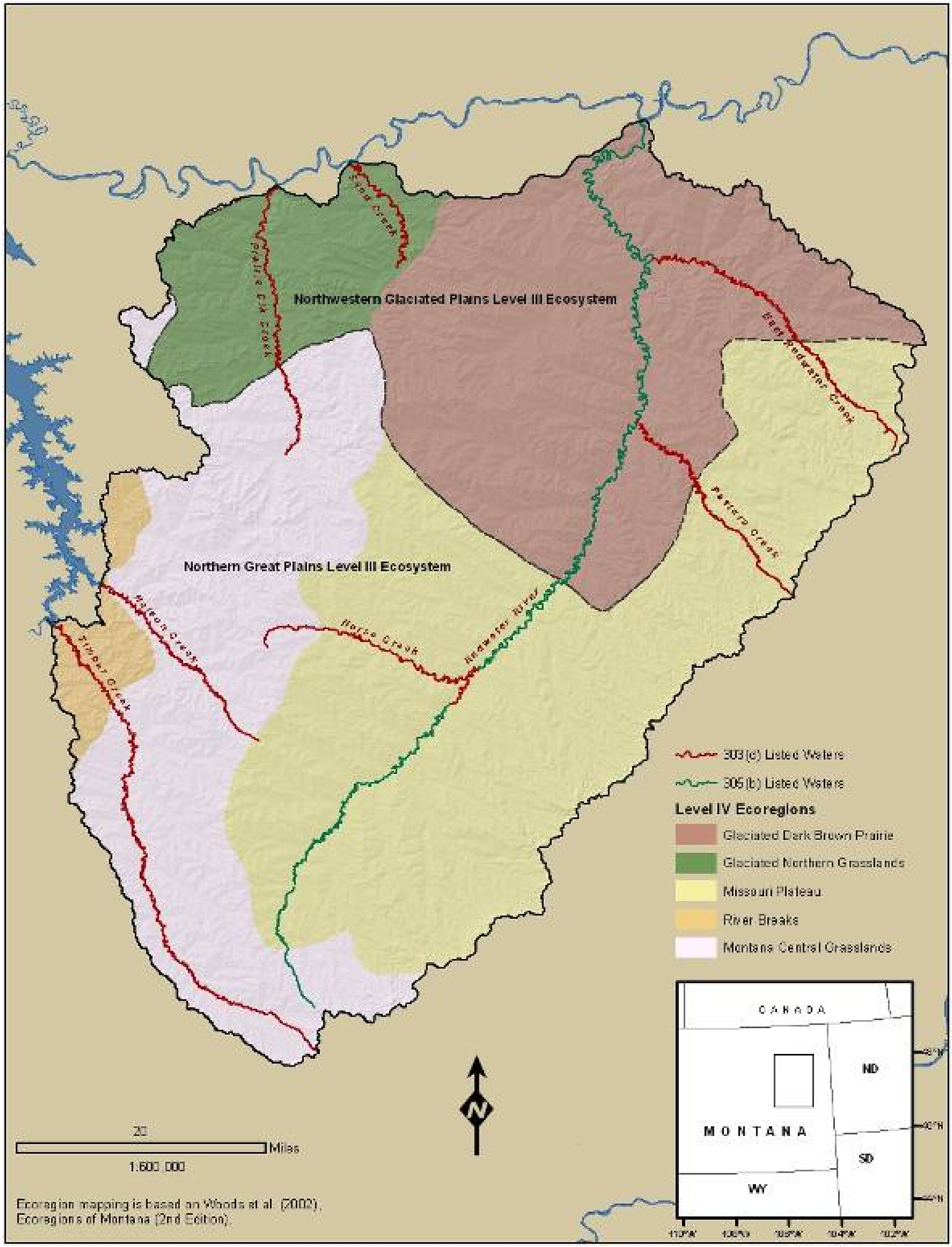
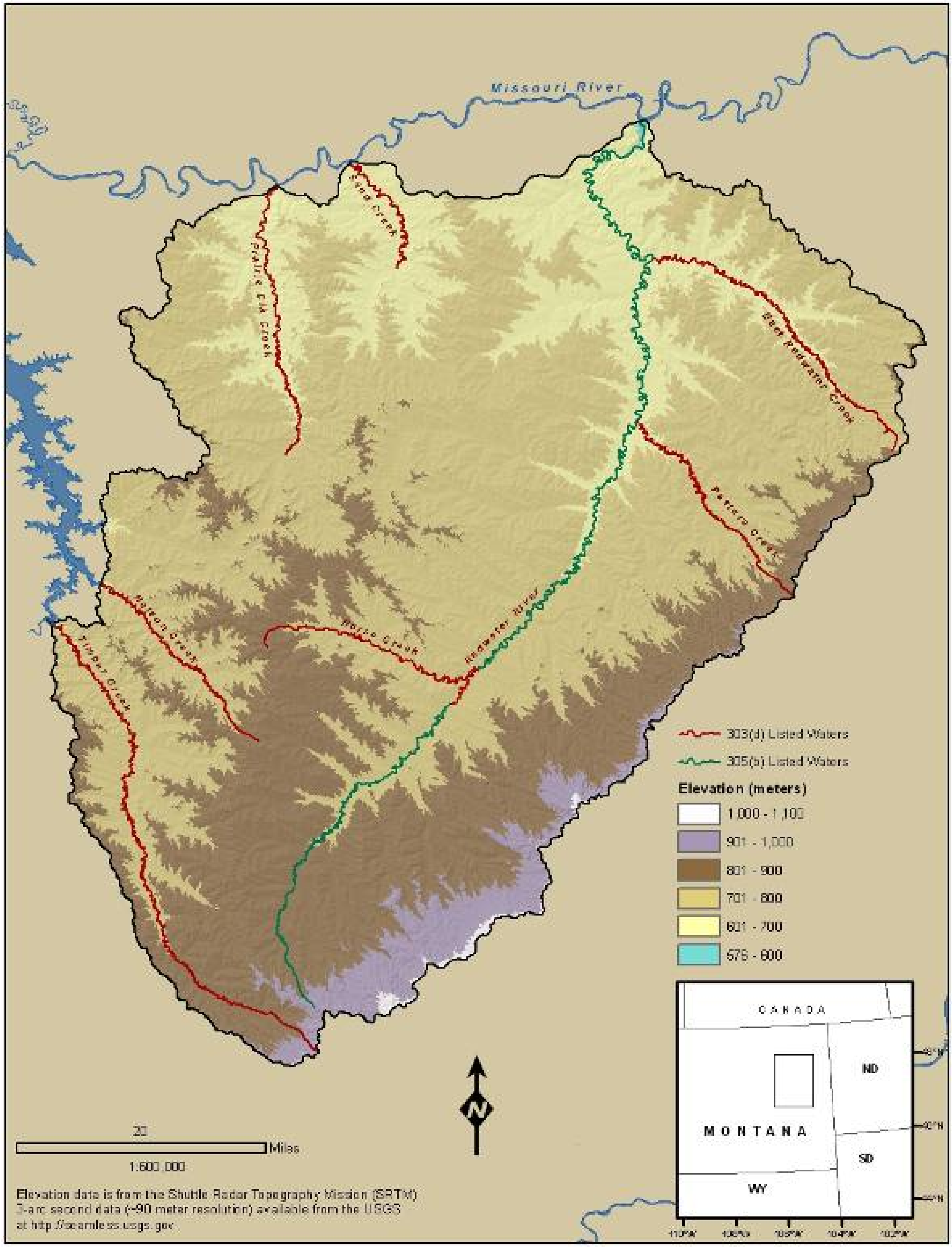


Figure A-2. Ecoregions



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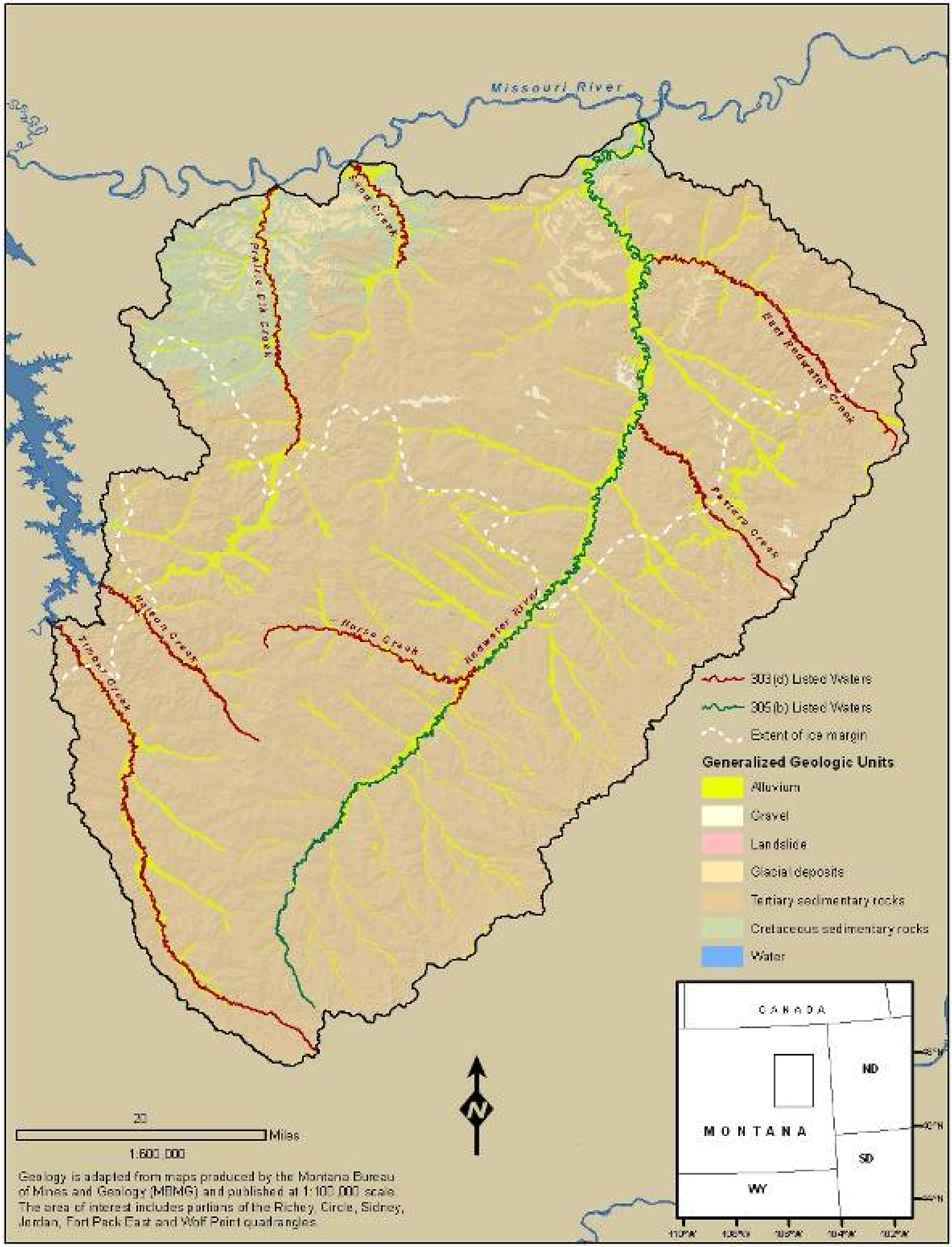

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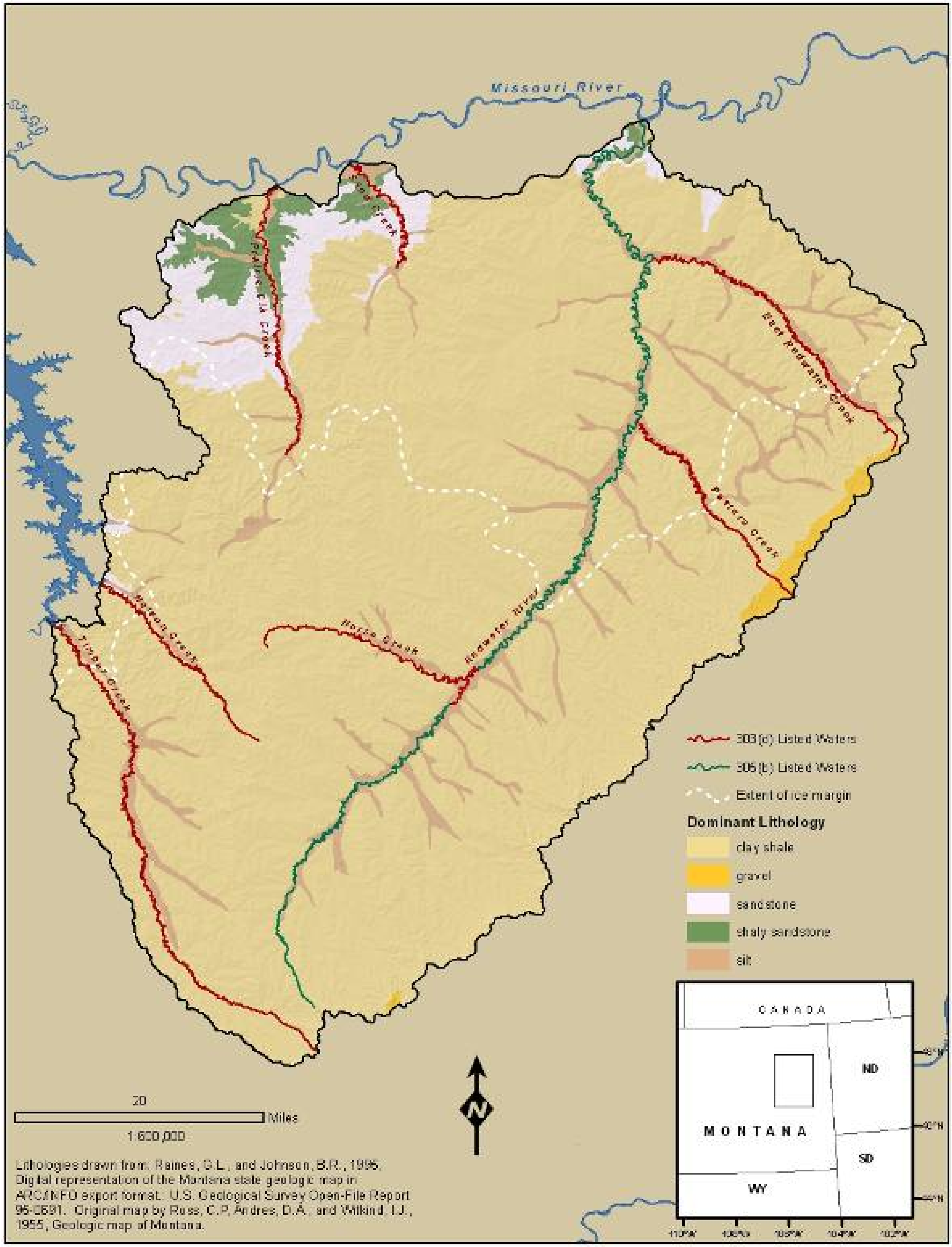


Figure A-4a. Lithology

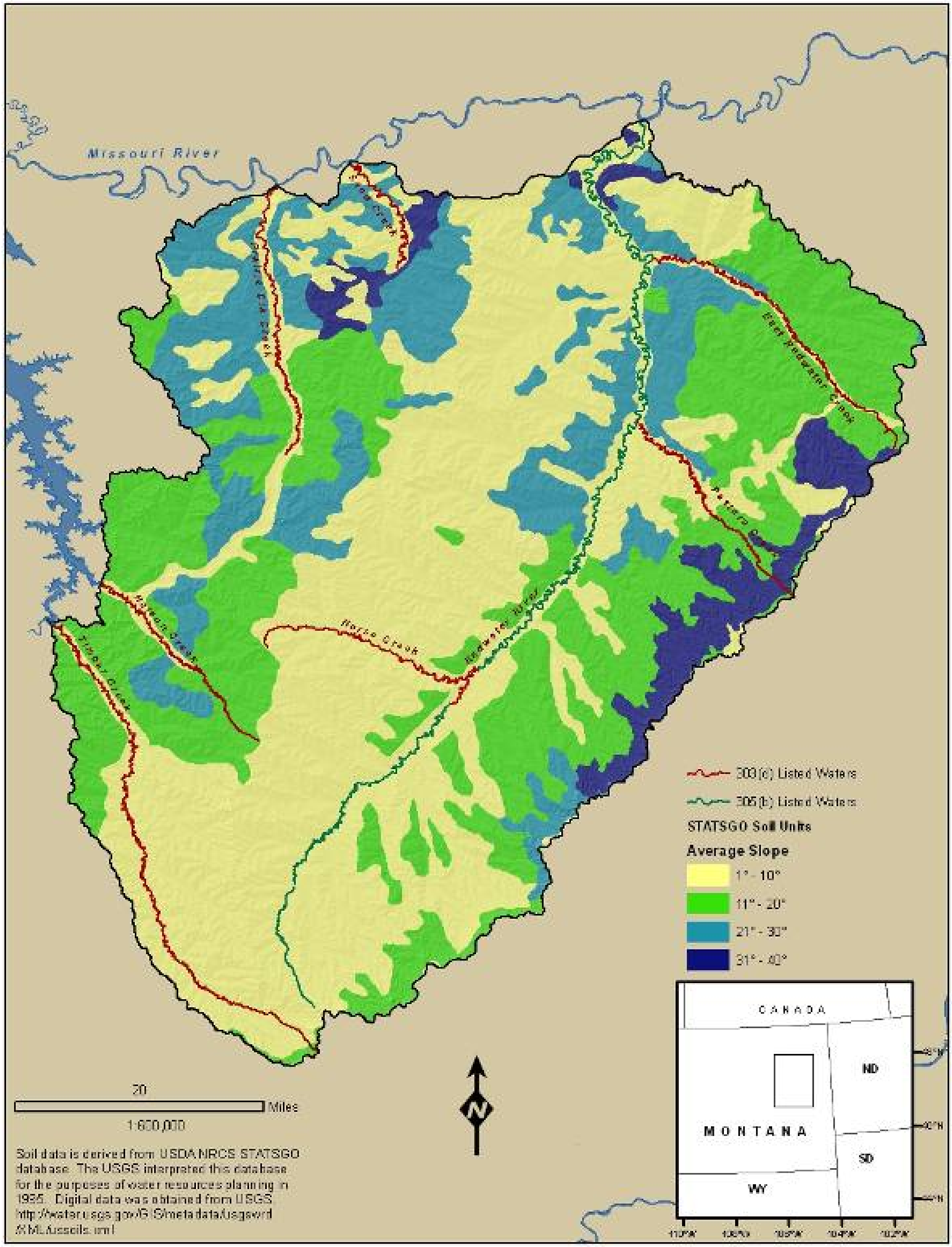


Figure A-5. STATSGO Soil Map Units

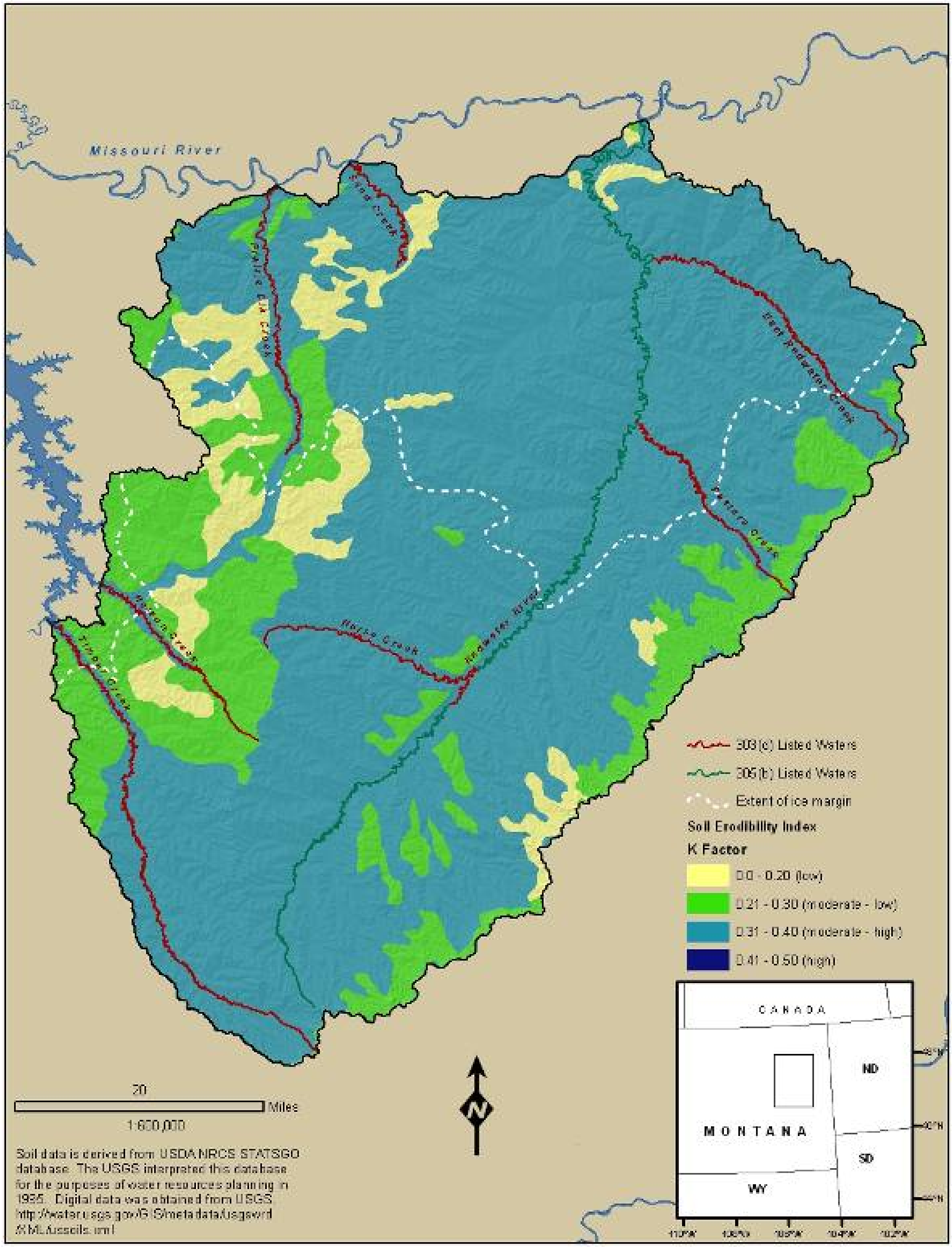


Figure A-5a. Soil Erodibility

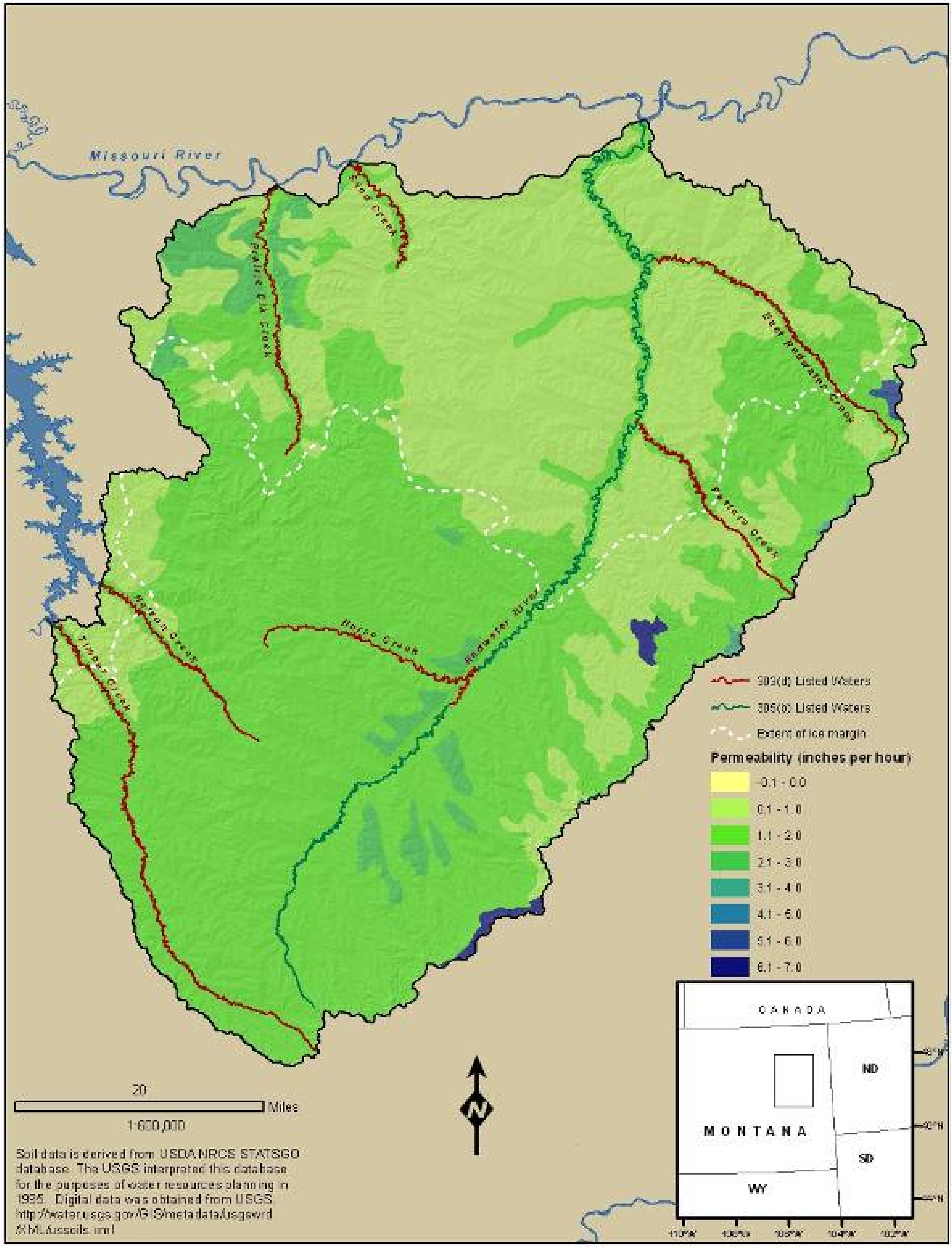


Figure A-5b. Soil Permeability

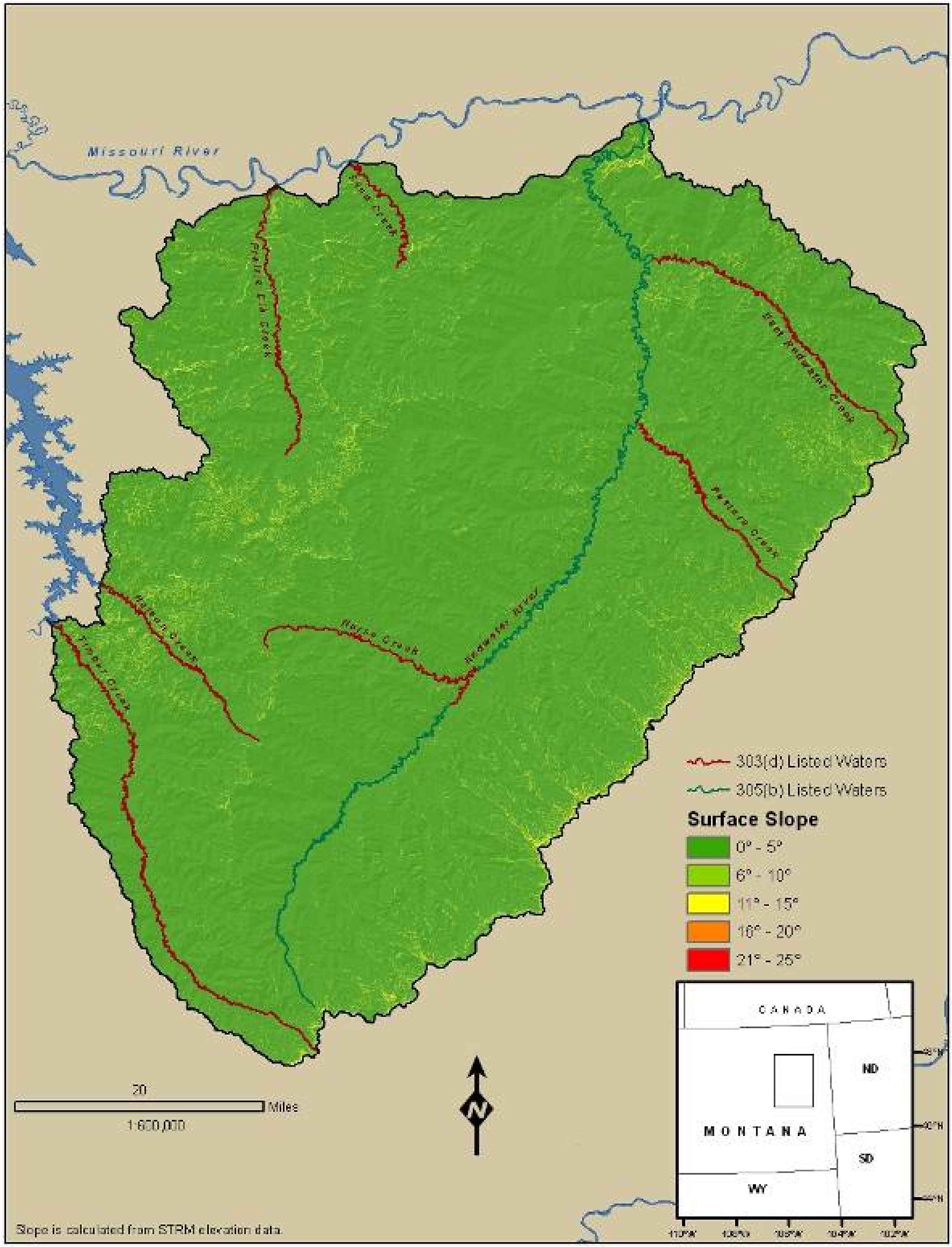


Figure A-6. Surface Slope

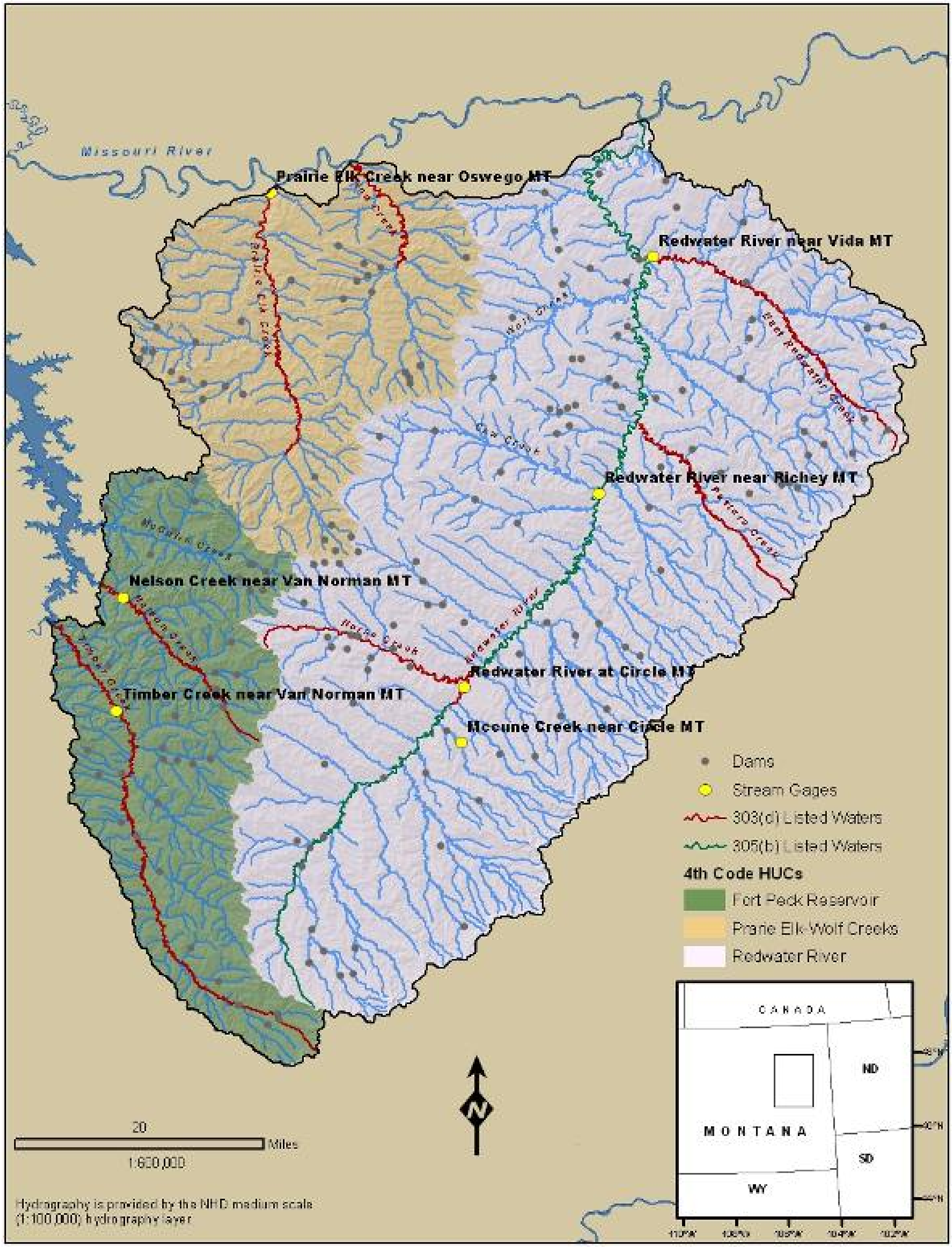


Figure A-7. Hydrography

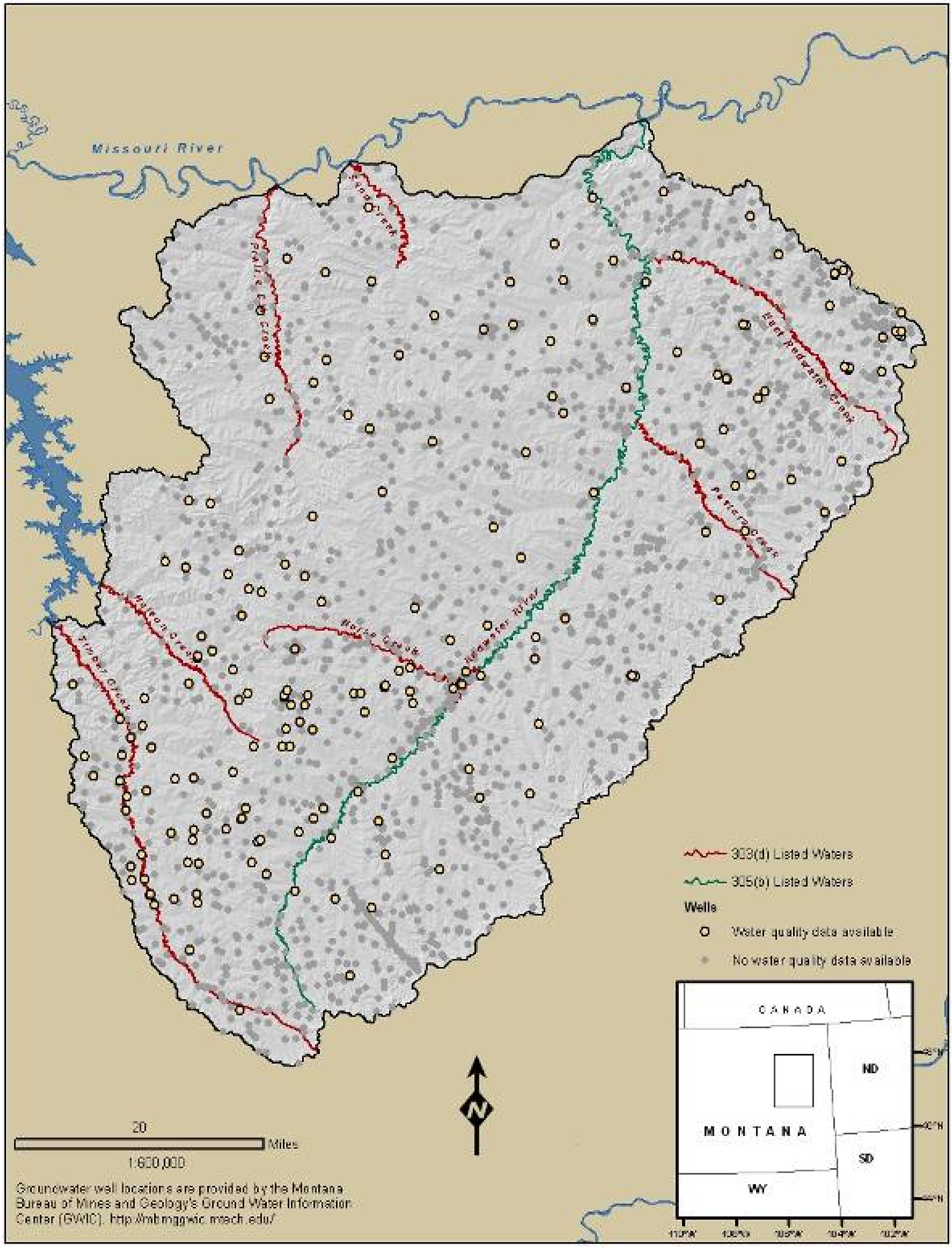


Figure A-8. GWIC

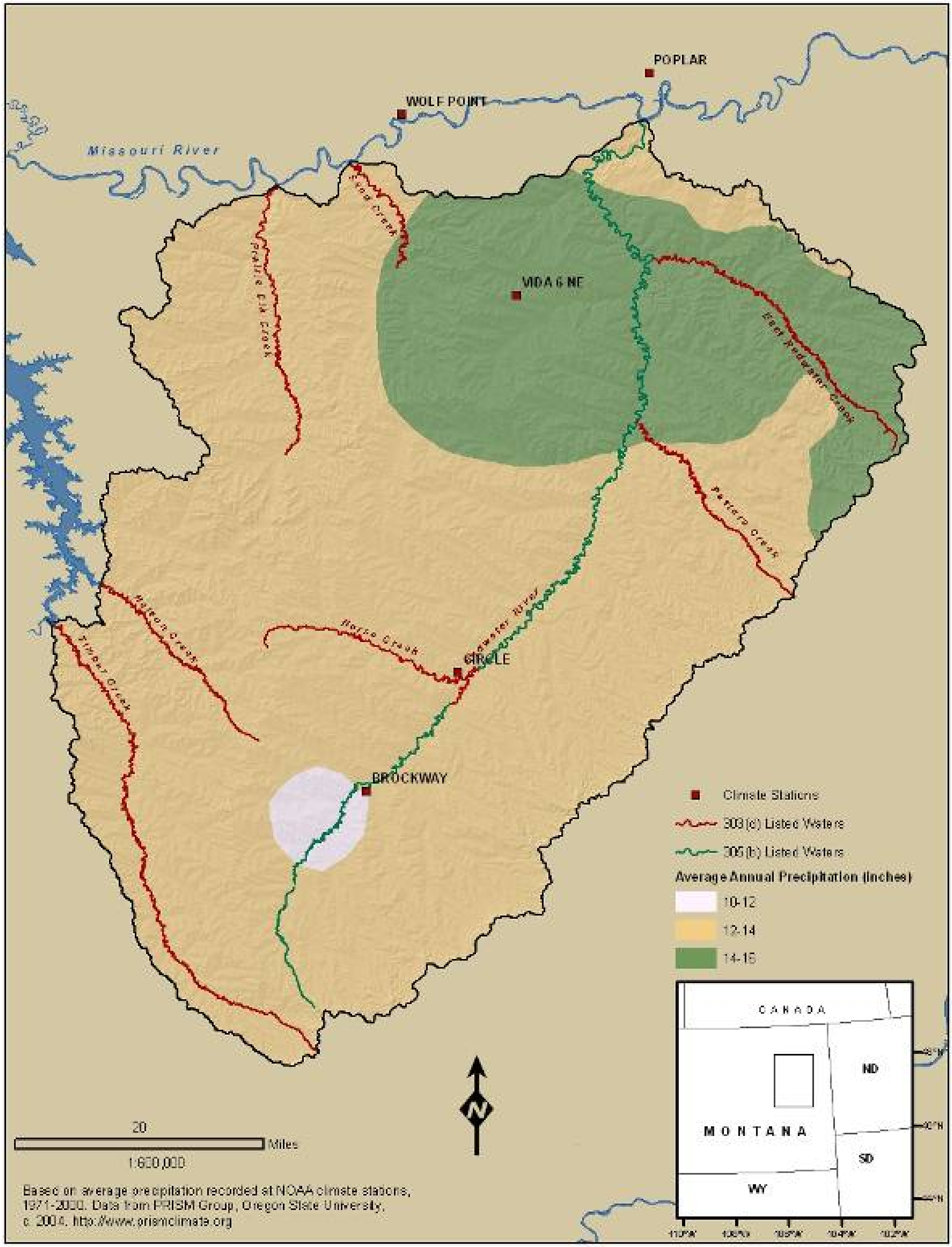


Figure A-9. Precipitation

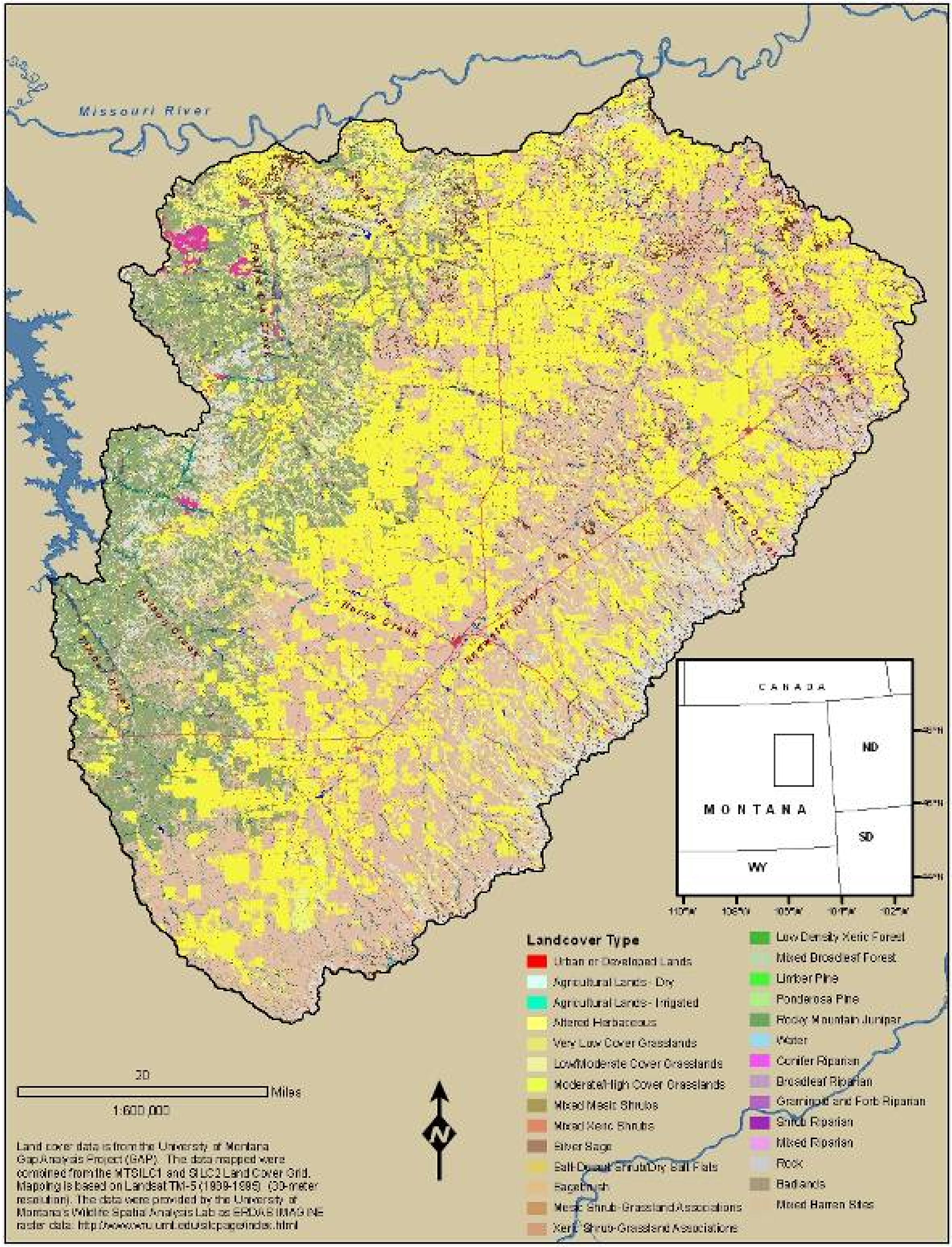


Figure A-10. GAP

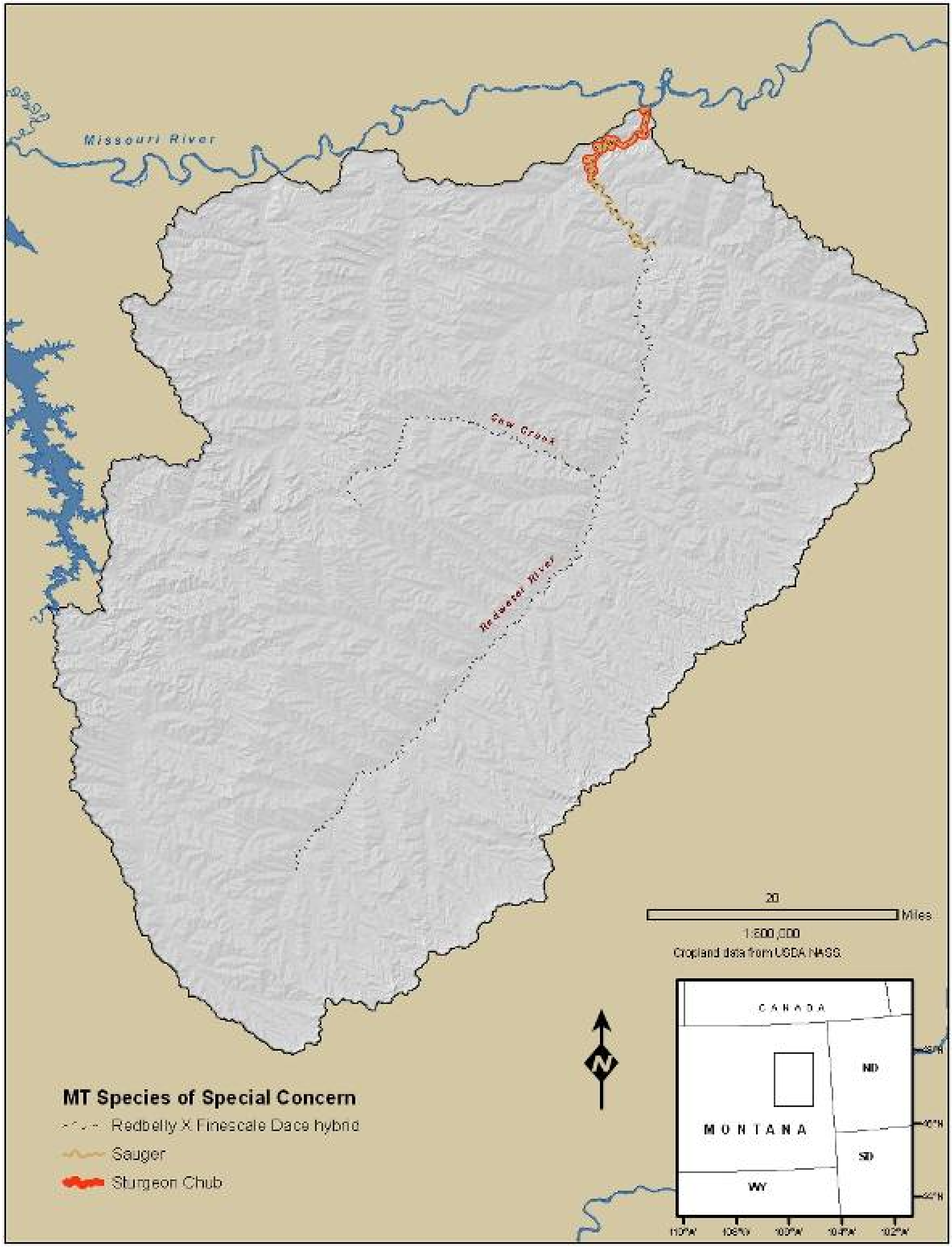


Figure A-11. Fish

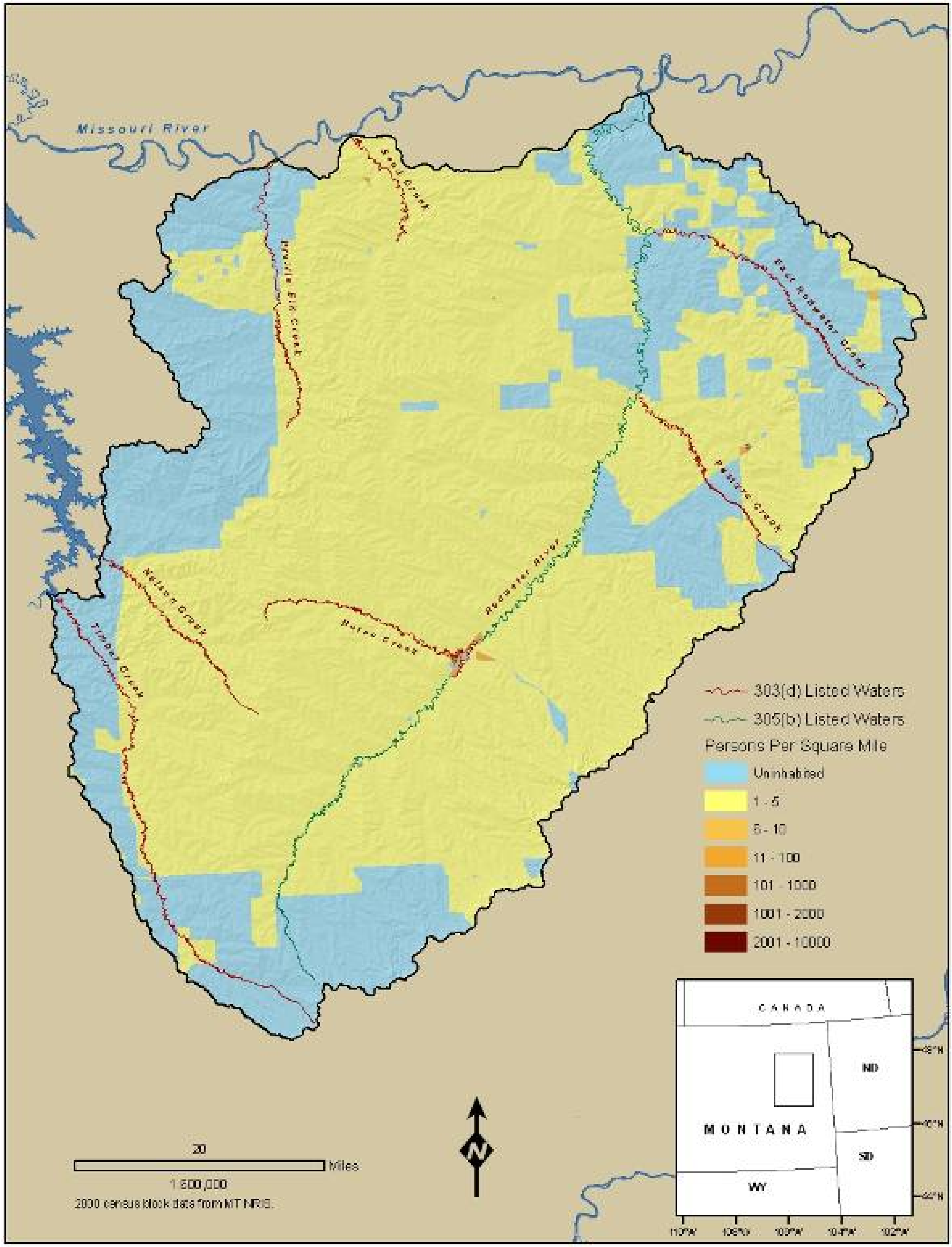


Figure A-12. Census

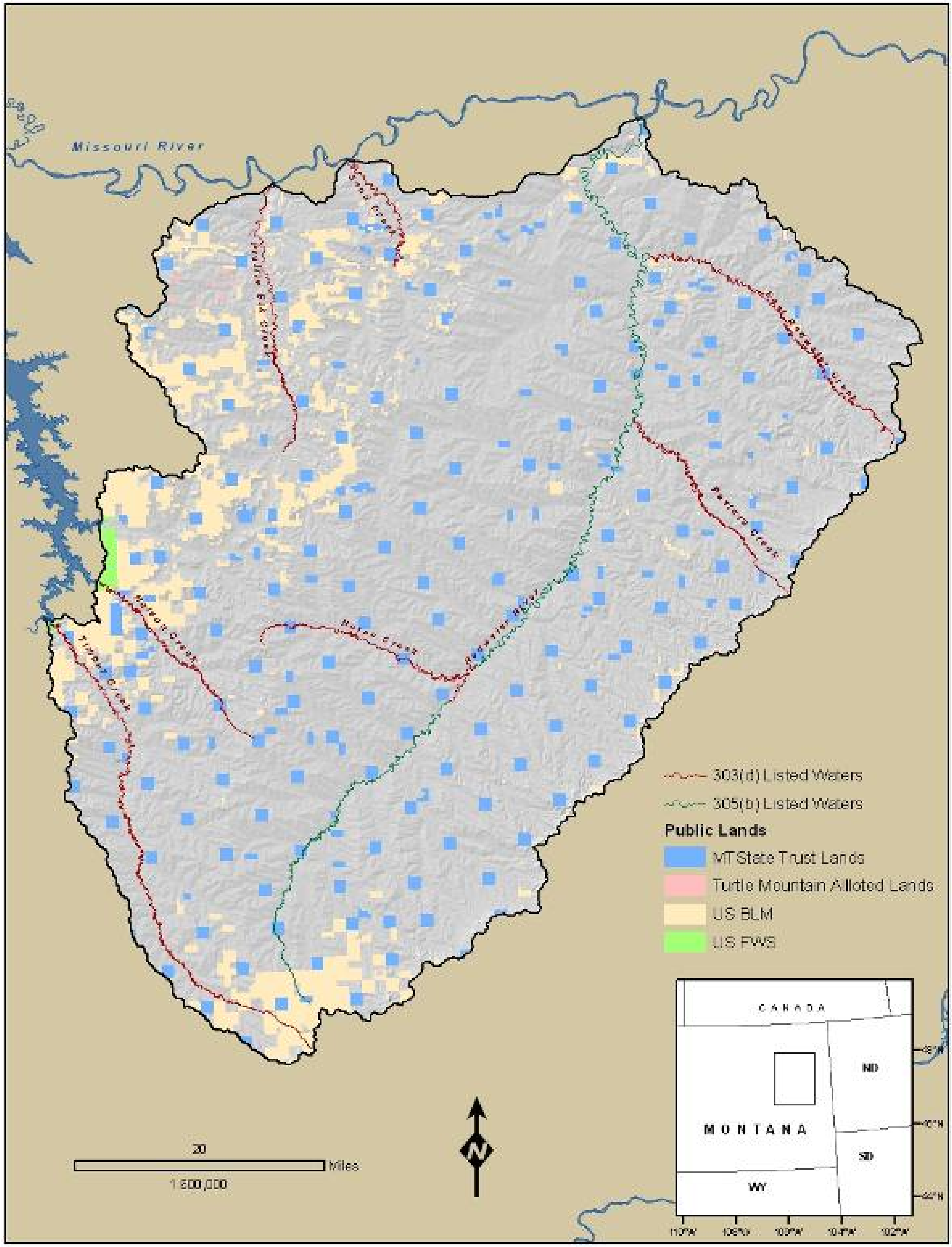
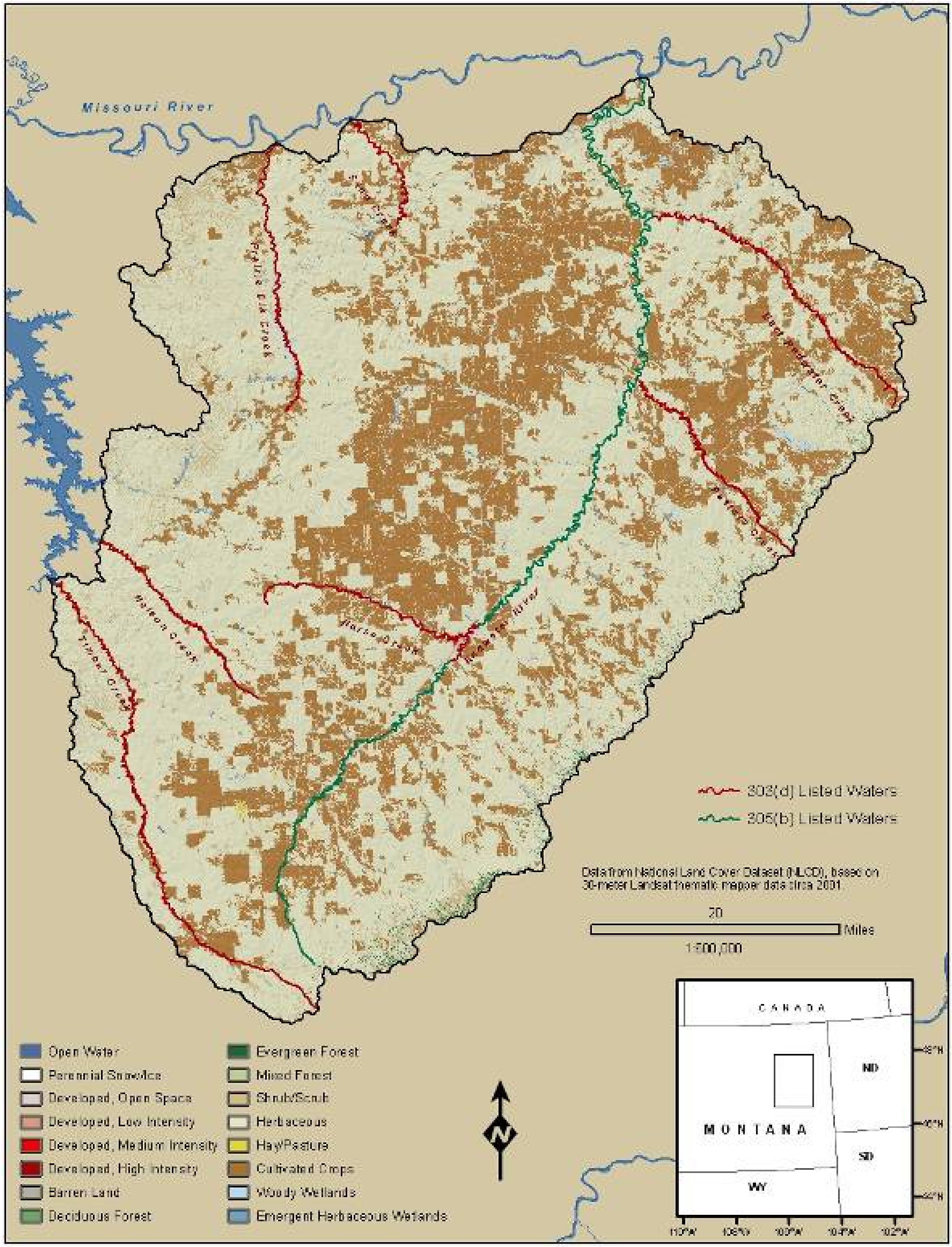


Figure A-13. Ownership



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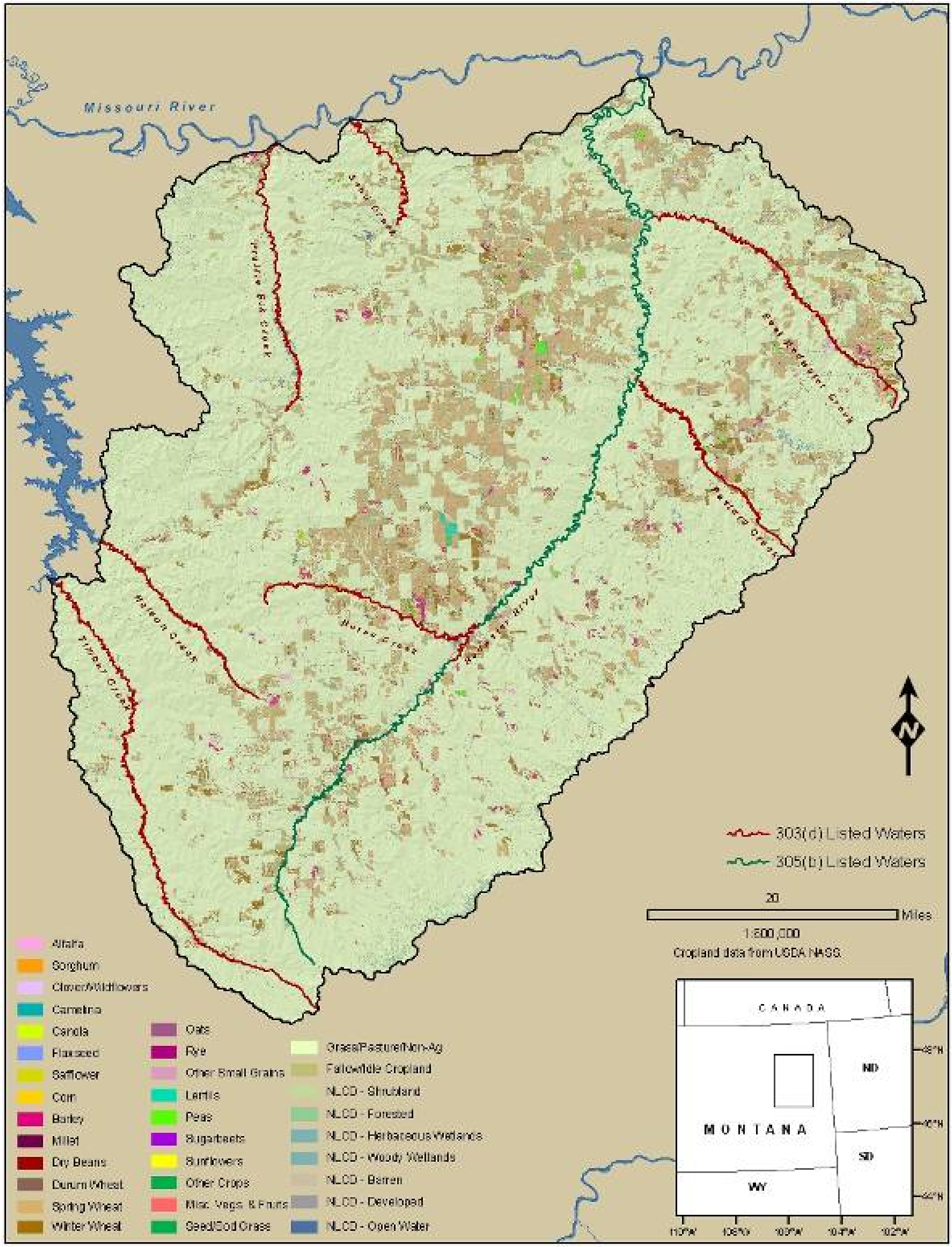

Figure A-15. Agricultural Land Use

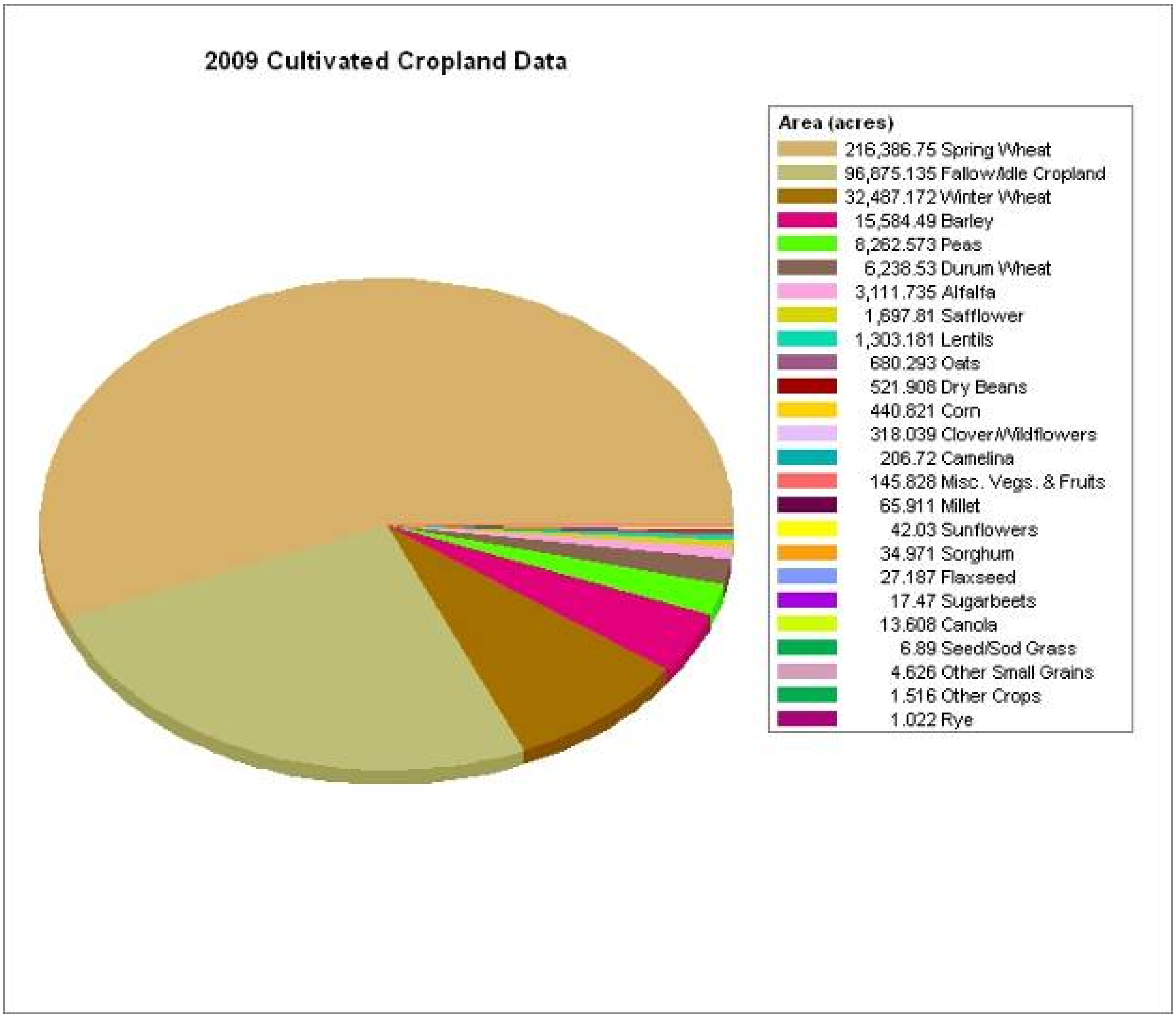

Figure A-16. Cultivated Crops

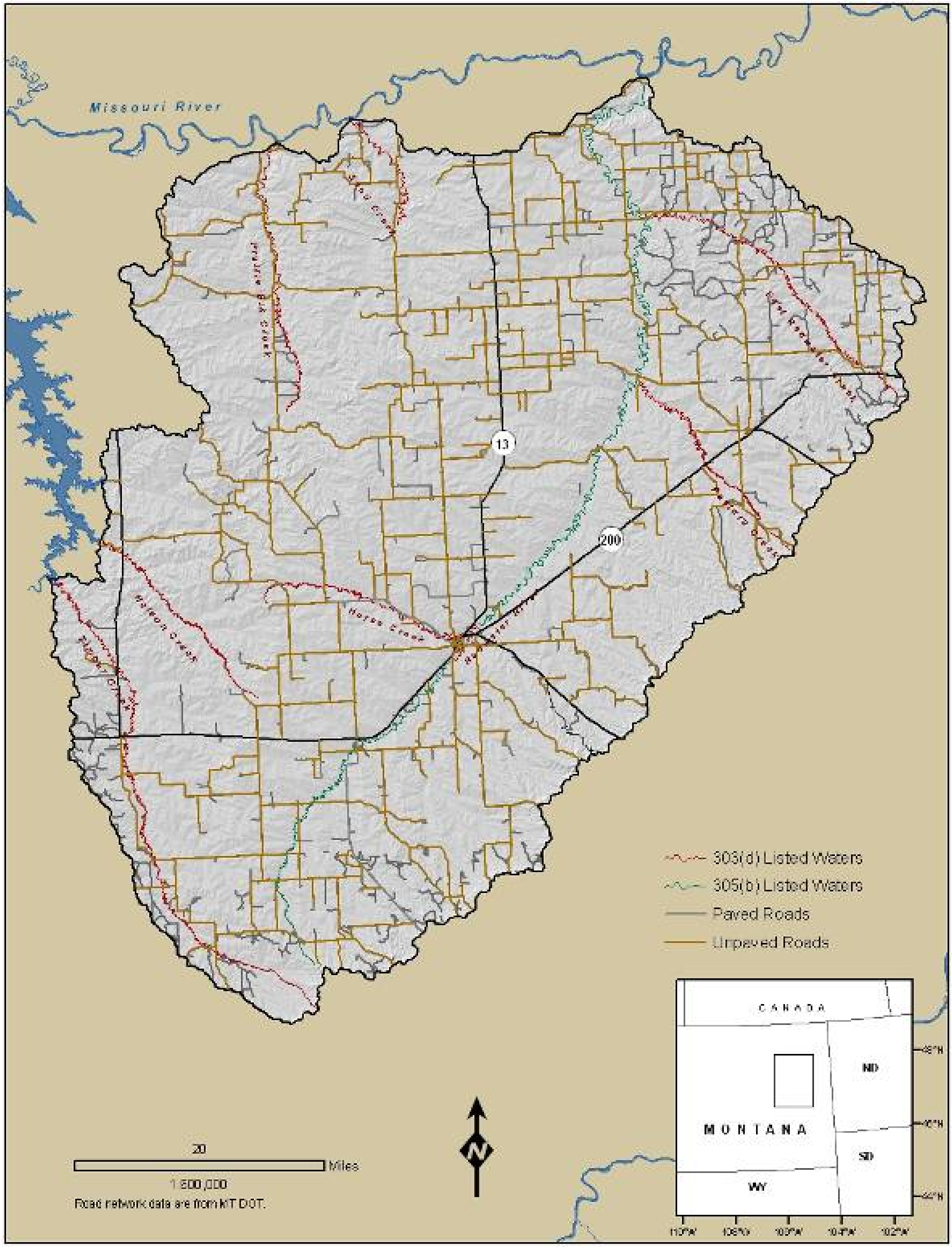

Figure A-17. Transportation

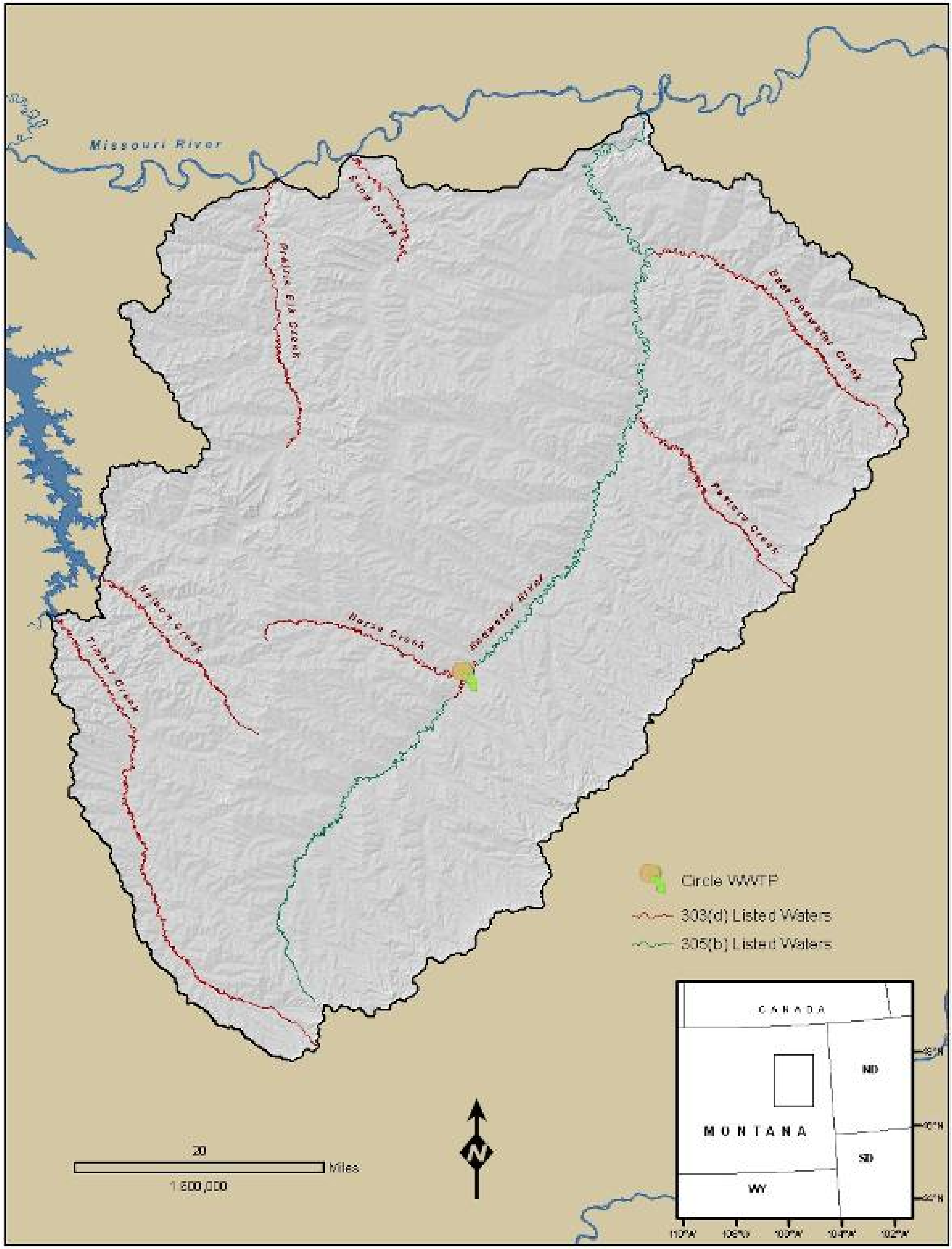

Figure A-18. MPDES Discharge Location

APPENDIX B
DATA TABLES

Table 1.1 Mean Daily Stream Discharge

DATE	REDWATER RIVER @ CIRCLE STN_06177500 (cfs)	REDWATER RIVER @ VIDA STN_06177825 (cfs)	PRAIRIE ELK CREEK STN 06175540 (cfs)	TIMBER CREEK STN 06131120 (cfs)	NELSON CREEK STN 06131200 (cfs)	ESTIMATED EAST REDWATER CREEK (FROM REDWATER @ VIDA) (cfs)	ESTIMATED HORSE CREEK (FROM TIMBER CREEK) (cfs)	ESTIMATED PASTURE CREEK (FROM TIMBER CREEK) (cfs)	ESTIMATED SAND CREEK (FROM PRAIRIE ELK CREEK) (cfs)
1-Jan	0.22	2.00	0.42	0.00	0.00	0.16	0.00	0.00	0.21
2-Jan	0.22	2.00	0.45	0.00	0.00	0.16	0.00	0.00	0.23
3-Jan	0.22	1.80	0.49	0.00	0.00	0.14	0.00	0.00	0.25
4-Jan	0.23	1.70	0.51	0.00	0.00	0.14	0.00	0.00	0.26
5-Jan	0.25	1.70	0.62	0.00	0.00	0.14	0.00	0.00	0.31
6-Jan	0.31	1.80	0.66	0.01	0.03	0.14	0.03	0.03	0.33
7-Jan	0.32	1.70	0.75	0.01	0.06	0.14	0.03	0.03	0.38
8-Jan	0.25	1.60	1.40	0.10	0.09	0.13	0.27	0.29	0.71
9-Jan	0.23	3.20	10.00	2.00	1.80	0.25	5.31	5.70	5.05
10-Jan	0.26	3.70	7.30	6.70	1.20	0.29	17.80	19.10	3.69
11-Jan	0.38	2.80	5.40	5.00	0.91	0.22	13.29	14.25	2.73
12-Jan	0.41	4.50	4.40	3.30	0.60	0.36	8.77	9.41	2.22
13-Jan	0.37	4.10	3.90	3.00	0.35	0.33	7.97	8.55	1.97
14-Jan	0.38	3.70	3.40	1.70	0.18	0.29	4.52	4.85	1.72
15-Jan	0.40	4.30	2.90	1.30	0.12	0.34	3.45	3.71	1.46
16-Jan	0.33	5.90	1.50	0.83	0.03	0.47	2.21	2.37	0.76
17-Jan	0.29	5.50	0.99	0.50	0.02	0.44	1.33	1.43	0.50
18-Jan	0.27	4.40	0.85	0.33	0.01	0.35	0.88	0.94	0.43
19-Jan	0.25	3.80	0.72	0.23	0.02	0.30	0.61	0.66	0.36
20-Jan	0.25	3.20	0.65	0.13	0.01	0.25	0.35	0.37	0.33
21-Jan	0.24	2.90	0.64	0.10	0.00	0.23	0.27	0.29	0.32
22-Jan	0.23	2.70	0.64	0.07	0.00	0.21	0.19	0.20	0.32
23-Jan	0.23	2.20	0.60	0.03	0.00	0.17	0.08	0.09	0.30
24-Jan	0.24	2.00	0.64	0.02	0.00	0.16	0.05	0.06	0.32
25-Jan	0.23	1.90	0.56	0.01	0.00	0.15	0.03	0.03	0.28
26-Jan	0.22	2.00	0.55	0.18	0.00	0.16	0.48	0.51	0.28
27-Jan	0.21	2.30	0.64	0.68	0.04	0.18	1.81	1.94	0.32

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28-Jan	0.22	2.50	11.00	0.35	1.30	0.20	0.93	1.00	5.55
29-Jan	0.31	2.30	24.00	2.40	1.00	0.18	6.38	6.84	12.12
30-Jan	1.40	2.30	16.00	2.70	0.81	0.18	7.17	7.70	8.08
31-Jan	1.50	4.20	15.00	3.40	0.29	0.33	9.03	9.69	7.57
1-Feb	3.30	12.00	16.00	2.00	0.36	0.95	5.31	5.70	8.08
2-Feb	4.00	27.00	15.00	2.40	0.29	2.14	6.38	6.84	7.57
3-Feb	2.90	23.00	13.00	2.00	0.16	1.83	5.31	5.70	6.56
4-Feb	3.20	21.00	11.00	2.30	0.03	1.67	6.11	6.56	5.55
5-Feb	19.00	19.00	11.00	1.00	0.00	1.51	2.66	2.85	5.55
6-Feb	21.00	17.00	9.90	1.30	0.00	1.35	3.45	3.71	5.00
7-Feb	11.00	13.00	8.80	1.00	0.00	1.03	2.66	2.85	4.44
8-Feb	6.80	12.00	8.50	0.85	0.20	0.95	2.26	2.42	4.29
9-Feb	7.00	11.00	9.30	1.20	0.45	0.87	3.19	3.42	4.70
10-Feb	12.00	18.00	8.80	1.80	0.19	1.43	4.78	5.13	4.44
11-Feb	8.40	25.00	8.70	2.40	0.39	1.99	6.38	6.84	4.39
12-Feb	6.60	24.00	8.30	6.60	0.61	1.91	17.54	18.82	4.19
13-Feb	6.20	24.00	7.90	10.00	1.40	1.91	26.57	28.51	3.99
14-Feb	8.60	30.00	17.00	14.00	1.20	2.38	37.20	39.91	8.58
15-Feb	13.00	40.00	20.00	15.00	0.95	3.18	39.86	42.76	10.10
16-Feb	22.00	47.00	25.00	12.00	1.20	3.73	31.88	34.21	12.62
17-Feb	18.00	63.00	29.00	10.00	2.80	5.00	26.57	28.51	14.64
18-Feb	15.00	76.00	34.00	9.90	4.50	6.04	26.30	28.22	17.17
19-Feb	22.00	210.00	63.00	8.00	6.70	16.68	21.26	22.81	31.81
20-Feb	30.00	251.00	76.00	9.50	10.00	19.93	25.24	27.08	38.38
21-Feb	27.00	297.00	111.00	11.00	8.90	23.59	29.23	31.36	56.05
22-Feb	26.00	344.00	102.00	9.50	6.00	27.32	25.24	27.08	51.51
23-Feb	24.00	192.00	142.00	9.40	3.20	15.25	24.98	26.80	71.71
24-Feb	19.00	77.00	31.00	7.70	3.00	6.12	20.46	21.95	15.65

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25-Feb	15.00	55.00	20.00	7.80	1.80	4.37	20.73	22.24	10.10
26-Feb	14.00	59.00	13.00	6.80	0.86	4.69	18.07	19.39	6.56
27-Feb	21.00	56.00	11.00	6.10	1.20	4.45	16.21	17.39	5.55
28-Feb	30.00	52.00	8.90	6.20	1.70	4.13	16.47	17.68	4.49
29-Feb	6.90	33.00	6.40	1.40	0.87	2.62	3.72	3.99	3.23
1-Mar	44.00	49.00	5.80	3.50	0.50	3.89	9.30	9.98	2.93
2-Mar	45.00	33.00	4.80	2.80	0.29	2.62	7.44	7.98	2.42
3-Mar	87.00	27.00	4.10	2.40	0.25	2.14	6.38	6.84	2.07
4-Mar	86.00	25.00	3.90	1.80	0.32	1.99	4.78	5.13	1.97
5-Mar	61.00	22.00	3.40	1.60	0.76	1.75	4.25	4.56	1.72
6-Mar	40.00	20.00	3.30	1.40	3.60	1.59	3.72	3.99	1.67
7-Mar	29.00	19.00	3.50	1.20	2.10	1.51	3.19	3.42	1.77
8-Mar	31.00	21.00	3.80	1.10	2.20	1.67	2.92	3.14	1.92
9-Mar	38.00	22.00	5.00	1.80	3.40	1.75	4.78	5.13	2.52
10-Mar	50.00	30.00	5.90	3.90	5.50	2.38	10.36	11.12	2.98
11-Mar	56.00	53.00	8.10	8.80	3.20	4.21	23.38	25.09	4.09
12-Mar	114.00	84.00	18.00	20.00	5.60	6.67	53.14	57.02	9.09
13-Mar	117.00	89.00	23.00	13.00	8.40	7.07	34.54	37.06	11.61
14-Mar	99.00	110.00	49.00	9.50	13.00	8.74	25.24	27.08	24.74
15-Mar	53.00	115.00	63.00	6.40	7.20	9.13	17.01	18.25	31.81
16-Mar	28.00	106.00	88.00	4.30	4.10	8.42	11.43	12.26	44.44
17-Mar	20.00	105.00	139.00	3.30	4.20	8.34	8.77	9.41	70.19
18-Mar	33.00	134.00	207.00	2.80	5.00	10.64	7.44	7.98	104.53
19-Mar	107.00	192.00	223.00	1.80	6.10	15.25	4.78	5.13	112.61
20-Mar	143.00	205.00	222.00	2.40	7.10	16.28	6.38	6.84	112.11
21-Mar	134.00	264.00	247.00	1.30	7.70	20.97	3.45	3.71	124.73
22-Mar	162.00	365.00	235.00	1.10	7.10	28.99	2.92	3.14	118.67
23-Mar	141.00	279.00	165.00	1.00	7.20	22.16	2.66	2.85	83.32

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24-Mar	94.00	218.00	109.00	1.00	6.40	17.31	2.66	2.85	55.04
25-Mar	57.00	235.00	83.00	0.86	11.00	18.66	2.29	2.45	41.91
26-Mar	34.00	180.00	76.00	0.75	11.00	14.30	1.99	2.14	38.38
27-Mar	45.00	152.00	64.00	8.40	7.10	12.07	22.32	23.95	32.32
28-Mar	54.00	145.00	44.00	6.00	3.50	11.52	15.94	17.11	22.22
29-Mar	39.00	119.00	29.00	3.90	2.60	9.45	10.36	11.12	14.64
30-Mar	85.00	101.00	20.00	2.80	2.90	8.02	7.44	7.98	10.10
31-Mar	90.00	104.00	18.00	2.40	2.40	8.26	6.38	6.84	9.09
1-Apr	81.00	107.00	37.00	2.10	1.50	8.50	5.58	5.99	18.68
2-Apr	60.00	110.00	25.00	1.90	1.40	8.74	5.05	5.42	12.62
3-Apr	47.00	96.00	18.00	1.80	1.20	7.62	4.78	5.13	9.09
4-Apr	30.00	85.00	12.00	1.60	1.10	6.75	4.25	4.56	6.06
5-Apr	30.00	78.00	9.70	1.40	0.88	6.19	3.72	3.99	4.90
6-Apr	24.00	72.00	8.60	1.30	1.00	5.72	3.45	3.71	4.34
7-Apr	19.00	81.00	28.00	1.20	1.50	6.43	3.19	3.42	14.14
8-Apr	15.00	130.00	54.00	1.00	2.40	10.32	2.66	2.85	27.27
9-Apr	17.00	339.00	104.00	0.89	3.20	26.92	2.36	2.54	52.52
10-Apr	19.00	612.00	89.00	0.77	20.00	48.60	2.05	2.20	44.94
11-Apr	13.00	327.00	38.00	0.71	7.70	25.97	1.89	2.02	19.19
12-Apr	11.00	186.00	22.00	0.63	2.50	14.77	1.67	1.80	11.11
13-Apr	8.40	114.00	11.00	0.57	1.90	9.05	1.51	1.63	5.55
14-Apr	9.10	92.00	23.00	0.52	2.70	7.31	1.38	1.48	11.61
15-Apr	7.60	89.00	33.00	0.50	2.60	7.07	1.33	1.43	16.66
16-Apr	7.90	125.00	28.00	0.49	4.20	9.93	1.30	1.40	14.14
17-Apr	9.70	252.00	48.00	0.44	7.80	20.01	1.17	1.25	24.24
18-Apr	11.00	211.00	35.00	0.42	4.40	16.76	1.12	1.20	17.67
19-Apr	8.80	147.00	17.00	0.43	2.10	11.67	1.14	1.23	8.58
20-Apr	6.70	104.00	11.00	0.43	1.30	8.26	1.14	1.23	5.55

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21-Apr	5.40	79.00	6.10	0.38	1.10	6.27	1.01	1.08	3.08
22-Apr	6.90	66.00	4.10	0.32	0.82	5.24	0.85	0.91	2.07
23-Apr	19.00	57.00	8.20	0.28	0.68	4.53	0.74	0.80	4.14
24-Apr	8.10	54.00	16.00	0.32	0.69	4.29	0.85	0.91	8.08
25-Apr	5.20	51.00	24.00	0.40	0.78	4.05	1.06	1.14	12.12
26-Apr	4.90	49.00	7.40	0.90	0.60	3.89	2.39	2.57	3.74
27-Apr	4.80	45.00	4.50	2.30	0.49	3.57	6.11	6.56	2.27
28-Apr	4.70	42.00	3.00	4.90	0.43	3.34	13.02	13.97	1.51
29-Apr	4.70	38.00	4.40	5.50	0.45	3.02	14.61	15.68	2.22
30-Apr	5.40	36.00	3.40	4.40	0.67	2.86	11.69	12.54	1.72
1-May	4.60	34.00	3.00	2.40	0.41	2.70	6.38	6.84	1.51
2-May	4.20	32.00	2.70	1.50	0.71	2.54	3.99	4.28	1.36
3-May	4.10	31.00	2.60	1.10	0.37	2.46	2.92	3.14	1.31
4-May	4.00	27.00	2.50	0.78	0.27	2.14	2.07	2.22	1.26
5-May	3.80	25.00	2.40	0.57	0.26	1.99	1.51	1.63	1.21
6-May	4.00	24.00	4.50	0.59	1.60	1.91	1.57	1.68	2.27
7-May	6.10	30.00	13.00	0.37	1.50	2.38	0.98	1.05	6.56
8-May	5.80	34.00	11.00	0.34	1.60	2.70	0.90	0.97	5.55
9-May	4.80	33.00	7.30	0.31	0.90	2.62	0.82	0.88	3.69
10-May	4.30	31.00	4.20	0.23	0.71	2.46	0.61	0.66	2.12
11-May	4.00	29.00	3.60	0.21	0.66	2.30	0.56	0.60	1.82
12-May	3.80	29.00	3.60	0.31	0.72	2.30	0.82	0.88	1.82
13-May	3.60	28.00	3.50	0.51	0.61	2.22	1.36	1.45	1.77
14-May	3.40	28.00	13.00	0.69	0.72	2.22	1.83	1.97	6.56
15-May	3.20	28.00	6.70	0.84	0.60	2.22	2.23	2.39	3.38
16-May	3.00	30.00	5.90	1.00	0.37	2.38	2.66	2.85	2.98
17-May	2.70	30.00	5.90	0.56	1.20	2.38	1.49	1.60	2.98
18-May	2.60	29.00	13.00	0.33	6.60	2.30	0.88	0.94	6.56

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19-May	2.50	31.00	30.00	0.30	9.40	2.46	0.80	0.86	15.15
20-May	5.70	31.00	20.00	0.37	0.86	2.46	0.98	1.05	10.10
21-May	4.30	28.00	18.00	0.41	0.64	2.22	1.09	1.17	9.09
22-May	2.90	26.00	6.10	0.46	0.37	2.06	1.22	1.31	3.08
23-May	2.70	27.00	3.50	0.60	1.10	2.14	1.59	1.71	1.77
24-May	4.10	29.00	2.80	0.54	0.78	2.30	1.43	1.54	1.41
25-May	2.80	29.00	2.60	0.40	2.90	2.30	1.06	1.14	1.31
26-May	2.40	27.00	2.70	0.34	1.40	2.14	0.90	0.97	1.36
27-May	2.20	23.00	2.30	0.30	0.39	1.83	0.80	0.86	1.16
28-May	2.20	21.00	14.00	0.82	1.00	1.67	2.18	2.34	7.07
29-May	2.30	21.00	20.00	0.70	1.20	1.67	1.86	2.00	10.10
30-May	2.50	26.00	24.00	0.75	0.93	2.06	1.99	2.14	12.12
31-May	3.60	41.00	69.00	0.82	4.40	3.26	2.18	2.34	34.84
1-Jun	3.80	42.00	22.00	0.68	1.70	3.34	1.81	1.94	11.11
2-Jun	5.50	46.00	9.90	0.54	0.64	3.65	1.43	1.54	5.00
3-Jun	3.30	42.00	5.80	0.41	0.41	3.34	1.09	1.17	2.93
4-Jun	2.90	35.00	3.90	0.33	0.30	2.78	0.88	0.94	1.97
5-Jun	5.70	29.00	7.40	0.24	0.38	2.30	0.64	0.68	3.74
6-Jun	30.00	25.00	4.70	0.19	0.68	1.99	0.50	0.54	2.37
7-Jun	26.00	22.00	6.90	0.21	0.73	1.75	0.56	0.60	3.48
8-Jun	10.00	20.00	15.00	0.55	0.74	1.59	1.46	1.57	7.57
9-Jun	15.00	20.00	11.00	0.73	0.89	1.59	1.94	2.08	5.55
10-Jun	5.00	18.00	5.10	1.40	0.39	1.43	3.72	3.99	2.58
11-Jun	6.20	19.00	6.20	1.20	0.34	1.51	3.19	3.42	3.13
12-Jun	8.50	242.00	90.00	1.00	0.45	19.22	2.66	2.85	45.45
13-Jun	11.00	138.00	103.00	0.87	1.90	10.96	2.31	2.48	52.01
14-Jun	11.00	97.00	74.00	0.77	6.30	7.70	2.05	2.20	37.37
15-Jun	8.50	56.00	139.00	1.90	10.00	4.45	5.05	5.42	70.19

Table 1.1 Mean Daily Stream Discharge

DATE	REDWATER RIVER @ CIRCLE STN_06177500 (cfs)	REDWATER RIVER @ VIDA STN_06177825 (cfs)	PRAIRIE ELK CREEK STN 06175540 (cfs)	TIMBER CREEK STN 06131120 (cfs)	NELSON CREEK STN 06131200 (cfs)	ESTIMATED EAST REDWATER CREEK (FROM REDWATER @ VIDA) (cfs)	ESTIMATED HORSE CREEK (FROM TIMBER CREEK) (cfs)	ESTIMATED PASTURE CREEK (FROM TIMBER CREEK) (cfs)	ESTIMATED SAND CREEK (FROM PRAIRIE ELK CREEK) (cfs)
16-Jun	13.00	48.00	27.00	3.10	1.20	3.81	8.24	8.84	13.63
17-Jun	60.00	40.00	18.00	6.10	2.40	3.18	0.27	17.39	9.09
18-Jun	17.00	39.00	10.00	3.70	1.80	3.10	16.21	10.55	5.05
19-Jun	12.00	35.00	7.00	1.90	0.70	2.78	1.20	5.42	0.98
20-Jun	33.00	30.00	40.00	1.50	1.60	2.38	0.69	4.28	0.59
21-Jun	9.30	57.00	79.00	3.90	8.80	4.53	9.83	11.12	0.25
22-Jun	24.00	153.00	33.00	6.60	2.90	12.15	5.05	18.82	0.16
23-Jun	16.00	79.00	20.00	6.90	0.53	6.27	3.99	19.67	0.03
24-Jun	19.00	57.00	11.00	3.50	0.32	4.53	10.36	9.98	3.53
25-Jun	5.60	39.00	6.30	2.00	3.60	3.10	17.54	5.70	20.20
26-Jun	8.30	34.00	31.00	0.92	2.80	2.70	18.33	2.62	39.89
27-Jun	4.90	33.00	15.00	0.56	0.40	2.62	9.30	1.60	16.66
28-Jun	4.00	30.00	4.60	0.80	0.26	2.38	5.31	2.28	10.10
29-Jun	38.00	35.00	4.30	0.42	0.12	2.78	2.44	1.20	5.55
30-Jun	14.00	32.00	3.00	0.24	0.06	2.54	1.49	0.68	3.18
1-Jul	7.80	31.00	37.00	0.27	0.05	2.46	2.13	0.77	15.65
2-Jul	5.20	48.00	11.00	0.25	5.20	3.81	1.12	0.71	7.57
3-Jul	4.40	219.00	24.00	0.18	1.20	17.39	0.64	0.51	2.32
4-Jul	23.00	101.00	33.00	0.13	27.00	8.02	0.72	0.37	2.17
5-Jul	36.00	107.00	54.00	0.10	1.90	8.50	0.66	0.29	1.51
6-Jul	19.00	169.00	16.00	0.08	1.10	13.42	0.48	0.23	18.68
7-Jul	14.00	123.00	10.00	0.06	0.30	9.77	0.35	0.17	5.55
8-Jul	6.40	74.00	4.50	0.04	0.14	5.88	0.27	0.13	12.12
9-Jul	4.00	52.00	3.30	0.02	5.60	4.13	0.21	0.06	16.66
10-Jul	4.50	40.00	53.00	0.48	1.70	3.18	0.16	1.37	27.27
11-Jul	9.50	49.00	21.00	0.80	1.30	3.89	0.11	2.28	8.08
12-Jul	4.90	65.00	5.70	0.20	0.17	5.16	0.05	0.57	5.05
13-Jul	5.50	41.00	2.80	0.04	2.10	3.26	1.28	0.11	2.27

Table 1.1 Mean Daily Stream Discharge

DATE	REDWATER RIVER @ CIRCLE STN_06177500 (cfs)	REDWATER RIVER @ VIDA STN_06177825 (cfs)	PRAIRIE ELK CREEK STN 06175540 (cfs)	TIMBER CREEK STN 06131120 (cfs)	NELSON CREEK STN 06131200 (cfs)	ESTIMATED EAST REDWATER CREEK (FROM REDWATER @ VIDA) (cfs)	ESTIMATED HORSE CREEK (FROM TIMBER CREEK) (cfs)	ESTIMATED PASTURE CREEK (FROM TIMBER CREEK) (cfs)	ESTIMATED SAND CREEK (FROM PRAIRIE ELK CREEK) (cfs)
14-Jul	18.00	33.00	14.00	0.01	0.86	2.62	2.13	0.03	1.67
15-Jul	37.00	26.00	4.30	0.00	0.15	2.06	0.53	0.00	26.76
16-Jul	11.00	23.00	7.30	0.00	0.05	1.83	0.11	0.00	10.60
17-Jul	21.00	21.00	6.60	0.00	0.69	1.67	0.03	0.00	2.88
18-Jul	16.00	18.00	3.00	0.56	3.20	1.43	0.00	1.60	1.41
19-Jul	16.00	17.00	3.30	0.00	0.28	1.35	0.00	0.00	7.07
20-Jul	16.00	15.00	2.40	0.00	0.14	1.19	0.00	0.00	2.17
21-Jul	8.00	13.00	1.80	0.01	0.51	1.03	1.49	0.03	3.69
22-Jul	9.50	11.00	1.80	0.00	1.60	0.87	0.00	0.00	3.33
23-Jul	9.00	9.30	1.60	0.00	0.28	0.74	0.00	0.00	1.51
24-Jul	5.40	8.50	1.80	0.00	0.22	0.68	0.03	0.00	1.67
25-Jul	3.80	7.90	3.10	0.00	5.20	0.63	0.00	0.00	1.21
26-Jul	3.20	7.50	2.20	0.00	0.62	0.60	0.00	0.00	0.91
27-Jul	4.20	7.50	1.70	0.00	0.44	0.60	0.00	0.00	0.91
28-Jul	4.70	6.90	1.40	0.00	0.17	0.55	0.00	0.00	0.81
29-Jul	4.20	6.10	2.80	0.00	0.40	0.48	0.00	0.00	0.91
30-Jul	3.10	5.90	21.00	0.00	0.83	0.47	0.00	0.00	1.57
31-Jul	2.40	5.60	6.60	0.00	0.33	0.44	0.00	0.00	1.11
1-Aug	4.80	5.50	2.80	0.00	0.94	0.44	0.00	0.00	0.86
2-Aug	3.00	12.00	31.00	0.00	2.10	0.95	0.00	0.00	0.71
3-Aug	1.90	16.00	5.60	0.00	2.40	1.27	0.00	0.00	1.41
4-Aug	1.40	19.00	3.10	0.00	0.37	1.51	0.00	0.00	10.60
5-Aug	4.90	21.00	3.70	0.00	0.49	1.67	0.00	0.00	3.33
6-Aug	2.60	41.00	3.30	0.00	0.09	3.26	0.00	0.00	1.41
7-Aug	3.10	21.00	7.10	0.00	6.60	1.67	0.00	0.00	15.65
8-Aug	2.20	15.00	2.90	0.00	1.30	1.19	0.00	0.00	2.83
9-Aug	1.10	12.00	4.40	0.00	1.30	0.95	0.00	0.00	1.57
10-Aug	2.50	9.80	5.30	0.00	0.30	0.78	0.00	0.00	1.87

Table 1.1 Mean Daily Stream Discharge

DATE	REDWATER RIVER @ CIRCLE STN_06177500 (cfs)	REDWATER RIVER @ VIDA STN_06177825 (cfs)	PRAIRIE ELK CREEK STN 06175540 (cfs)	TIMBER CREEK STN 06131120 (cfs)	NELSON CREEK STN 06131200 (cfs)	ESTIMATED EAST REDWATER CREEK (FROM REDWATER @ VIDA) (cfs)	ESTIMATED HORSE CREEK (FROM TIMBER CREEK) (cfs)	ESTIMATED PASTURE CREEK (FROM TIMBER CREEK) (cfs)	ESTIMATED SAND CREEK (FROM PRAIRIE ELK CREEK) (cfs)
11-Aug	10.00	8.70	2.30	0.00	0.31	0.69	0.00	0.00	1.67
12-Aug	1.50	6.70	1.60	0.00	0.23	0.53	0.00	0.00	3.59
13-Aug	0.99	5.90	1.40	0.00	0.10	0.47	0.00	0.00	1.46
14-Aug	0.89	4.50	1.20	0.00	2.00	0.36	0.00	0.00	2.22
15-Aug	0.91	4.00	1.20	0.00	19.00	0.32	0.00	0.00	2.68
16-Aug	3.90	3.90	1.30	0.00	9.30	0.31	0.00	0.00	1.16
17-Aug	1.20	3.60	1.70	0.00	0.69	0.29	0.00	0.00	0.81
18-Aug	0.72	3.10	1.30	0.00	0.21	0.25	0.00	0.00	0.71
19-Aug	0.51	3.60	1.10	0.00	0.36	0.29	0.00	0.00	0.61
20-Aug	0.36	4.40	0.99	0.00	0.10	0.35	0.00	0.00	0.61
21-Aug	0.30	3.90	0.97	0.00	0.04	0.31	0.00	0.00	0.66
22-Aug	1.80	3.60	0.97	0.00	0.03	0.29	0.00	0.00	0.86
23-Aug	2.20	3.00	0.99	0.00	0.03	0.24	0.00	0.00	0.66
24-Aug	2.30	2.90	1.10	0.00	0.44	0.23	0.00	0.00	0.56
25-Aug	0.50	2.80	0.99	0.00	0.12	0.22	0.00	0.00	0.50
26-Aug	0.30	2.50	0.97	0.00	0.04	0.20	0.00	0.00	0.49
27-Aug	0.28	2.30	1.00	0.00	0.02	0.18	0.00	0.00	0.49
28-Aug	0.24	2.20	1.00	0.00	0.01	0.17	0.00	0.00	0.50
29-Aug	0.27	2.20	0.97	0.00	0.01	0.17	0.00	0.00	0.56
30-Aug	0.48	2.40	4.80	0.00	0.02	0.19	0.00	0.00	0.50
31-Aug	3.00	2.40	5.20	0.00	0.01	0.19	0.00	0.00	0.49
1-Sep	1.40	2.40	1.60	0.00	0.00	0.19	0.00	0.00	0.50
2-Sep	0.76	2.30	1.20	0.00	0.00	0.18	0.00	0.00	0.50
3-Sep	0.94	2.50	1.00	0.00	0.00	0.20	0.00	0.00	0.29
4-Sep	0.55	2.30	0.98	0.00	0.00	0.18	0.00	0.00	0.21
5-Sep	1.10	2.10	0.98	0.00	0.00	0.17	0.00	0.00	0.11
6-Sep	0.56	1.90	0.98	0.00	0.00	0.15	0.00	0.00	0.00
7-Sep	0.61	1.90	0.97	0.00	0.00	0.15	0.00	0.00	0.49

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DATE	REDWATER RIVER @ CIRCLE STN_06177500 (cfs)	REDWATER RIVER @ VIDA STN_06177825 (cfs)	PRAIRIE ELK CREEK STN 06175540 (cfs)	TIMBER CREEK STN 06131120 (cfs)	NELSON CREEK STN 06131200 (cfs)	ESTIMATED EAST REDWATER CREEK (FROM REDWATER @ VIDA) (cfs)	ESTIMATED HORSE CREEK (FROM TIMBER CREEK) (cfs)	ESTIMATED PASTURE CREEK (FROM TIMBER CREEK) (cfs)	ESTIMATED SAND CREEK (FROM PRAIRIE ELK CREEK) (cfs)
8-Sep	0.38	2.00	1.50	0.00	0.22	0.16	0.00	0.00	2.42
9-Sep	0.32	2.10	4.30	0.00	0.51	0.17	0.00	0.00	2.63
10-Sep	0.34	1.90	1.70	0.00	0.10	0.15	0.00	0.00	0.81
11-Sep	0.26	1.90	1.30	0.00	0.06	0.15	0.00	0.00	0.61
12-Sep	0.24	4.00	36.00	0.00	1.10	0.32	0.00	0.00	0.50
13-Sep	0.27	4.10	31.00	0.00	0.51	0.33	0.00	0.00	0.49
14-Sep	0.29	4.00	13.00	0.00	0.24	0.32	0.00	0.00	0.49
15-Sep	0.29	3.40	3.10	0.00	0.04	0.27	0.00	0.00	0.49
16-Sep	0.29	2.80	1.60	0.00	0.01	0.22	0.00	0.00	0.49
17-Sep	0.27	2.80	1.30	0.00	0.02	0.22	0.00	0.00	0.76
18-Sep	0.33	2.90	9.40	0.00	0.01	0.23	0.00	0.00	2.17
19-Sep	0.73	9.50	60.00	0.00	23.00	0.75	0.00	0.00	0.86
20-Sep	0.95	15.00	32.00	0.00	0.46	1.19	0.00	0.00	0.66
21-Sep	0.71	15.00	8.60	0.00	0.20	1.19	0.00	0.00	18.18
22-Sep	0.57	10.00	3.00	0.00	0.16	0.79	0.00	0.00	15.65
23-Sep	0.55	8.90	6.50	0.00	0.14	0.71	0.00	0.00	6.56
24-Sep	0.43	7.90	9.30	0.00	0.23	0.63	0.00	0.00	1.57
25-Sep	40.00	7.00	3.50	0.00	0.07	0.56	0.00	0.00	0.81
26-Sep	9.20	6.00	2.00	0.00	0.09	0.48	0.00	0.00	0.66
27-Sep	3.40	5.30	2.50	0.00	0.06	0.42	0.00	0.00	4.75
28-Sep	1.90	5.10	7.50	0.00	0.04	0.41	0.00	0.00	30.30
29-Sep	1.30	4.40	3.30	0.00	0.03	0.35	0.00	0.00	16.16
30-Sep	1.10	4.20	5.10	0.00	0.02	0.33	0.00	0.00	4.34
1-Oct	0.83	4.60	9.40	0.00	0.02	0.37	0.00	0.00	1.51
2-Oct	0.75	4.20	6.10	0.00	0.02	0.33	0.00	0.00	3.28
3-Oct	0.72	4.10	3.10	0.00	0.01	0.33	0.00	0.00	4.70
4-Oct	0.69	4.10	2.30	0.00	0.01	0.33	0.00	0.00	1.77
5-Oct	0.66	3.90	2.80	0.00	0.01	0.31	0.00	0.00	1.01

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6-Oct	0.63	3.90	3.60	0.00	0.01	0.31	0.00	0.00	1.26
7-Oct	0.61	3.90	2.20	0.00	0.01	0.31	0.00	0.00	3.79
8-Oct	0.64	3.90	1.80	0.00	0.01	0.31	0.00	0.00	1.67
9-Oct	0.62	4.20	17.00	0.00	0.03	0.33	0.00	0.00	2.58
10-Oct	0.58	4.50	14.00	0.00	0.13	0.36	0.00	0.00	4.75
11-Oct	0.57	4.20	3.60	0.00	0.06	0.33	0.00	0.00	3.08
12-Oct	0.56	4.00	9.90	0.00	2.20	0.32	0.00	0.00	1.57
13-Oct	0.53	4.00	14.00	0.00	0.41	0.32	0.00	0.00	1.16
14-Oct	0.51	4.40	18.00	0.00	0.30	0.35	0.00	0.00	1.41
15-Oct	0.50	4.50	10.00	0.00	0.27	0.36	0.00	0.00	1.82
16-Oct	0.49	4.60	4.50	0.00	0.11	0.37	0.00	0.00	1.11
17-Oct	0.45	4.80	4.90	0.00	0.07	0.38	0.00	0.00	0.91
18-Oct	0.44	4.80	4.40	0.00	0.06	0.38	0.00	0.00	8.58
19-Oct	0.42	4.80	2.80	0.00	0.04	0.38	0.00	0.00	7.07
20-Oct	0.40	4.80	2.10	0.00	0.03	0.38	0.00	0.00	1.82
21-Oct	0.38	4.80	2.10	0.00	0.02	0.38	0.00	0.00	5.00
22-Oct	0.39	5.00	6.40	0.00	0.02	0.40	0.00	0.00	7.07
23-Oct	0.42	5.40	8.90	0.00	0.03	0.43	0.00	0.00	9.09
24-Oct	0.39	5.10	5.00	0.01	0.10	0.41	0.00	0.03	5.05
25-Oct	0.38	4.40	2.60	0.01	0.07	0.35	0.00	0.03	2.27
26-Oct	0.36	4.30	2.30	0.01	0.06	0.34	0.00	0.03	2.47
27-Oct	0.35	4.60	2.00	0.01	0.04	0.37	0.03	0.03	2.22
28-Oct	0.36	5.30	2.00	0.01	0.03	0.42	0.03	0.03	1.41
29-Oct	0.34	4.90	1.90	0.01	0.03	0.39	0.03	0.03	1.06
30-Oct	0.34	4.70	1.90	0.01	0.02	0.37	0.03	0.03	1.06
31-Oct	0.34	4.70	1.90	0.01	0.02	0.37	0.03	0.03	3.23
1-Nov	0.35	4.70	1.90	0.01	0.01	0.37	0.03	0.03	4.49
2-Nov	0.37	4.70	1.90	0.01	0.02	0.37	0.03	0.03	2.52

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3-Nov	0.37	4.70	1.90	0.01	0.01	0.37	0.03	0.03	1.31
4-Nov	0.37	4.80	1.90	0.01	0.02	0.38	0.03	0.03	1.16
5-Nov	0.35	4.60	2.00	0.01	0.02	0.37	0.03	0.03	1.01
6-Nov	0.36	4.70	2.00	0.01	0.02	0.37	0.03	0.03	1.01
7-Nov	0.37	4.90	2.00	0.01	0.01	0.39	0.03	0.03	0.96
8-Nov	0.34	4.90	2.00	0.01	0.01	0.39	0.03	0.03	0.96
9-Nov	0.32	4.90	1.90	0.01	0.01	0.39	0.03	0.03	0.96
10-Nov	0.31	4.80	1.90	0.01	0.01	0.38	0.03	0.03	0.96
11-Nov	0.32	4.70	1.80	0.01	0.01	0.37	0.03	0.03	0.96
12-Nov	0.33	4.80	1.70	0.01	0.01	0.38	0.03	0.03	0.96
13-Nov	0.36	5.00	1.80	0.01	0.01	0.40	0.03	0.03	0.96
14-Nov	0.36	5.50	1.90	0.01	0.01	0.44	0.03	0.03	1.01
15-Nov	0.36	5.60	2.00	0.00	0.01	0.44	0.03	0.00	1.01
16-Nov	0.35	5.60	2.10	0.00	0.01	0.44	0.03	0.00	1.01
17-Nov	0.35	5.60	2.10	0.00	0.01	0.44	0.03	0.00	1.01
18-Nov	0.34	5.50	2.20	0.00	0.01	0.44	0.00	0.00	0.96
19-Nov	0.35	5.00	2.10	0.00	0.01	0.40	0.00	0.00	0.96
20-Nov	0.34	4.70	2.00	0.00	0.01	0.37	0.00	0.00	0.91
21-Nov	0.36	4.40	1.90	0.00	0.02	0.35	0.00	0.00	0.86
22-Nov	0.37	4.30	1.70	0.00	0.02	0.34	0.00	0.00	0.91
23-Nov	0.37	4.80	1.80	0.00	0.02	0.38	0.00	0.00	0.96
24-Nov	0.38	4.80	1.70	0.00	0.02	0.38	0.00	0.00	1.01
25-Nov	0.41	5.00	1.50	0.00	0.02	0.40	0.00	0.00	1.06
26-Nov	0.41	5.00	1.40	0.00	0.01	0.40	0.00	0.00	1.06
27-Nov	0.40	4.90	1.30	0.00	0.01	0.39	0.00	0.00	1.11
28-Nov	0.39	4.80	1.30	0.02	0.01	0.38	0.00	0.06	1.06
29-Nov	0.38	4.60	1.20	0.02	0.01	0.37	0.00	0.06	1.01
30-Nov	0.37	4.10	1.20	0.02	0.01	0.33	0.00	0.06	0.96

Table 1.1 Mean Daily Stream Discharge

DATE	REDWATER RIVER @ CIRCLE STN_06177500 (cfs)	REDWATER RIVER @ VIDA STN_06177825 (cfs)	PRAIRIE ELK CREEK STN 06175540 (cfs)	TIMBER CREEK STN 06131120 (cfs)	NELSON CREEK STN 06131200 (cfs)	ESTIMATED EAST REDWATER CREEK (FROM REDWATER @ VIDA) (cfs)	ESTIMATED HORSE CREEK (FROM TIMBER CREEK) (cfs)	ESTIMATED PASTURE CREEK (FROM TIMBER CREEK) (cfs)	ESTIMATED SAND CREEK (FROM PRAIRIE ELK CREEK) (cfs)
1-Dec	0.39	4.00	1.10	0.01	0.01	0.32	0.05	0.03	0.86
2-Dec	0.36	3.80	1.10	0.01	0.01	0.30	0.05	0.03	0.91
3-Dec	0.36	3.80	1.30	0.01	0.01	0.30	0.05	0.03	0.86
4-Dec	0.36	3.80	1.40	0.01	0.01	0.30	0.03	0.03	0.76
5-Dec	0.35	4.00	1.50	0.01	0.07	0.32	0.03	0.03	0.71
6-Dec	0.34	4.20	1.60	0.00	0.06	0.33	0.03	0.00	0.66
7-Dec	0.33	4.00	1.30	0.00	0.05	0.32	0.03	0.00	0.66
8-Dec	0.33	3.90	1.20	0.00	0.05	0.31	0.03	0.00	0.61
9-Dec	0.34	4.10	1.10	0.00	0.03	0.33	0.00	0.00	0.61
10-Dec	0.34	4.00	1.10	0.00	0.02	0.32	0.00	0.00	0.56
11-Dec	0.34	3.70	1.00	0.00	0.02	0.29	0.00	0.00	0.56
12-Dec	1.20	3.40	0.92	0.00	0.01	0.27	0.00	0.00	0.66
13-Dec	1.60	3.20	0.94	0.00	0.01	0.25	0.00	0.00	0.71
14-Dec	1.20	3.00	0.90	0.00	0.01	0.24	0.00	0.00	0.76
15-Dec	0.68	2.90	0.89	0.00	0.01	0.23	0.00	0.00	0.81
16-Dec	0.51	2.80	0.78	0.00	0.01	0.22	0.00	0.00	0.66
17-Dec	0.35	2.70	0.79	0.00	0.01	0.21	0.00	0.00	0.61
18-Dec	0.32	2.80	0.71	0.00	0.01	0.22	0.00	0.00	0.56
19-Dec	0.31	2.80	0.66	0.00	0.02	0.22	0.00	0.00	0.56
20-Dec	0.30	2.80	0.70	0.00	0.03	0.22	0.00	0.00	0.50
21-Dec	0.28	2.80	0.73	0.00	0.02	0.22	0.00	0.00	0.46
22-Dec	0.28	2.80	0.66	0.00	0.01	0.22	0.00	0.00	0.47
23-Dec	0.27	2.70	0.59	0.00	0.01	0.21	0.00	0.00	0.45
24-Dec	0.27	2.60	0.52	0.00	0.01	0.21	0.00	0.00	0.45
25-Dec	0.27	2.30	0.60	0.00	0.01	0.18	0.00	0.00	0.39
26-Dec	0.27	2.30	0.66	0.00	0.01	0.18	0.00	0.00	0.40
27-Dec	0.26	2.30	0.73	0.00	0.01	0.18	0.00	0.00	0.36
28-Dec	0.24	2.30	0.74	0.00	0.00	0.18	0.00	0.00	0.33

Table 1.1 Mean Daily Stream Discharge

DATE	REDWATER RIVER @ CIRCLE STN_06177500 (cfs)	REDWATER RIVER @ VIDA STN_06177825 (cfs)	PRAIRIE ELK CREEK STN 06175540 (cfs)	TIMBER CREEK STN 06131120 (cfs)	NELSON CREEK STN 06131200 (cfs)	ESTIMATED EAST REDWATER CREEK (FROM REDWATER @ VIDA) (cfs)	ESTIMATED HORSE CREEK (FROM TIMBER CREEK) (cfs)	ESTIMATED PASTURE CREEK (FROM TIMBER CREEK) (cfs)	ESTIMATED SAND CREEK (FROM PRAIRIE ELK CREEK) (cfs)
29-Dec	0.25	2.10	0.63	0.00	0.00	0.17	0.00	0.00	0.35
30-Dec	0.24	2.10	0.55	0.00	0.00	0.17	0.00	0.00	0.37
31-Dec	0.23	2.00	0.46	0.00	0.00	0.16	0.00	0.00	0.33

Table 1.2 Inferred DO

Sample Number	Segment Name	Site ID	Station Description	Sample Date	Diatom-inferred DO (mg/L)
HM08D012	Timber Creek	6131120	Timber Creek at the highway 24 crossing	6/17/2008	4.7
HM08D006	Nelson Creek	6131200	Nelson Creek above hwy 24 Crossing	6/17/2008	5.3
HM08D004	Prairie Elk Creek	6175540	Prairie Elk Creek at Hwy 528 Crossing	6/18/2008	5.1
HM08D013	East Redwater Creek	5385EA-01	East Redwater River, near mouth	6/17/2008	5.8
336301	Horse Creek	M48HRSEC02	Horse Creek 5 miles above Circle	6/4/2003	6.2
HM08D019	Horse Creek	M48HRSEC02	Horse Creek 5 miles above Circle	6/18/2008	5.7
302401	Pasture Creek	M48PSTRC01	Pasture Creek near mouth	6/20/2003	6.2
HM08D014	Pasture Creek	M48PSTRC01	Pasture Creek near mouth	6/17/2008	6.1
302501	Pasture Creek	M48PSTRC02	Pasture Creek below Highway 200	6/20/2003	5.6
HM08D001	Pasture Creek	M48PSTRC03	Pasture Creek below Highway 200	6/17/2008	4.4
302101	East Redwater Creek	M48RDWEC01	East Redwater River near mouth	6/19/2003	6.4
302001	East Redwater Creek	M48RDWEC02	East Redwater River at County Road 308	6/19/2003	4.2
302201	East Redwater Creek	M48RDWEC03	East Redwater River below North Fork	6/19/2003	6.2
HM08D018	East Redwater Creek	M48RDWEC03	Redwater River, East, below North Fork	6/17/2008	4.4
302301	East Redwater Creek	M48RDWEC04	East Redwater River on state land	6/19/2003	3.7
HM08D020	East Redwater Creek	M48RDWEC05	Redwater River, East, South Fork	6/17/2008	4.5
HM08D002	Prairie Elk Creek	M49PREKC-06	Prairie Elk Creek, Arnston Ranch (SW¼ Sec. 7 T22N R46E)	6/18/2008	5.2
HM08D021	Sand Creek	M49SANDC-03	Sand Creek, West Fork, U/S of Sand Creek Road Crossing	6/18/2008	5.1
338701	Horse Creek	MCNHORC-02	Horse Creek 0.7 mile D/S of Denwoody	7/11/2003	5.5
338101	Horse Creek	MCNHORC-04	Horse Creek above Circle	7/11/2003	3.8
HM08D017	Horse Creek	MCNHORC-04	Horse Creek 0.6 mile U/S of the second Horse Creek Road crossing	6/18/2008	5.3
301901	Horse Creek	MCNHORC-05	Horse Creek near mouth above Highway 13	6/4/2003	4.1
301902	Horse Creek	MCNHORC-05	Horse Creek near mouth	7/11/2003	4.3

Table 1.2 Inferred DO

Sample Number	Segment Name	Site ID	Station Description	Sample Date	Diatom-inferred DO (mg/L)
HM08D010	Horse Creek	MCNHORC-05	Horse Creek U/S of the Highway 13 crossing	6/17/2008	5.1
338201	Nelson Creek	MCNNLSN-01	Nelson Creek one mile U/S of Crookers Coulee	7/9/2003	3.9
HM08D007	Nelson Creek	MCNNLSN-01	Nelson Creek one mile U/S of Crookers Coulee	6/17/2008	5.4
338301	Prairie Elk Creek	MCNPREK-4A	Prairie Elk Creek two miles D/S of the Pass Road crossing	9/16/2003	7.4
HM08D011	Prairie Elk Creek	MCNPREK-4A	Prairie Elk Creek two miles D/S of the Pass Road crossing	6/18/2008	6.6
200802	Redwater River	MCNREDW-01	Redwater River at Fairgrounds	8/27/2003	5.7
HM08D016	Redwater River	MCNREDW-01	Redwater River at Fairgrounds	6/16/2008	5.8
200801	Redwater River	MCNREDW-01	Redwater River at Fairgrounds	08/17/2000.	7.1
200901	Redwater River	MCNREDW-02	Redwater River at Cemetery Road	8/17/2000	6.7
200902	Redwater River	MCNREDW-02	Redwater River at Cemetery Road	8/27/2003	5.9
HM08D008	Redwater River	MCNREDW-02	Redwater River 0.5 mile D/S of Cemetery Road crossing	6/16/2008	5.8
201002	Redwater River	MCNREDW-03	Redwater River below airport	8/27/2003	7.5
HM08D009	Redwater River	MCNREDW-03	Redwater River 200 feet U/S of the Highway 200 crossing	6/16/2008	5.2
201001	Redwater River	MCNREDW-03	Redwater River below airport	08/17/2000.	5.4
201102	Redwater River	MCNREDW-04	Redwater River at Highway 13	8/27/2003	6
HM08D003	Redwater River	MCNREDW-04	Redwater River at Highway 13 (RW-4)	6/17/2008	5.1
201101	Redwater River	MCNREDW-04	Redwater River at Highway 13	08/17/2000.	5.6
338401	Sand Creek	MCNSAND-03	Sand Creek U/S of the Hubbard Road crossing	9/16/2003	6.4
HM08D005	Sand Creek	MCNSAND-03	Sand Creek, U/S of Hubbard Road Crossing	6/18/2008	4.6
338501	Sand Creek	MCNSAND-2A	Sand Creek at the Johnson residence	9/16/2003	6.3
HM08D015	Sand Creek	MCNSAND-2A	Sand Creek at the Johnson residence	6/18/2008	7.2

Table 1.3 Compiled Surface Water Nutrient Data

Segment ID	Site ID	Sample Date	Flow (cfs)	Chlor-a (mg/m2)	DO (mg/L)	Water Temp (°C)	pH (S.U.)	TDS (mg/L)	TSS (mg/L)	Total Ammonia as N (ug/L)	Total Ammonia as NH4 (ug/L)	TKN (ug/L)	Total N Calc (ug/L)	Total N per Sulfate Method (ug/L)	NO2 + NO3 as N (ug/L)	Total P (ug/L)	Total OrthoPhosphate (ug/L)	Total P as PO4 (ug/L)	Dissolved P (ug/L)
East Redwater Creek	474957105145701	6/22/82	16.00	--	--	--	--	--	--	170	220	1800	1850	--	< 100	< 10	--	--	--
East Redwater Creek	474957105145701	8/24/82	1.20	--	--	--	--	--	--	100	130	1200	1250	--	< 100	50	--	150	--
East Redwater Creek	474957105145701	10/19/82	5.40	--	--	--	--	--	--	150	190	1200	1250	--	< 100	10	--	30	--
East Redwater Creek	475401105123001	6/23/82	1.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
East Redwater Creek	475401105123001	10/19/82	0.14	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
East Redwater Creek	3EF	5/26/99	--	4.51	--	--	--	4010	36	--	--	1300	1320	--	20	80	--	--	--
East Redwater Creek	5188TR01	6/15/76	--	--	--	--	--	--	--	--	--	--	--	--	70	--	--	--	--
East Redwater Creek	5188TR01	6/15/76	0.02	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
East Redwater Creek	5288NO01	6/15/76	--	--	--	--	--	--	--	--	--	--	--	--	30	--	--	--	--
East Redwater Creek	5385EA01	8/23/95	--	--	--	--	--	--	--	--	--	1200	1205	--	< 10	77	--	--	--
East Redwater Creek	5385EA01	8/23/95	1.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
East Redwater Creek	5385EA01	6/17/08	0.39	--	11.57	27.12	8.47	4590	--	< 50	--	--	--	1170	< 10	55	--	--	18
East Redwater Creek	5385EA01	8/28/08	--	--	9.67	15.54	9.13	4760	--	< 50	--	--	--	1460	< 10	109	--	--	2
East Redwater Creek	M48RDWEC01	6/19/03	--	--	--	--	--	--	60800	50	--	2750	2755	--	< 10	--	--	--	--
East Redwater Creek	M48RDWEC01	6/19/03	--	--	--	--	--	--	--	--	--	--	--	--	--	189	--	--	--
East Redwater Creek	M48RDWEC01	6/19/03	--	174	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
East Redwater Creek	M48RDWEC01	6/19/03	5.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
East Redwater Creek	M48RDWEC02	6/19/03	5.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
East Redwater Creek	M48RDWEC02	6/19/03	--	--	--	--	--	--	30000	50	--	3230	3235	--	< 10	--	--	--	--
East Redwater Creek	M48RDWEC02	6/19/03	--	--	--	--	--	--	--	--	--	--	--	--	--	248	--	--	--
East Redwater Creek	M48RDWEC02	6/19/03	--	39	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
East Redwater Creek	M48RDWEC03	6/19/03	0.25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
East Redwater Creek	M48RDWEC03	6/19/03	--	--	--	--	--	--	51000	40	--	2420	2425	--	10	--	--	--	--
East Redwater Creek	M48RDWEC03	6/19/03	--	--	--	--	--	--	--	--	--	--	--	--	--	187	--	--	--
East Redwater Creek	M48RDWEC03	6/17/08	0.11	--	13.38	31.26	8.46	7230	--	< 50	--	--	--	2750	< 10	345	--	--	19
East Redwater Creek	M48RDWEC04	6/19/03	0.50	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
East Redwater Creek	M48RDWEC04	6/19/03	--	--	--	--	--	--	11000	< 10	--	1920	1960	--	40	--	--	--	--
East Redwater Creek	M48RDWEC04	6/19/03	--	--	--	--	--	--	--	--	--	--	--	--	--	151	--	--	--
East Redwater Creek	M48RDWEC05	6/17/08	0.03	--	16.77	29.44	8.74	10500	--	< 50	--	--	--	3140	< 10	111	--	--	10
East Redwater Creek	M48RWENF01	6/19/03	0.25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
East Redwater Creek	M48RWENF01	6/19/03	--	--	--	--	--	--	5500	90	--	2600	2620	--	20	--	--	--	--
East Redwater Creek	M48RWENF01	6/19/03	--	--	--	--	--	--	--	--	--	--	--	--	--	435	--	--	--
East Redwater Creek	M48RWENF01	6/17/08	0.03	--	11.18	26.42	8.43	7450	--	< 50	--	--	--	2380	10	205	--	--	24
Horse Creek	6177520	4/1/77	1.00	--	--	--	--	--	--	10	10	750	760	--	10	60	--	--	--
Horse Creek	6177520	10/19/77	0.03	--	--	--	--	--	--	180	230	3600	3610	--	10	100	--	--	--
Horse Creek	6177520	3/22/78	150.00	--	--	--	--	--	--	250	320	890	1380	--	490	210	--	--	--
Horse Creek	6177520	4/25/78	1.00	--	--	--	--	--	--	< 10	--	960	980	--	20	40	--	--	--
Horse Creek	6177520	5/9/78	2.40	--	--	--	--	--	--	10	10	1400	1400	--	10	80	--	--	--
Horse Creek	6177520	6/8/78	1.60	--	--	--	--	--	--	10	10	1100	1180	--	80	< 10	--	--	--
Horse Creek	6177520	7/12/78	1.80	--	--	--	--	--	--	30	40	1100	1150	--	< 100	40	--	--	--
Horse Creek	6177520	8/9/78	0.27	--	--	--	--	--	--	100	130	1500	1540	--	40	20	--	--	--
Horse Creek	6177520	9/13/78	0.66	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Horse Creek	6177520	10/11/78	0.66	--	--	--	--	--	--	10	10	1100	1150	--	< 100	50	--	--	--
Horse Creek	6177520	11/14/78	0.99	--	--	--	--	--	--	10	10	930	940	--	10	20	--	--	--
Horse Creek	6177520	3/19/79	20.00	--	--	--	--	--	--	350	450	1300	1810	--	510	140	--	--	--

Table 1.3 Compiled Surface Water Nutrient Data

Segment ID	Site ID	Sample Date	Flow (cfs)	Chlor-a (mg/m2)	DO (mg/L)	Water Temp (°C)	pH (S.U.)	TDS (mg/L)	TSS (mg/L)	Total Ammonia as N (ug/L)	Total Ammonia as NH4 (ug/L)	TKN (ug/L)	Total N Calc (ug/L)	Total N per Sulfate Method (ug/L)	NO2 + NO3 as N (ug/L)	Total P (ug/L)	Total OrthoPhosphate (ug/L)	Total P as PO4 (ug/L)	Dissolved P (ug/L)
Horse Creek	6177520	4/11/79	126.00	--	--	--	--	--	--	150	190	930	1140	--	210	80	--	--	--
Horse Creek	6177520	5/9/79	15.00	--	--	--	--	--	--	10	10	760	770	--	10	40	--	--	--
Horse Creek	6177520	6/5/79	2.80	--	--	--	--	--	--	10	10	3400	21400	--	18000	20	--	--	--
Horse Creek	6177520	7/10/79	1.40	--	--	--	--	--	--	20	20	2000	2040	--	40	50	--	--	--
Horse Creek	6177520	8/21/79	0.05	--	--	--	--	--	--	130	160	2700	2710	--	10	--	--	--	--
Horse Creek	6177520	6/22/82	0.52	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Horse Creek	6177520	10/19/82	0.28	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Horse Creek	4783HO01	8/23/95	--	--	--	--	--	--	--	--	--	1400	1420	--	20	88	--	--	--
Horse Creek	4783HO01	8/23/95	1.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Horse Creek	4881HO01	8/23/95	--	--	--	--	--	--	--	--	--	1100	1130	--	30	18	--	--	--
Horse Creek	M48DWDYC01	6/17/08	0.05	--	5.02	17.54	7.85	20300	--	< 50	--	--	--	3430	20	173	--	--	11
Horse Creek	M48HRSEC01	6/4/03	--	--	13	18	9.2	--	105000	--	--	2620	2660	--	40	--	--	--	--
Horse Creek	M48HRSEC01	6/4/03	--	--	--	--	--	--	--	--	--	--	--	--	--	139	--	--	--
Horse Creek	M48HRSEC02	6/4/03	--	--	10.4	16	8.7	--	92000	--	--	1380	1400	--	20	--	--	--	--
Horse Creek	M48HRSEC02	6/4/03	--	--	--	--	--	--	--	--	--	--	--	--	--	68	--	--	--
Horse Creek	M48HRSEC02	6/4/03	1.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Horse Creek	M48HRSEC02	6/18/08	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Horse Creek	MCNHORC-01	7/11/03	0.00	--	--	18.7	8.47	--	--	--	--	--	--	--	--	--	--	--	--
Horse Creek	MCNHORC-02	7/11/03	--	--	9.6	20.1	8.3	--	<10000	< 50	--	1300	1325	--	< 50	40	< 10	--	--
Horse Creek	MCNHORC-02	7/11/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Horse Creek	MCNHORC-03	6/7/05	--	--	9.58	14.1	7.64	--	646000	100	--	3500	3830	--	330	620	440	--	--
Horse Creek	MCNHORC-03	6/17/08	0.15	--	5.20	18.21	7.55	5240	--	< 50	--	--	--	965	< 10	41	--	--	5
Horse Creek	MCNHORC-03	8/27/08	--	--	14.80	15.00	8.58	7310	--	< 50	--	--	--	3270	< 10	247	--	--	4
Horse Creek	MCNHORC-04	7/11/03	--	--	7.36	26.3	9.11	--	20000	< 50	--	4500	4525	--	< 50	260	40	--	--
Horse Creek	MCNHORC-04	7/11/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Horse Creek	MCNHORC-04	6/18/08	0.12	--	7.45	19.04	8.80	8770	--	< 50	--	--	--	1670	< 10	37	--	--	10
Horse Creek	MCNHORC-05	7/11/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Horse Creek	MCNHORC-05	7/11/03	--	--	8.37	26.1	8.9	--	58000	< 50	--	2400	2425	--	< 50	150	30	--	--
Horse Creek	MCNHORC-05	8/6/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Horse Creek	MCNHORC-05	8/6/03	--	--	7.1	23.9	8.94	--	121000	< 50	--	4900	4925	--	< 50	580	20	--	--
Horse Creek	MCNHORC-05	8/13/03	--	--	9.4	26.2	9.03	--	120000	< 50	--	8300	8325	--	< 50	710	50	--	--
Horse Creek	MCNHORC-05	8/13/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Horse Creek	MCNHORC-05	8/20/03	--	--	7.53	21.2	9.17	--	71000	< 50	--	9700	9725	--	< 50	560	30	--	--
Horse Creek	MCNHORC-05	8/20/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Horse Creek	MCNHORC-05	8/27/03	--	--	8.86	20.8	9.3	--	64000	500	--	7900	7925	--	< 50	360	30	--	--
Horse Creek	MCNHORC-05	8/27/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Horse Creek	MCNHORC-05	5/5/04	--	--	9.35	17.7	8.33	--	33000	< 50	--	1900	1925	--	< 50	30	20	--	--
Horse Creek	MCNHORC-05	5/13/04	--	--	12.79	7.9	8.53	--	11000	< 50	--	2200	2225	--	< 50	80	10	--	--
Horse Creek	MCNHORC-05	5/20/04	--	--	8.17	17.3	8.46	--	18000	< 50	--	2700	2725	--	< 50	110	20	--	--
Horse Creek	MCNHORC-05	5/27/04	--	--	9.87	16.8	8.43	--	<10000	< 50	--	2200	2225	--	< 50	60	10	--	--
Horse Creek	MCNHORC-05	8/5/04	--	--	4.45	21.9	7.94	--	284000	870	--	5700	8380	--	2680	610	240	--	--
Horse Creek	MCNHORC-05	8/16/04	--	--	7.31	22.6	8.58	--	56000	< 50	--	4500	4525	--	< 50	270	50	--	--
Horse Creek	MCNHORC-05	8/16/04	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Horse Creek	MCNHORC-05	8/23/04	--	--	6.64	16.8	8.76	--	126000	50	--	4600	4625	--	< 50	280	50	--	--
Horse Creek	MCNHORC-05	8/23/04	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 1.3 Compiled Surface Water Nutrient Data

Segment ID	Site ID	Sample Date	Flow (cfs)	Chlor-a (mg/m2)	DO (mg/L)	Water Temp (°C)	pH (S.U.)	TDS (mg/L)	TSS (mg/L)	Total Ammonia as N (ug/L)	Total Ammonia as NH4 (ug/L)	TKN (ug/L)	Total N Calc (ug/L)	Total N per Sulfate Method (ug/L)	NO2 + NO3 as N (ug/L)	Total P (ug/L)	Total OrthoPhosphate (ug/L)	Total P as PO4 (ug/L)	Dissolved P (ug/L)
Horse Creek	MCNHORC-05	8/30/04	--	--	11.46	23.7	8.87	--	76000	< 50	--	5200	5225	--	< 50	270	40	--	--
Horse Creek	MCNHORC-05	8/30/04	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Horse Creek	MCNHORC-05	6/7/05	--	--	9.54	13.4	7.63	--	2860000	200	--	7500	7860	--	360	1680	790	--	--
Horse Creek	MCNHORC-05	6/17/08	0.04	--	2.73	19.98	8.44	7680	--	< 50	--	--	--	2580	< 10	137	--	--	40
Nelson Creek	6131200	10/16/75	1.10	--	--	--	--	--	--	60	80	1500	2130	--	630	200	--	--	--
Nelson Creek	6131200	12/10/75	0.23	--	--	--	--	--	--	10	10	1700	1890	--	190	20	--	--	--
Nelson Creek	6131200	2/25/76	4.10	--	--	--	--	--	--	50	60	1300	1340	--	40	190	--	--	--
Nelson Creek	6131200	3/17/76	7.70	--	--	--	--	--	--	90	120	2600	2680	--	80	180	--	--	--
Nelson Creek	6131200	4/27/76	0.12	--	--	--	--	--	--	< 10	--	1200	1210	--	10	50	--	--	--
Nelson Creek	6131200	6/16/76	1.60	--	--	--	--	--	--	40	50	730	1200	--	470	250	--	--	--
Nelson Creek	6131200	3/8/77	1.80	--	--	--	--	--	--	60	80	960	1110	--	150	70	--	--	--
Nelson Creek	6131200	4/5/77	0.37	--	--	--	--	--	--	30	40	1800	1810	--	10	80	--	--	--
Nelson Creek	6131200	7/12/77	0.50	--	--	--	--	--	--	10	10	800	1330	--	530	300	--	--	--
Nelson Creek	6131200	9/8/77	3.30	--	--	--	--	--	--	90	120	930	1270	--	340	180	--	--	--
Nelson Creek	6131200	3/20/78	68.00	--	--	--	--	--	--	30	40	1300	1620	--	320	710	--	--	--
Nelson Creek	6131200	3/27/78	116.00	--	--	--	--	--	--	80	100	930	1190	--	260	290	--	--	--
Nelson Creek	6131200	4/7/78	3.10	--	--	--	--	--	--	10	10	970	1060	--	90	90	--	--	--
Nelson Creek	6131200	5/8/78	11.00	--	--	--	--	--	--	20	30	3700	5000	--	1300	1900	--	--	--
Nelson Creek	6131200	6/7/78	5.60	--	--	--	--	--	--	30	40	1100	1300	--	200	260	--	--	--
Nelson Creek	6131200	7/5/78	11.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nelson Creek	6131200	7/10/78	0.53	--	--	--	--	--	--	70	90	970	1020	--	< 100	50	--	--	--
Nelson Creek	6131200	8/8/78	0.10	--	--	--	--	--	--	100	130	1500	1520	--	20	40	--	--	--
Nelson Creek	6131200	9/12/78	8.20	--	--	--	--	--	--	110	140	3900	4750	--	850	3600	--	--	--
Nelson Creek	6131200	10/10/78	0.17	--	--	--	--	--	--	40	50	910	960	--	< 100	50	--	--	--
Nelson Creek	6131200	11/13/78	0.18	--	--	--	--	--	--	60	80	790	870	--	80	20	--	--	--
Nelson Creek	6131200	12/12/78	0.10	--	--	--	--	--	--	30	40	1000	1020	--	20	30	--	--	--
Nelson Creek	6131200	3/25/79	52.00	--	--	--	--	--	--	30	40	860	990	--	130	90	--	--	--
Nelson Creek	6131200	4/17/79	125.00	--	--	--	--	--	--	120	150	1400	2400	--	1000	320	--	--	--
Nelson Creek	6131200	5/3/79	3.20	--	--	--	--	--	--	50	60	1000	1020	--	20	40	--	--	--
Nelson Creek	6131200	6/4/79	0.98	--	--	--	--	--	--	20	20	1200	1230	--	30	60	--	--	--
Nelson Creek	6131200	7/2/79	0.03	--	--	--	--	--	--	< 10	0	1100	1200	--	100	40	--	--	--
Nelson Creek	6131200	6/17/08	0.33	--	8.76	23.2	8.72	2550	--	< 50	--	--	--	1120	< 10	74	--	--	16
Nelson Creek	472830106044001	4/4/77	0.44	--	--	--	--	--	--	20	30	1100	1150	--	< 100	70	--	--	--
Nelson Creek	4978NE01	7/12/94	--	--	--	--	--	--	--	--	--	1000	1005	--	< 10	68	--	--	--
Nelson Creek	M31NLSNC01	6/17/08	0.00	--	11.05	20.1	9.65	6150	--	< 50	--	--	--	3390	< 10	93	--	--	15
Nelson Creek	M31NLSNC02	6/17/08	0.24	--	9.23	25.8	8.85	4040	--	< 50	--	--	--	1670	< 10	76	--	--	22
Nelson Creek	MCNNLSN-01	7/14/03	--	--	--	--	--	--	16000	< 50	--	3600	3625	--	< 50	190	30	--	--
Nelson Creek	MCNNLSN-01	7/14/03	--	--	--	--	--	--	18000	< 50	--	3500	3525	--	< 50	180	30	--	--
Nelson Creek	MCNNLSN-02	7/9/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nelson Creek	MCNNLSN-03	7/10/03	--	--	--	--	--	--	440000	< 50	--	< 500	275	--	< 50	180	150	--	--
Nelson Creek	MCNNLSN-03	7/10/03	--	--	--	--	--	--	440000	< 50	--	< 500	275	--	< 50	180	150	--	--
Nelson Creek	GCUS-06	3/08/07	--	--	9.9	0.2	6.71	154	33	0.05	--	--	--	--	130	--	0.013	--	--
Nelson Creek	JCIN-01	9/26/06	--	--	--	15.5	8.74	3380	345	0.24	--	--	--	--	50	--	0.004	--	--
Nelson Creek	JCIN-01	0/22/06	--	--	4.53	4.7	7.65	3130	140	0.17	--	--	--	--	20	--	0.006	--	--
Nelson Creek	JCIN-01	11/11/06	--	--	--	5.0	7.6	3150	75	0.25	--	--	--	--	30	--	--	--	--

Table 1.3 Compiled Surface Water Nutrient Data

Segment ID	Site ID	Sample Date	Flow (cfs)	Chlor-a (mg/m2)	DO (mg/L)	Water Temp (°C)	pH (S.U.)	TDS (mg/L)	TSS (mg/L)	Total Ammonia as N (ug/L)	Total Ammonia as NH4 (ug/L)	TKN (ug/L)	Total N Calc (ug/L)	Total N per Sulfate Method (ug/L)	NO2 + NO3 as N (ug/L)	Total P (ug/L)	Total OrthoPhosphate (ug/L)	Total P as PO4 (ug/L)	Dissolved P (ug/L)
Nelson Creek	JCIN-01	3/08/07	--	--	8.85	0.2	7.86	252	68	0.26	--	--	--	--	160	--	0.089	--	--
Nelson Creek	JCIN-01	4/16/07	--	--	15.08	20.6	8.23	3970	76	0.02	--	--	--	--	10	--	--	--	--
Nelson Creek	JCIN-01	5/09/07	--	--	8	25.9	9.17	4150	72	0.05	--	--	--	--	20	--	--	--	--
Nelson Creek	JCIN-01	6/12/07	--	--	5.38	22.4	8.99	3960	153	0.06	--	--	--	--	20	--	< 0.001	--	--
Nelson Creek	JCIN-01	7/10/20	--	--	10.09	28.1	9.36	4030	28	0.09	--	--	--	--	< 10	--	--	--	--
Nelson Creek	JCIN-01	8/07/07	--	--	0.2	20.4	8.61	5830	444	0.98	--	--	--	--	10	--	--	--	--
Nelson Creek	JCUS-03	3/08/07	--	--	9.67	3.6	7.06	127	30	0.17	--	--	--	--	250	--	0.146	--	--
Nelson Creek	NCDS-01	9/26/06	--	--	--	15.9	8.58	4400	9	0.11	--	--	--	--	< 50	--	< 0.001	--	--
Nelson Creek	NCDS-01	10/22/06	--	--	5.05	6.1	6.61	2720	13	< 0.010	--	--	--	--	< 10	--	0.014	--	--
Nelson Creek	NCDS-01	11/11/06	--	--	--	3.0	7.6	2460	6	< 0.010	--	--	--	--	30	--	--	--	--
Nelson Creek	NCDS-01	3/08/07	--	--	9.6	0.1	7.95	438	88	0.22	--	--	--	--	140	--	0.079	--	--
Nelson Creek	NCDS-01	4/16/07	--	--	3.37	8.9	8.55	5780	14	0.04	--	--	--	--	20	--	--	--	--
Nelson Creek	NCDS-01	5/09/07	--	--	0.41	13.8	8.73	6500	16	0.01	--	--	--	--	20	--	--	--	--
Nelson Creek	NCDS-01	6/12/07	--	--	5.22	18.3	8.58	4330	33	0.04	--	--	--	--	10	--	0.006	--	--
Nelson Creek	NCDS-01	7/09/07	--	--	8.65	18.4	9.69	8100	73	0.08	--	--	--	--	30	--	--	--	--
Nelson Creek	NCUS-02	3/08/07	--	--	8.96	4.1	8.03	1200	23	0.11	--	--	--	--	170	--	0.013	--	--
Nelson Creek	NCUS-02	4/17/07	--	--	3.93	7.7	8.68	13100	12	0.02	--	--	--	--	10	--	--	--	--
Nelson Creek	NCUS-02	5/10/07	--	--	5.64	12.2	8.9	11400	5	< 0.010	--	--	--	--	10	--	--	--	--
Nelson Creek	NCUS-02	6/14/07	--	--	2.42	18.3	8.87	9140	26	0.02	--	--	--	--	10	--	0.002	--	--
Nelson Creek	NCUS-02	7/11/07	--	--	4.64	22.5	8.94	6980	98	0.1	--	--	--	--	< 10	--	--	--	--
Nelson Creek	POND-25	6/13/07	--	--	11.61	23.1	9.67	1110	< 18	0.06	--	--	--	--	20	--	< 0.001	--	--
Nelson Creek	POND-25	7/10/07	--	--	8.71	24.4	9.89	11600	52	0.1	--	--	--	--	60	--	--	--	--
Nelson Creek	POND-25A	6/13/07	--	--	14.52	22.2	8.71	7630	4	0.07	--	--	--	--	20	--	0.003	--	--
Nelson Creek	POND-25A	7/09/07	--	--	11.25	21.5	9.02	14800	< 1	0.04	--	--	--	--	10	--	--	--	--
Nelson Creek	RES-01	9/26/06	--	--	--	10.6	6.77	480	497	0.14	--	--	--	--	20	--	0.1	--	--
Nelson Creek	RES-01	10/22/06	--	--	5.19	3.3	5.52	435	232	0.88	--	--	--	--	140	--	0.011	--	--
Nelson Creek	RES-01	11/11/06	--	--	--	2.0	7.5	492	613	3.02	--	--	--	--	90	--	--	--	--
Nelson Creek	RES-01	3/07/07	--	--	9.46	2.6	8.31	129	26	0.08	--	--	--	--	520	--	0.008	--	--
Nelson Creek	RES-01	4/16/07	--	--	7.01	9.8	7.63	135	62	0.11	--	--	--	--	80	--	--	--	--
Nelson Creek	RES-01	5/09/07	--	--	6.06	13.7	8.3	155	18	0.03	--	--	--	--	10	--	--	--	--
Nelson Creek	RES-01	6/12/07	--	--	10.13	21.9	8.82	233	211	0.41	--	--	--	--	30	--	< 0.001	--	--
Nelson Creek	RES-01	7/10/07	--	--	8.67	16.6	8.25	330	202	0.35	--	--	--	--	130	--	--	--	--
Nelson Creek	RES-01	8/07/07	--	--	9.87	26.0	7.19	458	949	0.48	--	--	--	--	20	--	--	--	--
Nelson Creek	RES-19	7/10/07	--	--	8.66	19.6	8.46	386	45	0.01	--	--	--	--	20	--	--	--	--
Nelson Creek	RES-19A	7/10/07	--	--	7.81	19.9	8.28	418	96	0.08	--	--	--	--	80	--	--	--	--
Nelson Creek	RES-20	6/13/07	--	--	15.83	29.1	8.81	253	212	0.12	--	--	--	--	50	--	0.007	--	--
Nelson Creek	RES-20	7/10/07	--	--	8.97	17.4	8.78	369	72	0.03	--	--	--	--	20	--	--	--	--
Nelson Creek	RES-20	8/07/07	--	--	8.23	31.0	9.04	669	94	0.13	--	--	--	--	< 10	--	--	--	--
Nelson Creek	RES-24	6/13/07	--	--	13.14	25.3	9.09	210	9	0.04	--	--	--	--	10	--	0.147	--	--
Nelson Creek	RES-24	7/09/07	--	--	1.4	20.5	8.11	231	13	0.48	--	--	--	--	20	--	--	--	--
Nelson Creek	RES-24	8/08/07	--	--	4.82	19.2	8.57	252	119	0.12	--	--	--	--	< 10	--	--	--	--
Nelson Creek	SFUS-01	9/26/06	--	--	--	15.9	8.26	55300	81	3.03	--	--	--	--	110	--	9.49	--	--
Nelson Creek	SFUS-01	10/22/06	--	--	1.92	5.9	8.55	60000	106	0.17	--	--	--	--	< 10	--	0.012	--	--
Nelson Creek	SFUS-01	3/08/07	--	--	7.84	2.4	7.97	935	12	0.08	--	--	--	--	180	--	0.065	--	--
Nelson Creek	SFUS-01	4/17/07	--	--	8.32	10.9	8.74	9540	17	0.02	--	--	--	--	10	--	--	--	--

Table 1.3 Compiled Surface Water Nutrient Data

Segment ID	Site ID	Sample Date	Flow (cfs)	Chlor-a (mg/m2)	DO (mg/L)	Water Temp (°C)	pH (S.U.)	TDS (mg/L)	TSS (mg/L)	Total Ammonia as N (ug/L)	Total Ammonia as NH4 (ug/L)	TKN (ug/L)	Total N Calc (ug/L)	Total N per Sulfate Method (ug/L)	NO2 + NO3 as N (ug/L)	Total P (ug/L)	Total OrthoPhosphate (ug/L)	Total P as PO4 (ug/L)	Dissolved P (ug/L)
Nelson Creek	SFUS-01	5/09/07	--	--	--	20.5	9.14	9560	4	0.01	--	--	--	--	30	--	--	--	--
Nelson Creek	SFUS-01	6/13/07	--	--	15.51	18.9	9.67	10900	12	0.09	--	--	--	--	10	--	0.008	--	--
Nelson Creek	SFUS-01	7/11/07	--	--	--	21.4	10.08	18500	22	0.12	--	--	--	--	10	--	--	--	--
Nelson Creek	UNUS-04	3/08/07	--	--	9.14	3.5	7.56	143	10	0.08	--	--	--	--	1250	--	0.026	--	--
Nelson Creek	UNUS-05	3/08/07	--	--	7.37	8.3	8.1	695	8	0.04	--	--	--	--	60	--	0.027	--	--
Nelson Creek	UNUS-05	4/17/07	--	--	5.05	4.8	8.21	3500	25	< 0.010	--	--	--	--	10	--	--	--	--
Nelson Creek	UNUS-05	5/10/07	--	--	6.1	10.8	8.39	3260	132	0.02	--	--	--	--	10	--	--	--	--
Nelson Creek	GCUS-06	3/08/07	--	--	9.9	0.2	6.71	154	33	0.05	--	--	--	--	130	--	0.013	--	--
Pasture Creek	474226105150301	6/23/82	0.48		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pasture Creek	474226105150301	10/19/82	0.25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pasture Creek	3B	5/25/99	--	--	--	--	--	3760	< 10	--	--	1100	1130	--	30	28	--	--	--
Pasture Creek	5185PA01	8/23/95	--	--	--	--	--	--	--	--	--	1100	1110	--	10	38	--	--	--
Pasture Creek	5185PA01	8/23/95	1.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pasture Creek	M48PSTRC01	6/20/03	--	--	--	--	--	--	3000	< 10	--	970	975	--	< 10	--	--	--	--
Pasture Creek	M48PSTRC01	6/20/03	--	--	--	--	--	--	--	--	--	--	--	--	--	27	--	--	--
Pasture Creek	M48PSTRC01	6/20/03	--	24 g/m2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pasture Creek	M48PSTRC01	6/17/08	0.14	--	15.70	25.64	8.77	4000	--	< 50	--	--	--	907	< 10	28	--	--	10
Pasture Creek	M48PSTRC01	8/28/08	--	--	9.03	12.37	8.90	8270	--	< 50	--	--	--	2330	< 10	137	--	--	5
Pasture Creek	M48PSTRC02	6/20/03	--	--	--	--	--	--	85000	60	--	2110	2130	--	20	--	--	--	--
Pasture Creek	M48PSTRC02	6/20/03	--	--	--	--	--	--	--	--	--	--	--	--	--	99	--	--	--
Pasture Creek	M48PSTRC03	6/17/08	0.13	--	12.17	22.80	8.50	6560	--	< 50	--	--	--	1980	10	140	--	--	52
Prarie Elk Creek	6175540	10/14/75	125	--	--	--	--	--	--	350	450	3300	3300.00	--	--	1500	--	--	--
Prarie Elk Creek	6175540	11/21/75	2.6	--	13.2	--	--	--	96000	<0.01		460	470	--	10	30	--	--	--
Prarie Elk Creek	6175540	12/11/75	2.6	--	11.4	--	--	--	--	10	10	3000	4000	--	1000	430	--	--	--
Prarie Elk Creek	6175540	1/29/76	87	--	12.2	--	--	--	--	90	120	2400	2730	--	330	160	--	--	--
Prarie Elk Creek	6175540	3/3/76	1.9	--	10.2	--	--	--	--	110	140	1600	1690	--	90	120	--	--	--
Prarie Elk Creek	6175540	3/18/76	285	--	10.5	--	--	--	--	260	330	4600	4760	--	160	820	--	--	--
Prarie Elk Creek	6175540	4/28/76	2.8	--	9.8	--	--	--	--	10	10	8500	130000	--	2000	1800	--	--	--
Prarie Elk Creek	6175540	5/27/76	1.9	--	8.9	--	--	--	--	30	40	550	560	--	10	80	--	--	--
Prarie Elk Creek	6175540	6/13/76	1170	--	7.8	--	--	--	--	120	150	4600	5350	--	750	2500	--	--	--
Prarie Elk Creek	6175540	7/21/76	2.1	--	8.7	--	--	--	--	<0.01	--	520	540	--	20	70	--	--	--
Prarie Elk Creek	6175540	8/20/76	1.6	--	8.2	--	--	--	--	<0.01	--	820	870	--	< 100	80	--	--	--
Prarie Elk Creek	6175540	9/22/76	1.8	--	8.9	--	--	--	--	30	40	510	520	--	10	60	--	--	--
Prarie Elk Creek	6175540	10/21/76	1.8	--	11.8	--	--	--	99000	40	50	480	530	--	< 100	60	--	--	--
Prarie Elk Creek	6175540	11/18/76	2.5	--	12	--	--	--	--	30	40	520	550	--	30	40	--	--	--
Prarie Elk Creek	6175540	12/22/76	1	--	11.8	--	--	--	--	170	220	460	520	--	60	20	--	--	--
Prarie Elk Creek	6175540	1/18/77	0.02	--	5.8	--	--	--	--	100	130	260	280	--	20	10	--	--	--
Prarie Elk Creek	6175540	2/10/77	0.5	--	2	--	--	--	--	130	170	630	650	--	20	90	--	--	--
Prarie Elk Creek	6175540	3/15/77	14	--	12	--	--	--	--	110	140	750	1040	--	290	450	--	--	--
Prarie Elk Creek	6175540	4/7/77	2.5	--	10	--	--	--	--	<0.01		480	800	--	320	70	--	--	--
Prarie Elk Creek	6175540	5/20/77	1.7	--	9.4	--	--	--	--	110	140	580	600	--	20	80	--	--	--
Prarie Elk Creek	6175540	6/16/77	39	--	7	--	--	--	--	300	390	1800	1800	--		2900	--	--	--
Prarie Elk Creek	6175540	7/12/77	2.1	--	8.4	--	--	--	--	<0.01		880	910	--	30	130	--	--	--
Prarie Elk Creek	6175540	8/18/77	0.81	--	8.8	--	--	--	--	<0.01		510	520	--	10	130	--	--	--
Prarie Elk Creek	6175540	9/14/77	1.2	--		--	--	--	--	200	260	10000	13200	--	3200	5300	--	--	--

Table 1.3 Compiled Surface Water Nutrient Data

Segment ID	Site ID	Sample Date	Flow (cfs)	Chlor-a (mg/m2)	DO (mg/L)	Water Temp (°C)	pH (S.U.)	TDS (mg/L)	TSS (mg/L)	Total Ammonia as N (ug/L)	Total Ammonia as NH4 (ug/L)	TKN (ug/L)	Total N Calc (ug/L)	Total N per Sulfate Method (ug/L)	NO2 + NO3 as N (ug/L)	Total P (ug/L)	Total OrthoPhosphate (ug/L)	Total P as PO4 (ug/L)	Dissolved P (ug/L)
Prarie Elk Creek	6175540	10/21/77	1.5	--	12.2	--	--	--	--	10	10	330	500	--	170	60	--	--	--
Prarie Elk Creek	6175540	11/9/77	2.4	--	13.4	--	--	--	--	40	50	600	630	--	30	40	--	--	--
Prarie Elk Creek	6175540	12/13/77	0.72	--	10.8	--	--	--	--	280	360	510	690	--	180	50	--	--	--
Prarie Elk Creek	6175540	1/26/78	0.1	--	8	--	--	--	--	230	300	220	240	--	20	60	--	--	--
Prarie Elk Creek	6175540	3/21/78	1630	--	10.8	--	--	--	--	380	490	3100	3450	--	350	2000	--	--	--
Prarie Elk Creek	6175540	4/28/78	3	--	10.6	--	--	--	--	40	50	450	550	--	100	40	--	--	--
Prarie Elk Creek	6175540	5/12/78	7	--	9.8	--	--	--	--	40	50	3200	6200	--	3000	1300	--	--	--
Prarie Elk Creek	6175540	6/5/78	11	--	9	--	--	--	--	10	10	1100	1150	--	< 100	60	--	--	--
Prarie Elk Creek	6175540	7/25/78	2.1	--	7.4	--	--	--	--	10	10	700	710	--	10	40	--	--	--
Prarie Elk Creek	6175540	8/23/78	1.6	--	7.9	--	--	--	--	30	40	700	750	--	< 100	70	--	--	--
Prarie Elk Creek	6175540	9/13/78	217	--	6.8	--	--	--	--	140	180	2400	3280	--	880	2300	--	--	--
Prarie Elk Creek	6175540	10/23/78	2.9	--	11.4	--	--	--	--	20	30	350	370	--	20	20	--	--	--
Prarie Elk Creek	6175540	11/16/78	5.1	--	13.5	--	--	--	--	10	10	400	590	--	190	30	--	--	--
Prarie Elk Creek	6175540	12/14/78	1.1	--	12.6	--	--	--	--	50	60	310	400	--	90	20	--	--	--
Prarie Elk Creek	6175540	1/9/79	E0.2	--		--	--	--	--	40	50	230	270	--	40	20	--	--	--
Prarie Elk Creek	6175540	3/30/79	55	--	12.2	--	--	--	--	100	130	620	930	--	310	120	--	--	--
Prarie Elk Creek	6175540	4/10/79	794	--	10.6	--	--	--	--	70	90	1800	2020	--	220	500	--	--	--
Prarie Elk Creek	6175540	5/14/79	8	--	9	--	--	--	--	10	10	610	630	--	20	10	--	30	--
Prarie Elk Creek	6175540	6/6/79	3.6	--		--	--	--	--	30	40	520	700	--	180	20	--	60	--
Prarie Elk Creek	6175540	7/12/79	2	--	8.9	--	--	--	--	10	10	610	640	--	30	30	--	90	--
Prarie Elk Creek	6175540	8/13/79	1.7	--	9.3	--	--	--	--	40	50	720	730	--	10	50	--	150	--
Prarie Elk Creek	6175540	9/13/79	2	--	10.2	--	--	--	--	60	70	780	930	--	150	40	--	120	--
Prarie Elk Creek	6175540	06/18/08	1.95	--	6.75	28.1	8.19	NA	--	< 50	--	--	3090	3090	2580	599	--	--	4
Prarie Elk Creek	6175540	08/28/08	0.58	--	9.38	22.87	9.16	--	--	< 50	--	--	1990	1990	< 10	201	--	--	3
Prarie Elk Creek	5480PR01	8/10/95		--	--	--	--	--	--	--	--	500	510.00	--	10	48	--	--	--
Prarie Elk Creek	M49PREKC01	6/3/03	--	--	--	--	--	--	5040000	--	--	4960	5390.00	--	430	--	--	--	--
Prarie Elk Creek	M49PREKC01	6/3/03	0.00	24.4	--	--	--	--	--	--	--	--	--	--	--	1910	--	--	--
Prarie Elk Creek	M49PREKC02	06/03/03	--	--	--	--	--	--	80000	--	--	1790	1810	--	20	143	--	--	--
Prarie Elk Creek	M49PREKC02	06/18/08	0.001		9.46	28.3	8.57	NA	--	< 50	--	--	988	988	20	72	--	--	10
Prarie Elk Creek	M49PREKC03	7/12/03	E 0	20.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Prarie Elk Creek	M49PREKC04	7/12/03	E 0	0.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Prarie Elk Creek	M49PREKC05	7/12/03	--	1.8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Prarie Elk Creek	M49PREKC05	7/12/03	--	6.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Prarie Elk Creek	M49PREKC06	06/18/08	0	--	10.96	19.1	9.19	NA	--	< 50	--	--	2780	2780	10	62	--	--	16
Prarie Elk Creek	M49PREKC07	06/18/08	0	--	8.22	20.7	9.01	NA	--	< 50	--	--	2810	2810	< 10	81	--	--	14
Prarie Elk Creek	MCNPREK-01	07/12/03	0.00	--	--	--	--	--	<10000	< 50	--	2100	2125	--	< 50	60	20	--	--
Prarie Elk Creek	MCNPREK-01	06/21/05	--	--	--	--	--	--	12000	< 50	--	< 500	275	--	< 50	80	40	--	--
Prarie Elk Creek	MCNPREK-03	07/12/03	--	--	--	--	--	--	35000	< 50	--	1400	1425	--	< 50	100	20	--	--
Prarie Elk Creek	MCNPREK-04	10/06/03	--	--	--	--	--	--	51000	< 50	--	1400	1425	--	< 50	80	50	--	--
Prarie Elk Creek	MCNPREK-06	07/12/03	--	--	--	--	--	--	8850000	160	--	800	1960	--	1160	920	850	--	--
Prarie Elk Creek	MCNPREK-4A	10/06/03	--	--	--	--	--	--	89000	260	--	1000	1100	--	100	80	10	--	--
Prarie Elk Creek	MCNPREK-4A	06/18/08	0.60	--	6.82	26.0	8.20	NA		< 50	--		1410	1410	600	163	--	--	11
Prarie Elk Creek	MCNPREK-4A	08/28/08	0.41	--	10.57	22.49	8.94			160	--		1150	1150	120	146	--	--	6
Prarie Elk Creek	MCNPREK-4AA	10/06/03	--	--	--	--	--	--	38000	< 50	--	600	625	--	< 50	40	40	--	--
Prarie Elk Creek	MCNPREK-4B	10/06/03	--	--	--	--	--	--	86000	80	--	600	625	--	< 50	80	10	--	--

Table 1.3 Compiled Surface Water Nutrient Data

Segment ID	Site ID	Sample Date	Flow (cfs)	Chlor-a (mg/m2)	DO (mg/L)	Water Temp (°C)	pH (S.U.)	TDS (mg/L)	TSS (mg/L)	Total Ammonia as N (ug/L)	Total Ammonia as NH4 (ug/L)	TKN (ug/L)	Total N Calc (ug/L)	Total N per Sulfate Method (ug/L)	NO2 + NO3 as N (ug/L)	Total P (ug/L)	Total OrthoPhosphate (ug/L)	Total P as PO4 (ug/L)	Dissolved P (ug/L)
Prarie Elk Creek	MCNPREK-5B	10/6/03	--	--	--	--	--	--	69000	60	--	600	--	--	< 50	70	10	--	--
Redwater River	6177500	10/21/74	0.03	--	--	--	--	--	30000	170	220	1200	1230	--	30	40	--	--	--
Redwater River	6177500	11/18/74	0.11	--	--	--	--	--	--	60	80	470	520	--	< 100	20	--	--	--
Redwater River	6177500	12/16/74	0.07	--	--	--	--	--	--	100	130	510	560	--	50	40	--	--	--
Redwater River	6177500	1/20/75	0.07	--	--	--	--	--	--	390	500	880	900	--	20	20	--	--	--
Redwater River	6177500	2/24/75	0.05	--	--	--	--	--	--	--	--	--	--	--	20	70	--	--	--
Redwater River	6177500	3/18/75	0.26	--	--	--	--	--	--	130	170	460	480	--	20	20	--	--	--
Redwater River	6177500	4/14/75	22.00	--	--	--	--	--	--	50	60	970	1030	--	60	70	--	--	--
Redwater River	6177500	5/21/75	3.90	--	--	--	--	--	--	< 10	--	580	630	--	< 100	30	--	--	--
Redwater River	6177500	6/18/75	0.91	--	--	--	--	--	--	< 10	--	670	690	--	20	50	--	--	--
Redwater River	6177500	7/22/75	2.60	--	--	--	--	--	--	130	170	1100	1150	--	50	90	--	--	--
Redwater River	6177500	8/19/75	0.09	--	--	--	--	--	--	< 10	--	940	950	--	10	70	--	--	--
Redwater River	6177500	9/25/75	0.14	--	--	--	--	--	--	< 10	--	1300	1320	--	20	40	--	--	--
Redwater River	6177500	10/29/75	0.18	--	--	--	--	--	27000	50	60	920	940	--	20	90	--	--	--
Redwater River	6177500	11/20/75	0.24	--	--	--	--	--	--	< 10	--	1400	1420	--	20	10	--	--	--
Redwater River	6177500	12/10/75	0.29	--	--	--	--	--	--	200	260	950	970	--	20	< 10	--	--	--
Redwater River	6177500	1/27/76	0.96	--	--	--	--	--	--	50	60	1800	2030	--	230	40	--	--	--
Redwater River	6177500	2/25/76	12.00	--	--	--	--	--	--	50	60	930	990	--	60	30	--	--	--
Redwater River	6177500	3/19/76	7.20	--	--	--	--	--	--	40	50	1000	1010	--	10	40	--	--	--
Redwater River	6177500	4/29/76	2.20	--	--	--	--	--	--	10	10	710	790	--	80	20	--	--	--
Redwater River	6177500	5/26/76	2.40	--	--	--	--	--	--	40	50	650	660	--	10	50	--	--	--
Redwater River	6177500	6/14/76	16.00	--	--	--	--	--	--	170	220	1400	1720	--	320	120	--	--	--
Redwater River	6177500	7/20/76	0.32	--	--	--	--	--	--	< 10	--	790	840	--	< 100	80	--	--	--
Redwater River	6177500	8/18/76	0.83	--	--	--	--	--	--	< 10	--	1600	1710	--	110	100	--	--	--
Redwater River	6177500	9/22/76	0.14	--	--	--	--	--	--	20	30	540	550	--	10	70	--	--	--
Redwater River	6177500	10/20/76	0.09	--	--	--	--	--	<1000	40	50	650	700	--	< 100	20	--	--	--
Redwater River	6177500	11/17/76	0.07	--	--	--	--	--	--	< 10	--	710	730	--	20	20	--	--	--
Redwater River	6177500	12/21/76	0.11	--	--	--	--	--	--	440	570	910	940	--	30	20	--	--	--
Redwater River	6177500	1/18/77	0.05	--	--	--	--	--	--	860	1110	1500	1510	--	10	< 10	--	--	--
Redwater River	6177500	2/17/77	0.11	--	--	--	--	--	--	670	860	1100	1160	--	60	30	--	--	--
Redwater River	6177500	3/8/77	3.30	--	--	--	--	--	--	10	10	550	630	--	80	20	--	--	--
Redwater River	6177500	4/22/77	0.96	--	--	--	--	--	--	10	10	460	470	--	10	20	--	--	--
Redwater River	6177500	5/19/77	0.67	--	--	--	--	--	--	20	30	630	640	--	10	40	--	--	--
Redwater River	6177500	6/14/77	0.11	--	--	--	--	--	--	< 10	--	680	730	--	< 100	90	--	--	--
Redwater River	6177500	7/13/77	0.07	--	--	--	--	--	--	30	40	970	980	--	10	120	--	--	--
Redwater River	6177500	9/12/77	0.09	--	--	--	--	--	--	30	40	530	540	--	10	60	--	--	--
Redwater River	6177500	10/19/77	0.09	--	--	--	--	--	--	50	60	720	730	--	10	60	--	--	--
Redwater River	6177500	11/7/77	0.11	--	--	--	--	--	--	20	30	660	670	--	10	50	--	--	--
Redwater River	6177500	12/13/77	0.10	--	--	--	--	--	--	530	680	710	740	--	30	20	--	--	--
Redwater River	6177500	1/12/78	0.10	--	--	--	--	--	--	790	1020	1000	1040	--	40	20	--	--	--
Redwater River	6177500	3/22/78	1060.00	--	--	--	--	--	--	280	360	1600	2000	--	400	610	--	--	--
Redwater River	6177500	4/25/78	7.10	--	--	--	--	--	--	10	10	660	790	--	130	20	--	--	--
Redwater River	6177500	5/9/78	15.00	--	--	--	--	--	--	30	40	720	730	--	10	40	--	--	--
Redwater River	6177500	6/8/78	21.00	--	--	--	--	--	--	10	10	800	820	--	20	10	--	--	--
Redwater River	6177500	7/12/78	30.00	--	--	--	--	--	--	30	40	920	970	--	< 100	60	--	--	--

Table 1.3 Compiled Surface Water Nutrient Data

Segment ID	Site ID	Sample Date	Flow (cfs)	Chlor-a (mg/m2)	DO (mg/L)	Water Temp (°C)	pH (S.U.)	TDS (mg/L)	TSS (mg/L)	Total Ammonia as N (ug/L)	Total Ammonia as NH4 (ug/L)	TKN (ug/L)	Total N Calc (ug/L)	Total N per Sulfate Method (ug/L)	NO2 + NO3 as N (ug/L)	Total P (ug/L)	Total OrthoPhosphate (ug/L)	Total P as PO4 (ug/L)	Dissolved P (ug/L)
Redwater River	6177500	8/9/78	2.60	--	--	--	--	--	--	50	60	760	770	--	10	< 10	--	--	--
Redwater River	6177500	9/14/78	3.60	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	6177500	10/11/78	4.20	--	--	--	--	--	--	20	30	830	840	--	10	20	--	--	--
Redwater River	6177500	11/13/78	3.60	--	--	--	--	--	--	30	40	620	650	--	30	20	--	--	--
Redwater River	6177500	12/13/78	2.60	--	--	--	--	--	--	80	100	760	810	--	50	20	--	--	--
Redwater River	6177500	1/8/79	0.30	--	--	--	--	--	--	260	330	870	920	--	50	20	--	--	--
Redwater River	6177500	2/20/79	0.60	--	--	--	--	--	--	260	330	700	840	--	140	< 10	--	--	--
Redwater River	6177500	3/19/79	143.00	--	--	--	--	--	--	70	90	840	1370	--	530	80	--	--	--
Redwater River	6177500	4/11/79	489.00	--	--	--	--	--	--	90	120	860	1480	--	620	210	--	--	--
Redwater River	6177500	5/9/79	50.00	--	--	--	--	--	--	30	40	630	950	--	320	30	--	90	--
Redwater River	6177500	6/5/79	13.00	--	--	--	--	--	--	30	40	900	940	--	40	10	--	30	--
Redwater River	6177500	7/10/79	2.40	--	--	--	--	--	--	20	20	1800	1840	--	40	30	--	90	--
Redwater River	6177500	8/21/79	0.89	--	--	--	--	--	--	50	60	440	450	--	10	140	--	430	--
Redwater River	6177500	9/12/79	0.18	--	--	--	--	--	--	40	50	320	390	--	70	20	--	60	--
Redwater River	6177500	10/17/79	0.28	--	--	--	--	--	--	10	10	950	960	--	10	30	--	90	--
Redwater River	6177500	11/6/79	0.96	--	--	--	--	--	--	80	100	660	670	--	10	10	--	30	--
Redwater River	6177500	12/4/79	1.80	--	--	--	--	--	--	60	70	680	830	--	150	10	--	30	--
Redwater River	6177500	1/8/80	0.35	--	--	--	--	--	--	130	160	1300	1480	--	180	20	--	60	--
Redwater River	6177500	2/19/80	0.91	--	--	--	--	--	--	110	130	660	810	--	150	10	--	30	--
Redwater River	6177500	3/26/80	5.50	--	--	--	--	--	--	80	100	1000	1040	--	40	30	--	90	--
Redwater River	6177500	4/22/80	1.70	--	--	--	--	--	--	0	0	1100	1110	--	10	60	--	180	--
Redwater River	6177500	5/13/80	0.35	--	--	--	--	--	--	40	50	1000	1730	--	730	40	--	120	--
Redwater River	6177500	6/10/80	0.10	--	--	--	--	--	--	10	10	740	750	--	10	40	--	120	--
Redwater River	6177500	7/28/80	0.01	--	--	--	--	--	--	0	0	1700	1700	--	0	70	--	210	--
Redwater River	6177500	8/27/80	0.02	--	--	--	--	--	--	60	70	1400	1800	--	400	350	--	1100	--
Redwater River	6177500	9/17/80	0.01	--	--	--	--	--	--	70	80	1900	1900	--	0	70	--	210	--
Redwater River	6177500	10/21/80	0.02	--	--	--	--	--	--	40	50	1400	1400	--	0	90	--	280	--
Redwater River	6177500	11/19/80	0.08	--	--	--	--	--	--	40	50	1200	1200	--	0	50	--	150	--
Redwater River	6177500	12/17/80	0.28	--	--	--	--	--	--	80	100	830	930	--	100	30	--	90	--
Redwater River	6177500	1/20/81	0.58	--	--	--	--	--	--	120	150	550	600	--	50	50	--	150	--
Redwater River	6177500	2/18/81	1.00	--	--	--	--	--	--	80	100	90	90	--	0	30	--	90	--
Redwater River	6177500	3/10/81	0.61	--	--	--	--	--	--	40	50	730	740	--	10	30	--	90	--
Redwater River	6177500	4/28/81	0.24	--	--	--	--	--	--	60	80	1100	1120	--	20	40	--	120	--
Redwater River	6177500	5/21/81	0.13	--	--	--	--	--	--	90	120	1900	1940	--	40	60	--	180	--
Redwater River	6177500	6/29/81	0.08	--	--	--	--	--	--	90	120	1300	1580	--	280	40	--	120	--
Redwater River	6177500	10/30/81	0.08	--	--	--	--	--	--	240	310	1400	1420	--	20	40	--	120	--
Redwater River	6177500	12/3/81	0.01	--	--	--	--	--	--	270	350	990	1120	--	130	40	--	120	--
Redwater River	6177500	3/4/82	6.20	--	--	--	--	--	--	280	360	1600	1840	--	240	50	--	150	--
Redwater River	6177500	4/22/82	3.00	--	--	--	--	--	--	180	230	1100	1150	--	< 100	80	--	250	--
Redwater River	6177500	5/26/82	6.20	--	--	--	--	--	--	180	230	700	750	--	< 100	70	--	210	--
Redwater River	6177500	6/22/82	3.00	--	--	--	--	--	--	190	240	1900	1950	--	< 100	< 10	--	--	--
Redwater River	6177500	8/24/82	0.05	--	--	--	--	--	--	140	180	1100	1150	--	< 100	60	--	180	--
Redwater River	6177500	9/21/82	0.03	--	--	--	--	--	--	160	210	2100	2150	--	< 100	30	--	90	--
Redwater River	6177500	10/19/82	0.06	--	--	--	--	--	--	180	230	1600	1650	--	< 100	40	--	120	--
Redwater River	6177500	11/29/82	0.31	--	--	--	--	--	--	150	190	1000	1050	--	< 100	20	--	60	--

Table 1.3 Compiled Surface Water Nutrient Data

Segment ID	Site ID	Sample Date	Flow (cfs)	Chlor-a (mg/m2)	DO (mg/L)	Water Temp (°C)	pH (S.U.)	TDS (mg/L)	TSS (mg/L)	Total Ammonia as N (ug/L)	Total Ammonia as NH4 (ug/L)	TKN (ug/L)	Total N Calc (ug/L)	Total N per Sulfate Method (ug/L)	NO2 + NO3 as N (ug/L)	Total P (ug/L)	Total OrthoPhosphate (ug/L)	Total P as PO4 (ug/L)	Dissolved P (ug/L)
Redwater River	6177500	1/11/83	11.00	--	--	--	--	--	--	170	220	1000	1200	--	200	50	--	150	--
Redwater River	6177500	2/23/83	17.00	--	--	--	--	--	--	180	230	1400	1450	--	< 100	80	--	250	--
Redwater River	6177500	4/12/83	2.00	--	--	--	--	--	--	150	190	800	850	--	< 100	20	--	60	--
Redwater River	6177500	5/24/83	2.70	--	--	--	--	--	--	70	90	1100	1150	--	< 100	10	--	30	--
Redwater River	6177500	6/28/83	0.04	--	--	--	--	--	--	< 60	--	900	950	--	< 100	30	--	90	--
Redwater River	6177500	8/22/83	0.01	--	--	--	--	--	--	140	180	1500	1550	--	< 100	30	--	90	--
Redwater River	6177500	9/27/83	0.01	--	--	--	--	--	--	50	60	1600	1650	--	< 100	30	--	90	--
Redwater River	6177500	10/17/83	0.04	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	6177500	11/28/83	0.06	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	6177500	1/11/84	0.10	--	--	--	--	--	--	480	620	600	650	--	< 100	< 10	--	--	--
Redwater River	6177500	2/1/84	0.01	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	6177500	4/5/84	0.62	--	--	--	--	--	--	40	50	600	650	--	< 100	30	--	90	--
Redwater River	6177500	5/15/84	0.08	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	6177500	6/20/84	60.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	6177500	6/27/84	14.00	--	--	--	--	--	--	30	40	1000	1050	--	< 100	60	--	--	--
Redwater River	6177500	9/19/84	0.04	--	--	--	--	--	--	20	30	800	850	--	< 100	40	--	--	--
Redwater River	6177500	10/25/84	0.10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	6177500	12/12/84	0.11	--	--	--	--	--	--	130	170	500	550	--	< 100	20	--	--	--
Redwater River	6177500	2/27/85	5.30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	6177500	3/13/85	1.60	--	--	--	--	--	--	90	120	900	950	--	< 100	10	--	--	--
Redwater River	6177500	5/24/85	0.14	--	--	--	--	--	--	70	90	800	850	--	< 100	40	--	120	--
Redwater River	6177500	8/21/85	0.02	--	--	--	--	--	--	70	90	1000	1050	--	< 100	20	--	60	--
Redwater River	473052105253901	6/22/82	7.70	--	--	--	--	--	--	140	180	--	--	--	< 100	20	--	60	--
Redwater River	473052105253901	8/24/82	0.41	--	--	--	--	--	--	90	120	900	950	--	< 100	70	--	210	--
Redwater River	473052105253901	10/19/82	1.10	--	--	--	--	--	--	130	170	1800	1850	--	< 100	20	--	60	--
Redwater River	474256105150401	6/23/82	14.00	--	--	--	--	--	--	160	210	1300	1350	--	< 100	20	--	60	--
Redwater River	474256105150401	8/24/82	1.20	--	--	--	--	--	--	70	90	900	950	--	< 100	50	--	150	--
Redwater River	474256105150401	10/19/82	4.90	--	--	--	--	--	--	120	150	1200	1250	--	< 100	10	--	30	--
Redwater River	480111105182001	10/25/79	9.40	--	--	--	--	--	--	40	50	550	550	--	0	10	--	30	0
Redwater River	480111105182001	6/23/82	25.00	--	--	--	--	--	--	110	140	1500	1550	--	< 100	20	--	60	--
Redwater River	480111105182001	8/24/82	2.20	--	--	--	--	--	--	90	120	800	850	--	< 100	70	--	210	--
Redwater River	480111105182001	10/19/82	7.70	--	--	--	--	--	--	70	90	1600	1650	--	< 100	20	--	60	--
Redwater River	480315105125001	10/25/79	7.40	--	--	--	--	--	--	50	60	680	680	--	0	10	--	30	0
Redwater River	480315105125001	6/23/82	25.00	--	--	--	--	--	--	250	320	1600	1650	--	< 100	30	--	90	--
Redwater River	480315105125001	8/24/82	2.30	--	--	--	--	--	--	120	150	800	850	--	< 100	80	--	250	--
Redwater River	480315105125001	10/20/82	7.40	--	--	--	--	--	--	100	130	1700	1750	--	< 100	20	--	60	--
Redwater River	4581RE01	10/22/74	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	4581RE01	10/22/74	--	--	--	--	--	--	--	--	--	--	--	--	--	--	110	--	--
Redwater River	4581RE01	10/22/74	40.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	4581RE02	9/27/75	--	--	--	--	--	--	--	--	--	--	--	--	20	--	--	--	--
Redwater River	4783RE01	3/16/76	--	--	--	--	--	--	9000	--	--	--	--	--	50	--	20	--	--
Redwater River	4783RE01	3/16/76	2.70	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	4783RE01	6/16/78	--	--	--	--	--	--	--	30	--	--	--	--	40	70	< 10	--	--
Redwater River	4783RE01	8/15/78	--	--	8.35	--	--	--	45890	40	--	690	695	--	< 10	40	10	--	--
Redwater River	4783RE01	8/15/78	1.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 1.3 Compiled Surface Water Nutrient Data

Segment ID	Site ID	Sample Date	Flow (cfs)	Chlor-a (mg/m2)	DO (mg/L)	Water Temp (°C)	pH (S.U.)	TDS (mg/L)	TSS (mg/L)	Total Ammonia as N (ug/L)	Total Ammonia as NH4 (ug/L)	TKN (ug/L)	Total N Calc (ug/L)	Total N per Sulfate Method (ug/L)	NO2 + NO3 as N (ug/L)	Total P (ug/L)	Total OrthoPhosphate (ug/L)	Total P as PO4 (ug/L)	Dissolved P (ug/L)
Redwater River	4783RE01	3/26/79	--	--	--	--	--	--	51200	160	--	770	1060	--	290	130	70	--	--
Redwater River	4783RE01	3/26/79	250.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	4783RE01	7/13/79	--	--	--	--	--	--	37590	10	--	750	755	--	< 10	40	10	--	--
Redwater River	4783RE01	7/13/79	3.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	4783RE01	10/15/79	--	--	--	--	--	--	25200	< 10	--	350	355	--	< 10	10	0	--	--
Redwater River	2D	05/26/99	--	0.41	--	--	--	4910	< 10	--	--	1600	1620	--	20	19	--	--	--
Redwater River	2F	05/26/99	--	--	--	--	--	4580	52	--	--	1300	1330	--	30	75	--	--	--
Redwater River	M48RDWR01	5/18/02	--	--	--	--	--	--	--	--	--	--	970	--	< 0.6	--	--	--	--
Redwater River	M48RDWR01	5/18/02	--	--	--	--	--	--	75700	--	--	--	--	--	--	--	--	--	--
Redwater River	M48RDWR01	6/13/02	--	--	--	--	--	--	--	--	--	--	1017	--	< 0.6	--	--	--	--
Redwater River	M48RDWR01	6/13/02	--	--	--	--	--	--	78300	--	--	--	--	--	--	--	--	--	--
Redwater River	M48RDWR01	7/17/02	--	--	--	--	--	--	--	--	--	--	1221	--	< 0.6	--	--	--	--
Redwater River	M48RDWR01	7/17/02	--	--	--	--	--	--	49700	--	--	--	--	--	--	--	--	--	--
Redwater River	M48RDWR01	7/17/02	--	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	M48RDWR01	7/17/02	--	141	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	M48RDWR01	8/14/02	--	--	--	--	--	--	--	--	--	--	1031	--	< 0.6	--	--	--	--
Redwater River	M48RDWR01	8/14/02	--	--	--	--	--	--	41500	--	--	--	--	--	--	--	--	--	--
Redwater River	MCNREDW-01	8/6/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	MCNREDW-01	8/6/03	--	--	6.62	23.3	8.37	--	<10000	< 50	--	1000	1025	--	< 50	40	< 10	--	--
Redwater River	MCNREDW-01	8/13/03	--	--	4.1	25	8.29	--	<10000	< 50	--	1200	1225	--	< 50	40	< 10	--	--
Redwater River	MCNREDW-01	8/13/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	MCNREDW-01	8/20/03	--	--	4.48	22.1	8.25	--	<10000	< 50	--	1500	1525	--	< 50	40	< 10	--	--
Redwater River	MCNREDW-01	8/20/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	MCNREDW-01	8/27/03	--	--	7.94	20.7	8.44	--	<10000	< 50	--	1700	1725	--	< 50	40	< 10	--	--
Redwater River	MCNREDW-01	8/27/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	MCNREDW-01	5/5/04	--	--	10.54	16.9	8.07	--	13000	< 50	--	1000	1025	--	< 50	80	< 10	--	--
Redwater River	MCNREDW-01	5/13/04	--	--	12.88	7.3	8.37	--	<10000	< 50	--	900	925	--	< 50	30	< 10	--	--
Redwater River	MCNREDW-01	5/27/04	--	--	14.44	16.5	8.39	--	<10000	< 50	--	1300	1325	--	< 50	30	< 10	--	--
Redwater River	MCNREDW-01	8/5/04	--	--	8.46	21.3	8.28	--	<10000	< 50	--	1200	1225	--	< 50	30	< 10	--	--
Redwater River	MCNREDW-01	8/16/04	--	--	10.32	19.9	8.33	--	<10000	< 50	--	1100	1125	--	< 50	30	< 10	--	--
Redwater River	MCNREDW-01	8/23/04	--	--	6.34	17.1	8.19	--	<10000	< 50	--	1000	1025	--	< 50	30	< 10	--	--
Redwater River	MCNREDW-01	8/23/04	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	MCNREDW-01	8/30/04	--	--	11.89	21.6	8.56	--	<10000	< 50	--	1100	1125	--	< 50	30	< 10	--	--
Redwater River	MCNREDW-01	8/30/04	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	MCNREDW-01	6/16/08	0.01	--	11.60	22.8	8.31	NA	--	< 50	--	--	--	815	< 10	49	--	--	32
Redwater River	MCNREDW-01	8/27/08	--	--	9.43	17.98	8.39	--	--	< 50	--	--	--	1070	10	43	--	--	4
Redwater River	MCNREDW-02	8/6/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	MCNREDW-02	8/6/03	--	--	6.3	21.4	8.33	--	55000	< 50	--	1300	1325	--	< 50	60	< 10	--	--
Redwater River	MCNREDW-02	8/13/03	--	--	4.8	23.4	8.35	--	32000	< 50	--	1800	1825	--	< 50	70	20	--	--
Redwater River	MCNREDW-02	8/13/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	MCNREDW-02	8/20/03	--	--	4.25	19.5	8.3	--	11000	< 50	--	1600	1625	--	< 50	60	10	--	--
Redwater River	MCNREDW-02	8/20/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	MCNREDW-02	8/27/03	--	--	7.72	18.5	8.48	--	10000	< 50	--	1800	1825	--	< 50	50	10	--	--
Redwater River	MCNREDW-02	8/27/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	MCNREDW-02	5/5/04	--	--	9.72	17.5	8.05	--	37000	< 50	--	1100	1125	--	< 50	40	20	--	--

Table 1.3 Compiled Surface Water Nutrient Data

Segment ID	Site ID	Sample Date	Flow (cfs)	Chlor-a (mg/m2)	DO (mg/L)	Water Temp (°C)	pH (S.U.)	TDS (mg/L)	TSS (mg/L)	Total Ammonia as N (ug/L)	Total Ammonia as NH4 (ug/L)	TKN (ug/L)	Total N Calc (ug/L)	Total N per Sulfate Method (ug/L)	NO2 + NO3 as N (ug/L)	Total P (ug/L)	Total OrthoPhosphate (ug/L)	Total P as PO4 (ug/L)	Dissolved P (ug/L)
Redwater River	MCNREDW-02	5/13/04	--	--	13.8	8.2	8.34	--	12000	< 50	--	1200	1225	--	< 50	30	< 10	--	--
Redwater River	MCNREDW-02	5/20/04	--	--	12.66	20.3	8.27	--	<10000	< 50	--	1200	1225	--	< 50	30	< 10	--	--
Redwater River	MCNREDW-02	5/27/04	--	--	12.22	16	8.31	--	<10000	< 50	--	1000	1025	--	< 50	30	< 10	--	--
Redwater River	MCNREDW-02	8/5/04	--	--	14.54	24	8.16	--	<10000	< 50	--	1500	1525	--	< 50	30	< 10	--	--
Redwater River	MCNREDW-02	8/16/04	--	--	9.71	16	8.0	--	<10000	< 50	--	1400	1425	--	< 50	40	20	--	--
Redwater River	MCNREDW-02	8/23/04	--	--	9.4	15.4	7.95	--	<10000	< 50	--	900	925	--	< 50	30	10	--	--
Redwater River	MCNREDW-02	8/23/04	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	MCNREDW-02	8/30/04	--	--	12.23	17.9	8.14	--	<10000	< 50	--	1100	1125	--	< 50	30	10	--	--
Redwater River	MCNREDW-02	8/30/04	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	MCNREDW-02	6/16/08	0.28	--	12.19	22.8	8.48	NA	--	< 50	--	--	--	671	< 10	21	--	--	4
Redwater River	MCNREDW-02	8/27/08	0.15	--	9.16	16.16	8.64	--	--	< 50	--	--	--	1470	< 10	34	--	--	4
Redwater River	MCNREDW-03	8/6/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	MCNREDW-03	8/6/03	--	--	7.3	22.4	8.88	--	36000	< 50	--	1500	1525	--	< 50	100	< 10	--	--
Redwater River	MCNREDW-03	8/13/03	--	--	6.6	24.4	8.92	--	33000	< 50	--	1700	1725	--	< 50	100	30	--	--
Redwater River	MCNREDW-03	8/13/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	MCNREDW-03	8/20/03	--	--	6.11	21.9	8.92	--	81000	< 50	--	3200	3225	--	< 50	270	30	--	--
Redwater River	MCNREDW-03	8/20/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	MCNREDW-03	8/27/03	--	--	7.45	20.1	8.96	--	47000	60	--	2300	2300	--	--	110	20	--	--
Redwater River	MCNREDW-03	8/27/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	MCNREDW-03	5/5/04	--	--	7.2	16.3	8.01	--	108000	60	--	1600	1625	--	< 50	120	50	--	--
Redwater River	MCNREDW-03	5/13/04	--	--	11.92	6.0	8.39	--	33000	100	--	1800	1825	--	< 50	130	100	--	--
Redwater River	MCNREDW-03	5/20/04	--	--	8.01	19.3	8.31	--	40000	< 50	--	1400	1425	--	< 50	70	30	--	--
Redwater River	MCNREDW-03	5/27/04	--	--	7.96	14	8.24	--	38000	< 50	--	1700	1725	--	< 50	60	40	--	--
Redwater River	MCNREDW-03	8/5/04	--	--	7.6	21.4	8.41	--	158000	< 50	--	2300	2325	--	< 50	260	70	--	--
Redwater River	MCNREDW-03	8/16/04	--	--	5.44	21.5	8.42	--	94000	< 50	--	1900	1925	--	< 50	150	100	--	--
Redwater River	MCNREDW-03	8/23/04	--	--	7.83	16.1	8.43	--	94000	< 50	--	1800	1825	--	< 50	140	70	--	--
Redwater River	MCNREDW-03	8/30/04	--	--	6.26	18.5	8.63	--	89000	< 50	--	1700	1725	--	< 50	150	60	--	--
Redwater River	MCNREDW-03	6/23/05	--	--	4.19	24.1	8.14	--	23000	< 50	--	1300	1325	--	< 50	50	20	--	--
Redwater River	MCNREDW-03	6/16/08	0.16	--	7.42	22.1	8.74	NA	--	< 50	--	--	--	751	< 10	60	--	--	3
Redwater River	MCNREDW-03	8/27/08	0.06	--	8.51	16.47	8.89	--	--	< 50	--	--	--	1350	< 10	132	--	--	2
Redwater River	MCNREDW-04	8/6/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwater River	MCNREDW-04	8/6/03	--	--	9.79	22.6	8.4	--	92000	< 50	--	3100	3125	--	< 50	300	40	--	--
Redwater River	MCNREDW-04	8/13/03	--	--	8.2	23.9	9.0	--	108000	< 50	--	2400	2425	--	< 50	340	80	--	--
Redwater River	MCNREDW-04	8/20/03	--	--	8.86	21.9	9.14	--	186000	290	--	7300	--	--	< 50	480	90	--	--
Redwater River	MCNREDW-04	8/27/03	--	--	6.63	19.3	9.23	--	133000	480	--	6500	6525	--	< 50	420	110	--	--
Redwater River	MCNREDW-04	2/17/04	--	--	7.8	2.1	7.6	--	--	1160	--	2900	2925	--	< 50	150	120	--	--
Redwater River	MCNREDW-04	5/5/04	--	--	8.32	16.2	8.08	--	116000	< 50	--	1800	1825	--	< 50	170	90	--	--
Redwater River	MCNREDW-04	5/13/04	--	--	13.77	6.4	8.47	--	22000	< 50	--	1800	1825	--	< 50	120	20	--	--
Redwater River	MCNREDW-04	5/20/04	--	--	9.91	19.7	8.52	--	60000	< 50	--	1800	1825	--	< 50	120	30	--	--
Redwater River	MCNREDW-04	5/27/04	--	--	9.0	14.1	8.4	--	52000	< 50	--	2200	2225	--	< 50	120	30	--	--
Redwater River	MCNREDW-04	8/5/04	--	--	12.12	22.4	8.61	--	92000	310	--	4100	4125	--	< 50	330	40	--	--
Redwater River	MCNREDW-04	8/16/04	--	--	11.41	22.2	8.75	--	78000	< 50	--	4600	4625	--	< 50	250	60	--	--
Redwater River	MCNREDW-04	8/30/04	--	--	12.01	19	9.04	--	68000	< 50	--	4500	4525	--	< 50	270	50	--	--
Redwater River	MCNREDW-04	6/7/05	--	--	7.71	13.6	7.59	--	2850000	210	--	7100	7430	--	330	1710	860	--	--
Redwater River	MCNREDW-04	6/17/08	0.25	--	7.33	21.98	8.32	NA	--	< 50	--	--	--	859	< 10	86	--	--	51

Table 1.3 Compiled Surface Water Nutrient Data

Segment ID	Site ID	Sample Date	Flow (cfs)	Chlor-a (mg/m2)	DO (mg/L)	Water Temp (°C)	pH (S.U.)	TDS (mg/L)	TSS (mg/L)	Total Ammonia as N (ug/L)	Total Ammonia as NH4 (ug/L)	TKN (ug/L)	Total N Calc (ug/L)	Total N per Sulfate Method (ug/L)	NO2 + NO3 as N (ug/L)	Total P (ug/L)	Total OrthoPhosphate (ug/L)	Total P as PO4 (ug/L)	Dissolved P (ug/L)
Redwater River	MCNREDW-04	8/27/08	0.00	--	10.92	16.41	8.95	--	--	< 50	--	--	--	2080	< 10	162	--	--	6
Redwater River	MCNREDW-1-8	6/7/05	--	--	6.59	12.7	7.58	--	2220000	100	--	5900	6180	--	280	1440	710	--	--
Redwater River	MCNREDW-2A	6/7/05	--	--	6.97	12.9	7.8	--	3420000	100	--	10500	10790	--	290	1900	890	--	--
Redwater River	MCNREDW-3A	6/22/05	--	--	9.4	30.2	8.48	--	15000	< 50	--	1100	1125	--	< 50	30	20	--	--
Redwater River	MCNREDW-3D	6/22/05	--	--	10.62	30	8.87	--	376000	< 50	--	1600	1625	--	< 50	260	240	--	--
Redwater River	MCNREDW-3G	6/22/05	--	--	8.94	30.3	8.42	--	31000	< 50	--	1400	1425	--	< 50	50	20	--	--
Redwater River	WMTP99-R025	9/26/01	--	--	10	14.5	8.65	--	34900	--	--	--	--	--	--	--	--	--	--
Sand Creek	5481SA01	8/21/95	--	--	--	--	--	--	--	--	--	8600	10030	--	1430	3960	--	--	--
Sand Creek	5481SA01	8/21/95	1.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sand Creek	M49SANDC01	6/4/03	3.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sand Creek	M49SANDC01	6/4/03	--	--	--	--	--	--	6700000	--	--	7990	8520	--	530	--	--	--	--
Sand Creek	M49SANDC01	6/4/03	--	--	--	--	--	--	--	--	--	--	--	--	--	3560	--	--	--
Sand Creek	M49SANDC01	6/18/08	1.17	--	7.18	28.77	8.97	NA	--	< 50	--	--	--	1860	1050	442	--	--	19
Sand Creek	M49SANDC01	8/28/08	0.22	--	11.70	17.16	8.90	--	--	< 50	--	--	--	730	< 10	50	--	--	1
Sand Creek	M49SANDC02	7/12/03	0.50	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sand Creek	M49SANDC02	7/12/03	--	409	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sand Creek	M49SANDC02	6/18/08	0.06	--	8.02	21.16	8.81	NA	--	< 50	--	--	--	1220	270	454	--	--	36
Sand Creek	M49SANDC03	6/18/08	0.32	--	9.05	26.64	8.88	NA	--	< 50	--	--	--	1560	30	123	--	--	14
Sand Creek	M49SANDC03	8/28/08	0.00	--	10.00	20.81	7.02	--	--	< 50	--	--	--	540	< 10	14	--	--	2
Sand Creek	MCNSAND-01	7/12/03	--	--	--	--	--	--	3870000	< 50	--	900	1990	--	1090	1370	--	700	--
Sand Creek	MCNSAND-03	9/16/03	--	--	--	--	--	--	10000	90	--	6700	6725	--	< 50	400	--	40	--
Sand Creek	MCNSAND-03	6/18/08	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sand Creek	MCNSAND-2A	9/16/03	--	--	--	--	--	--	204000	130	--	1100	1125	--	< 50	140	--	150	--
Sand Creek	MCNSAND-2A	6/18/08	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Timber Creek	6131120	3/17/76	3.50	--	--	--	--	--	--	50	60	2100	2110	--	10	60	--	--	--
Timber Creek	6131120	4/28/76	0.76	--	--	--	--	--	--	10	10	1100	1150	--	< 100	50	--	--	--
Timber Creek	6131120	6/14/76	21.00	--	--	--	--	--	--	130	170	1300	1560	--	260	270	--	--	--
Timber Creek	6131120	4/5/77	1.10	--	--	--	--	--	--	50	60	1300	1310	--	10	70	--	--	--
Timber Creek	6131120	3/23/78	57.00	--	--	--	--	--	--	220	280	690	950	--	260	150	--	--	--
Timber Creek	6131120	4/17/78	1.90	--	--	--	--	--	--	< 10	--	570	590	--	20	30	--	--	--
Timber Creek	6131120	5/8/78	3.40	--	--	--	--	--	--	40	50	720	750	--	30	60	--	--	--
Timber Creek	6131120	6/7/78	5.50	--	--	--	--	--	--	80	100	1200	1290	--	90	60	--	--	--
Timber Creek	6131120	7/10/78	4.70	--	--	--	--	--	--	30	40	1100	1150	--	< 100	70	--	--	--
Timber Creek	6131120	8/8/78	0.48	--	--	--	--	--	--	70	90	1400	1420	--	20	50	--	--	--
Timber Creek	6131120	9/14/78	0.89	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Timber Creek	6131120	10/10/78	0.55	--	--	--	--	--	--	20	30	720	730	--	10	40	--	--	--
Timber Creek	6131120	11/13/78	0.81	--	--	--	--	--	--	10	10	720	730	--	10	20	--	--	--
Timber Creek	6131120	12/12/78	0.40	--	--	--	--	--	--	50	60	950	1000	--	50	40	--	--	--
Timber Creek	6131120	3/21/79	47.00	--	--	--	--	--	--	80	100	1000	1130	--	130	40	--	--	--
Timber Creek	6131120	4/17/79	128.00	--	--	--	--	--	--	60	70	860	970	--	110	80	--	250	--
Timber Creek	6131120	5/8/79	27.00	--	--	--	--	--	--	50	60	1200	1210	--	10	60	--	180	--
Timber Creek	6131120	6/4/79	3.00	--	--	--	--	--	--	80	100	1400	1400	--	--	40	--	120	--
Timber Creek	6131120	7/2/79	0.59	--	--	--	--	--	--	10	10	960	970	--	10	30	--	90	--
Timber Creek	6131120	8/20/79	0.10	--	--	--	--	--	--	10	10	770	780	--	10	40	--	120	--
Timber Creek	6131120	9/11/79	0.11	--	--	--	--	--	--	50	60	790	820	--	30	50	--	150	--

Table 1.3 Compiled Surface Water Nutrient Data

Segment ID	Site ID	Sample Date	Flow (cfs)	Chlor-a (mg/m2)	DO (mg/L)	Water Temp (°C)	pH (S.U.)	TDS (mg/L)	TSS (mg/L)	Total Ammonia as N (ug/L)	Total Ammonia as NH4 (ug/L)	TKN (ug/L)	Total N Calc (ug/L)	Total N per Sulfate Method (ug/L)	NO2 + NO3 as N (ug/L)	Total P (ug/L)	Total OrthoPhosphate (ug/L)	Total P as PO4 (ug/L)	Dissolved P (ug/L)
Timber Creek	6131120	8/28/08	--	--	9.15	19.21	9.39	--	--	< 50	--	--	--	2190	< 10	102	--	--	2
Timber Creek	4878TI01	7/12/94	--	--	--	--	--	--	--	--	--	1100	1110	--	10	25	--	--	--
Timber Creek	6131120	6/17/08	0.45	--	12.42	25.3	9.08	NA	--	< 50	--	--	--	1060	< 10	31	--	--	27
Timber Creek	M31TMBRC01	6/2/03	0.50	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Timber Creek	M31TMBRC01	6/16/04	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Timber Creek	M31TMBRC02	6/16/04	--	--	--	--	--	--	13600	--	--	820	1020	--	200	--	--	--	--
Timber Creek	M31TMBRC02	6/16/04	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Timber Creek	M31TMBRC02	6/16/04	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Timber Creek	M31TMBRC02	6/16/04	--	--	--	--	--	--	--	--	--	--	--	--	--	28	--	--	--
Timber Creek	M31TMBRC03	6/18/04	--	--	--	--	--	--	13500	--	--	1760	1765	--	< 10	--	--	--	--
Timber Creek	M31TMBRC03	6/18/04	--	0.7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Timber Creek	M31TMBRC03	6/18/04	2.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Timber Creek	M31TMBRC03	6/18/04	--	--	--	--	--	--	--	--	--	--	--	--	--	48	--	--	--
Timber Creek	M31TMBRC03	6/17/08	0.26	--	7.70	27.8	9.13	NA	--	< 50	--	--	--	2120	< 10	85	--	--	30
Timber Creek	M31TMBRC03	8/29/08	--	--	0.45	13.11	8.44	--	--	2390	--	--	--	8700	20	643	--	--	30
Timber Creek	M31TMBRC04	6/17/04	--	--	--	--	--	--	23500	--	--	4640	4645	--	< 10	--	--	--	--
Timber Creek	M31TMBRC04	6/17/04	--	8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Timber Creek	M31TMBRC04	6/17/04	0.10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Timber Creek	M31TMBRC04	6/17/04	--	--	--	--	--	--	--	--	--	--	--	--	--	327	--	--	--
Timber Creek	M31TMBRC04	6/16/08	0.10	--	9.62	25.2	8.82	NA	--	< 50	--	--	--	2720	< 10	130	--	--	40
Timber Creek	M31TMBRC05	6/18/04	--	--	--	--	--	--	26500	--	--	2180	2185	--	< 10	--	--	--	--
Timber Creek	M31TMBRC05	6/18/04	--	20	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Timber Creek	M31TMBRC05	6/18/04	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Timber Creek	M31TMBRC05	6/18/04	--	--	--	--	--	--	--	--	--	--	--	--	--	121	--	--	--
Timber Creek	M31TMBRC06	6/17/04	--	--	--	--	--	--	1110000	--	--	--	--	--	--	--	--	--	--
Timber Creek	M31TMBRC06	6/17/04	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Timber Creek	MCNTMBR-01	7/10/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Timber Creek	MCNTMBR-01	7/10/03	--	--	--	--	--	--	85000	--	--	5400	5425	--	< 50	490	100	--	--
Timber Creek	MCNTMBR-02	7/10/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Timber Creek	MCNTMBR-04	7/10/03	--	--	--	--	--	--	<10000	100	--	5100	5125	--	< 50	180	20	--	--
Timber Creek	MCNTMBR-04	7/10/03	0.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Timber Creek	MCNTMBR-06	7/10/03	--	--	--	--	--	--	81000	< 50	--	1600	1625	--	< 50	100	60	--	--

Table 1.4 Surface Water Salinity – Listed Segments

Agency Code	Station ID	Latitude	Longitude	Station Name	Site Description	Activity Start Date	Instantaneous Discharge (cfs)	Total Dissolved Solids (mg/L)	SAR	Specific Conductance (uS/cm)	Sulfate-S (mg/L)
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	10/16/75	1.1		12	1850	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	12/10/75	0.23		17	3250	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	02/25/76	4.1		6	995	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	03/17/76	7.7		7	1380	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	04/27/76	0.12		19	5850	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	06/16/76	1.6		10	1490	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	03/08/77	1.8		18	4300	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	04/05/77	0.37		22	4800	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	07/12/77	0.5		4	770	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	09/08/77	3.3		7	1160	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	03/20/78	68		2	272	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	03/27/78	116		3	418	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	04/07/78	3.1		8	2180	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	05/08/78	11		16	2720	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	06/07/78	5.6		10	2550	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	07/05/78	11				
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	07/10/78	0.53		14	3090	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	08/08/78	0.1		17	4800	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	09/12/78	8.2			1160	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	10/10/78	0.17		13	4620	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	11/13/78	0.18		20	6470	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	12/12/78	0.1		26	9200	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	03/25/79	52		3	447	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	04/17/79	125		4	1080	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	05/03/79	3.2		13	4820	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	06/04/79	0.98		17	7380	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	07/02/79	0.03		23	8200	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	02/22/83	4			620	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	03/04/83	1.9			2530	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	03/11/83	1			3090	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	04/13/83	0.07			4600	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	05/25/83	0.18			5100	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	01/29/84	18			760	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	03/21/84	3.9			2700	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	04/04/84	0.47			3150	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	06/12/84	0.6			1490	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	06/14/84	19			842	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	06/21/84	1.9			965	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	06/26/84	0.24			2080	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	02/26/85	2.6			780	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	02/28/85	6			800	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	03/19/85	1.5			2180	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	04/10/85	0.2			3600	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	04/12/00	0.05			9590	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	07/10/00	7.2			1040	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	03/13/01	7.6			1480	

Table 1.4 Surface Water Salinity – Listed Segments

Agency Code	Station ID	Latitude	Longitude	Station Name	Site Description	Activity Start Date	Instantaneous Discharge (cfs)	Total Dissolved Solids (mg/L)	SAR	Specific Conductance (uS/cm)	Sulfate-S (mg/L)
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	03/27/01	0.32			3540	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	07/17/01	0.12			1390	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	04/16/02	1.1			4040	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	03/24/03	0.88			4860	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	05/07/03	0.01			6860	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	06/16/03	0.25			5820	
USGS	6131200	47.53555	-106.15248	Nelson Creek	U/S MT HWY 24 crossing	06/17/08	0.33	2550		3550	
Private	NCDS-01	47.47146	-106.0785	Nelson Creek	90 D/S of trail crossing	09/26/06		4400	20.3	10090	2780
Private	NCDS-01	47.47146	-106.0785	Nelson Creek	90 D/S of trail crossing	10/22/06		2720	16.4	31030	1500
Private	NCDS-01	47.47146	-106.0785	Nelson Creek	90 D/S of trail crossing	11/11/06		2460	15.2	3200	1180
Private	NCDS-01	47.47146	-106.0785	Nelson Creek	90 D/S of trail crossing	03/08/07		438	4.86	605	178
Private	NCDS-01	47.47146	-106.0785	Nelson Creek	90 D/S of trail crossing	04/16/07		5780	28.7	7370	3450
Private	NCDS-01	47.47146	-106.0785	Nelson Creek	90 D/S of trail crossing	05/09/07		6500	36.7	8122	3880
Private	NCDS-01	47.47146	-106.0785	Nelson Creek	90 D/S of trail crossing	06/12/07		4330	24.5	5629	2250
Private	NCDS-01	47.47146	-106.0785	Nelson Creek	90 D/S of trail crossing	07/09/07		8100	54.2	9697	4900
Private	NCUS-02	47.44675	-105.99245	Nelson Creek	NE¼SW¼S33T20NR25E	03/08/07		1200	7.84	1700	746
Private	NCUS-02	47.44675	-105.99245	Nelson Creek	NE¼SW¼S33T20NR25E	04/17/07		13100	35.1	14300	9150
Private	NCUS-02	47.44675	-105.99245	Nelson Creek	NE¼SW¼S33T20NR25E	05/10/07		11400	31.4	12580	7720
Private	NCUS-02	47.44675	-105.99245	Nelson Creek	NE¼SW¼S33T20NR25E	06/14/07		9140	25	10280	6150
Private	NCUS-02	47.44675	-105.99245	Nelson Creek	NE¼SW¼S33T20NR25E	07/11/07		6980	25.9	8627	3660
Private	POND-25	47.45766	-106.04968	Nelson Creek	SW¼SE¼S25R20NR44E	06/13/07		1110	29	1704	176
Private	POND-25	47.45766	-106.04968	Nelson Creek	SW¼SE¼S25R20NR44E	07/10/07		11600	218	14020	5830
Private	SFUS-01	47.43253	-106.01641	Nelson Creek, South Fork	3100 m U/S of mouth (Nelson Creek)	09/26/06		55300	68.1	7062	46800
Private	SFUS-01	47.43253	-106.01641	Nelson Creek, South Fork	3100 m U/S of mouth (Nelson Creek)	10/22/06		60000	64.1	275700	43100
Private	SFUS-01	47.43253	-106.01641	Nelson Creek, South Fork	3100 m U/S of mouth (Nelson Creek)	03/08/07		935	5.63	1394	517
Private	SFUS-01	47.43253	-106.01641	Nelson Creek, South Fork	3100 m U/S of mouth (Nelson Creek)	04/17/07		9540	22.6	10820	6030
Private	SFUS-01	47.43253	-106.01641	Nelson Creek, South Fork	3100 m U/S of mouth (Nelson Creek)	05/09/07		9560	25.6	13620	6210
Private	SFUS-01	47.43253	-106.01641	Nelson Creek, South Fork	3100 m U/S of mouth (Nelson Creek)	06/13/07		10900	25	12240	7310
Private	SFUS-01	47.43253	-106.01641	Nelson Creek, South Fork	3100 m U/S of mouth (Nelson Creek)	07/11/07		18500	30.5	18750	12300
Private	JCIN-01	47.45922	-106.02804	Johnson Coulee	1400 m U/S of mouth	09/26/06		4400	20.3	10090	2780
Private	JCIN-01	47.45922	-106.02804	Johnson Coulee	1400 m U/S of mouth	10/22/06		2720	16.4	31030	1500
Private	JCIN-01	47.45922	-106.02804	Johnson Coulee	1400 m U/S of mouth	11/11/06		2460	15.2	3200	1180
Private	JCIN-01	47.45922	-106.02804	Johnson Coulee	1400 m U/S of mouth	03/08/07		438	4.86	605	178
USGS	6177520	47.42529	-105.61667	Horse Creek	D/S Horse Creek Road crossing, one mile west of Circle MT	04/01/77	1		14	5200	
USGS	6177520	47.42529	-105.61667	Horse Creek	D/S Horse Creek Road crossing, one mile west of Circle MT	10/19/77	0.03		29	13300	
USGS	6177520	47.42529	-105.61667	Horse Creek	D/S Horse Creek Road crossing, one mile west of Circle MT	03/22/78	150		2	489	
USGS	6177520	47.42529	-105.61667	Horse Creek	D/S Horse Creek Road crossing, one mile west of Circle MT	04/25/78	1		11	4900	
USGS	6177520	47.42529	-105.61667	Horse Creek	D/S Horse Creek Road crossing, one mile west of Circle MT	05/09/78	2.4		15	6700	
USGS	6177520	47.42529	-105.61667	Horse Creek	D/S Horse Creek Road crossing, one mile west of Circle MT	06/08/78	1.6		15	5500	
USGS	6177520	47.42529	-105.61667	Horse Creek	D/S Horse Creek Road crossing, one mile west of Circle MT	07/12/78	1.8		6	2510	

Table 1.4 Surface Water Salinity – Listed Segments

Agency Code	Station ID	Latitude	Longitude	Station Name	Site Description	Activity Start Date	Instantaneous Discharge (cfs)	Total Dissolved Solids (mg/L)	SAR	Specific Conductance (uS/cm)	Sulfate-S (mg/L)
USGS	6177520	47.42529	-105.61667	Horse Creek	D/S Horse Creek Road crossing, one mile west of Circle MT	08/09/78	0.27		12	4900	
USGS	6177520	47.42529	-105.61667	Horse Creek	D/S Horse Creek Road crossing, one mile west of Circle MT	10/11/78	0.66		13	5200	
USGS	6177520	47.42529	-105.61667	Horse Creek	D/S Horse Creek Road crossing, one mile west of Circle MT	11/14/78	0.99		15	7200	
USGS	6177520	47.42529	-105.61667	Horse Creek	D/S Horse Creek Road crossing, one mile west of Circle MT	03/19/79	20		6	1670	
USGS	6177520	47.42529	-105.61667	Horse Creek	D/S Horse Creek Road crossing, one mile west of Circle MT	04/11/79	126		2	749	
USGS	6177520	47.42529	-105.61667	Horse Creek	D/S Horse Creek Road crossing, one mile west of Circle MT	05/09/79	15		7	3480	
USGS	6177520	47.42529	-105.61667	Horse Creek	D/S Horse Creek Road crossing, one mile west of Circle MT	06/05/79	2.8		12	6150	
USGS	6177520	47.42529	-105.61667	Horse Creek	D/S Horse Creek Road crossing, one mile west of Circle MT	07/10/79	1.4		25	7300	
USGS	6177520	47.42529	-105.61667	Horse Creek	D/S Horse Creek Road crossing, one mile west of Circle MT	08/21/79	0.05		20	9080	
USGS	6177520	47.42529	-105.61667	Horse Creek	D/S Horse Creek Road crossing, one mile west of Circle MT	06/22/82	0.52			7250	
USGS	6177520	47.42529	-105.61667	Horse Creek	D/S Horse Creek Road crossing, one mile west of Circle MT	10/19/82	0.28			8900	
USGS	472125105562600	47.35694	-105.94056	Nelson Creek, South Fork	T19N, R45E, SE¼ Section 35	07/17/75			1	1500	
USGS	472615105410901	47.43750	-105.68583	Horse Creek	T19N, R47E, NE¼ Section 2	07/28/75			8	1640	
USGS	472615105410902	47.43750	-105.68583	Horse Creek	T19N, R47E, NE¼ Section 2	07/28/75			10	3230	
USGS	472625105400000	47.44028	-105.66667	Horse Creek	T19N, R47E, NE¼ Section 1	07/28/75			9	2980	
USGS	472700105394501	47.45000	-105.66250	Horse Creek	T20N, R47E, NE¼ Section 36	05/06/76			52	3400	
USGS	472806105514100	47.46833	-105.86139	Horse Creek, South Fork	T20N, R46E, NE¼ Section 28	08/12/75			2	1440	
USGS	472830106044001	47.47500	-106.07778	Nelson Creek	800 m U/S of Crookers Coulee mouth	04/04/77	0.44		23	4900	
USGS	473118105484500	47.52167	-105.81250	Horse Creek, North Fork	T20N, R46E, NW¼ Section 2	08/08/75			1	1020	
USGS	473308105502200	47.55222	-105.83944	Horse Creek, North Fork	T21N, R46E, NE¼ Section 29	09/20/75			10	2980	
USGS	474516104494500	47.75444	-104.82917	East Redwater Creek	T23N, R54E, NE¼ Section 18	10/17/75			0.1	600	
USGS	474859105033100	47.81639	-105.05861	East Redwater Creek	T24N, R52E, NW¼ Section 28	10/07/75			6	2250	
USGS	474910104472501	47.81944	-104.79028	East Redwater Creek, North Fork	T24N, R54E, SE¼ Section 21	09/01/78			62	2820	
USGS	475210104540001	47.86944	-104.90000	Horse Creek	T25N, R53E, SE¼ Section 32	09/06/78			68	2550	
USGS	475218104540201	47.87167	-104.90056	Horse Creek	T25N, R53E, SE¼ Section 32	11/12/75			66	2500	
USGS	475226104530400	47.87389	-104.88444	Horse Creek	T25N, R53E, SW¼ Section 33	11/21/75			0.3	1330	
MONT-DEQ	5288NO01	47.81528	-104.86944	East Redwater Creek, North Fork	D/S Richland County Rd 317 Crossing	06/01/76				4469	
MONT-DEQ	5288NO01	47.81528	-104.86944	East Redwater Creek, North Fork	D/S Richland County Rd 317 Crossing	06/15/76	1	3629		4735	2025
USGS	5385EA01	47.89810	-105.20690	East Redwater Creek	320 m U/S from the mouth	06/23/82	1			4780	
USGS	5385EA01	47.89810	-105.20690	East Redwater Creek	320 m U/S from the mouth	10/19/82	0.14			3680	
MONT-DEQ	5385EA01	47.89810	-105.20690	East Redwater Creek	320 m U/S from the mouth	06/17/08	0.39	4590		6217	2600
MONT-DEQ	5385EA01	47.89810	-105.20690	East Redwater Creek	320 m U/S from the mouth	08/28/08	0	4760		6906	3200
MONT-DEQ	G020001	47.71470	-104.87030	East Redwater Creek	D/S Richland County Rd 317 Crossing	06/15/76				8210	
MONT-DEQ	G020002	47.71472	-104.87028	East Redwater Creek	D/S Richland County Rd 317 Crossing	06/01/76				8210	
MONT-DEQ	G020007	48.05330	-105.21500	East Redwater Creek	At Nickwall Road crossing	06/03/03				4200	
MONT-DEQ	G020010	47.89810	-105.20690	East Redwater Creek	At mouth	08/23/95			97.014		
MONT-DEQ	M31NLSNC01	47.44600	-106.02330	Nelson Creek	900 m D/S South Fork confluence	06/17/08	0	6150		7720	
MONT-DEQ	M31NLSNC02	47.51810	-106.11760	Nelson Creek	D/S of Coal Creek confluence	06/17/08	0.24	4040		5630	

Table 1.4 Surface Water Salinity – Listed Segments

Agency Code	Station ID	Latitude	Longitude	Station Name	Site Description	Activity Start Date	Instantaneous Discharge (cfs)	Total Dissolved Solids (mg/L)	SAR	Specific Conductance (uS/cm)	Sulfate-S (mg/L)
MONT-DEQ	M48HRSEC02	47.45680	-105.68750	Horse Creek	0.75 mile D/S Denwoody Creek Confluence	06/04/03				7700	
MONT-DEQ	M48RDWEC01	47.90020	-105.17230	East Redwater Creek	At mouth	06/19/03	5	4590			1960
MONT-DEQ	M48RDWEC02	47.86610	-105.06610	East Redwater Creek	At County Road 308 crossing	06/19/03	5	3400			3610
MONT-DEQ	M48RDWEC03	47.83168	-104.99729	East Redwater Creek	Below confluence of North Fork, E. Redwater Creek	06/19/03	0.25	4540			2680
MONT-DEQ	M48RDWEC03	47.83168	-104.99729	East Redwater Creek	At confluence with North Fork	06/17/08	0.11	7230		9280	3900
MONT-DEQ	M48RDWEC04	47.75800	-104.92280	East Redwater Creek	T23N, R53E, NE¼ Section 16	06/19/03	0.5	1690			905
MONT-DEQ	M48RDWEC05	47.73398	-104.90907	East Redwater Creek	T23N, R53E, SW¼ Section 22	06/17/08	0.03	10500		12600	6600
MONT-DEQ	M48RWENF01	47.83020	-104.99550	East Redwater Creek, North Fork	At confluence with East Redwater Creek	06/19/03	0.25	1450			1690
MONT-DEQ	M48RWENF01	47.83020	-104.99550	East Redwater Creek, North Fork	At confluence with East Redwater Creek	06/17/08	0.03	7450		9201	4700
MONT-DEQ	MCNHORC-01	47.49480	-105.88820	Horse Creek	near headwaters - aka HORCK-01	07/11/03				2140	
MONT-DEQ	MCNHORC-01	47.49480	-105.88820	Horse Creek	near headwaters - aka HORCK-01	07/11/03		1090		2140	
MONT-DEQ	MCNHORC-02	47.48280	-105.77130	Horse Creek	Moos Farm above private on-stream reservoir	07/11/03				6800	
MONT-DEQ	MCNHORC-02	47.48280	-105.77130	Horse Creek	Moos Farm above private on-stream reservoir	07/11/03		4560		6800	
MONT-DEQ	MCNHORC-02	47.48280	-105.77130	Horse Creek	Moos Farm above private on-stream reservoir	07/11/03		4750			
MONT-DEQ	MCNHORC-02	47.48280	-105.77130	Horse Creek	Moos Farm above private on-stream reservoir	07/11/03					
MONT-DEQ	MCNHORC-03	47.47080	-105.73190	Horse Creek	HWY 252 crossing	07/11/03				6370	
MONT-DEQ	MCNHORC-03	47.47080	-105.73190	Horse Creek	HWY 252 crossing	07/11/03				6370	
MONT-DEQ	MCNHORC-03	47.47080	-105.73190	Horse Creek	HWY 252 crossing	06/07/05		581			
MONT-DEQ	MCNHORC-03	47.47080	-105.73190	Horse Creek	HWY 252 crossing	06/07/05				600	
MONT-DEQ	MCNHORC-03	47.47080	-105.73190	Horse Creek	HWY 252 crossing	06/17/08	0.15	5240		6160	
MONT-DEQ	MCNHORC-03	47.47080	-105.73190	Horse Creek	HWY 252 crossing	08/27/08	0	7310		8988	
MONT-DEQ	MCNHORC-04	47.42490	-105.62330	Horse Creek	At Zahn access crossing	07/11/03				9170	
MONT-DEQ	MCNHORC-04	47.42490	-105.62330	Horse Creek	At Zahn access crossing	07/11/03				9170	
MONT-DEQ	MCNHORC-04	47.42490	-105.62330	Horse Creek	At Zahn access crossing	07/11/03		7770			
MONT-DEQ	MCNHORC-04	47.42490	-105.62330	Horse Creek	At Zahn access crossing	06/18/08	0.12	8770		9980	
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	06/04/03				7700	
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	07/11/03				6920	
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	07/11/03				6920	
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	07/11/03		5500			
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	08/06/03				8740	
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	08/06/03				8740	
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	08/06/03		7780			
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	08/13/03		8380		9300	
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	08/13/03				9300	
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	08/13/03		8380			
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	08/20/03		9530		10400	
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	08/20/03				10400	
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	08/27/03		10900		11600	
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	08/27/03				11600	
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	05/05/04				5490	
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	05/13/04				5790	
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	05/20/04				5880	
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	05/27/04				6130	
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	08/05/04				4690	
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	08/16/04				9900	
MONT-DEQ	MCNHORC-05	47.42380	-105.57880	Horse Creek	U/S of Highway 13 crossing	08/23/04				10400	

Table 1.5 Surface Water Salinity – Unlisted Segments

Agency Code	Station ID	Latitude	Longitude	Station Name	Site Description	Activity Start Date	Instantaneous Discharge (cfs)	Total Dissolved Solids (mg/L)	Sodium Adsorption Ratio (SAR)	Specific Conductance (uS/cm)	Sulfate-S (mg/L)
MONT-DEQ	6131120	47.40573	-106.17419	Timber Creek	At Highway 24 crossing	06/17/08	0.45			6280	2700
MONT-DEQ	6131120	47.40573	-106.17419	Timber Creek	At Highway 24 crossing	08/28/08	0			11044	4600
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	10/14/75	125			720	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	11/21/75	2.6		21	2600	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	12/11/75	2.6		12	1030	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	01/29/76	87		7	650	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	03/03/76	1.9		8	1060	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	03/18/76	285		3	257	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	04/28/76	2.8		13	1260	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	05/27/76	1.9		23	2420	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	06/13/76	1170		3	435	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	07/21/76	2.1		11	1400	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	08/20/76	1.6		12	1510	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	09/22/76	1.8		25	2600	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	10/21/76	1.8		22	2530	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	11/18/76	2.5		24	2900	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	12/22/76	1		21	2800	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	01/18/77	0.02		10	1590	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	02/10/77	0.5		10	1640	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	03/15/77	14		11	1060	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	04/07/77	2.5		15	1820	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	05/20/77	1.7		27	2800	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	06/16/77	39		6	640	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	07/12/77	2.1		31	2850	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	08/18/77	0.81		43	3200	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	09/14/77	1.2		15	1040	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	10/21/77	1.5		21	2330	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	11/09/77	2.4		23	2680	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	12/13/77	0.72		25	3200	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	01/26/78	0.1		11	2290	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	03/21/78	1630			180	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	04/28/78	3		13	1850	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	05/12/78	7		11	1180	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	06/05/78	11		10	1600	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	07/25/78	2.1		16	2050	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	08/23/78	1.6		22	2430	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	09/13/78	217			616	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	10/23/78	2.9		17	2110	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	11/16/78	5.1		20	2750	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	12/14/78	1.1		20	2800	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	01/09/79	0.2		11	2320	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	03/30/79	55		4	590	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	04/10/79	794		2	320	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	04/18/79	273				
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	05/14/79	8		12	3000	

Table 1.5 Surface Water Salinity – Unlisted Segments

Agency Code	Station ID	Latitude	Longitude	Station Name	Site Description	Activity Start Date	Instantaneous Discharge (cfs)	Total Dissolved Solids (mg/L)	Sodium Adsorption Ratio (SAR)	Specific Conductance (uS/cm)	Sulfate-S (mg/L)
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	06/06/79	3.6		16	2460	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	07/12/79	2		20	2620	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	08/13/79	1.7		23	2650	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	09/13/79	2		24	2680	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	10/21/82	1.9			1670	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	12/02/82	1.6			2910	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	01/12/83	41			610	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	02/24/83	42			400	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	03/10/83	3.9			1620	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	04/11/83	2.2			2140	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	06/24/83	1.1			1750	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	08/31/83	0.75			3310	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	10/06/83	1.6			1080	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	11/28/83	1.5			2840	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	01/29/84	144			182	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	03/06/84	2.3			1920	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	04/05/84	2.8			965	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	05/16/84	1.1			2240	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	06/14/84	600			465	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	06/15/84	78			720	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	06/18/84	19			628	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	06/21/84	436			468	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	06/22/84	108			640	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	06/27/84	3.9			1100	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	07/13/84	1.2			1180	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	08/02/84	0.92			2220	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	09/12/84	1.2			3000	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	10/17/84	0.99			2760	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	12/07/84	0.81			3360	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	01/16/85	0.72			2720	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	02/25/85	64			290	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	02/26/85	35			262	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	03/01/85	20			445	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	03/06/85	4.8			880	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	03/08/85	7			945	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	03/11/85	18			754	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	03/18/85	5.5			1100	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	04/02/85	153			420	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	04/08/85	5.3			800	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	05/23/85	1.2			2670	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	08/02/85	0.98			3350	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	08/20/85	1.1			2170	
USGS	6175540	47.99891	-105.86723	Prairie Elk Creek	D/S of Highway 528 crossing	06/18/08	1.95			1178	
USGS	6175580	48.01446	-105.71000	Sand Creek	U/S of Highway 528 crossing	10/29/75	0.62		15	1800	
USGS	6175580	48.01446	-105.71000	Sand Creek	U/S of Highway 528 crossing	03/20/76	52		3	360	
USGS	6175580	48.01446	-105.71000	Sand Creek	U/S of Highway 528 crossing	06/13/76	165		5	655	

Table 1.5 Surface Water Salinity – Unlisted Segments

Agency Code	Station ID	Latitude	Longitude	Station Name	Site Description	Activity Start Date	Instantaneous Discharge (cfs)	Total Dissolved Solids (mg/L)	Sodium Adsorption Ratio (SAR)	Specific Conductance (uS/cm)	Sulfate-S (mg/L)
USGS	6175580	48.01446	-105.71000	Sand Creek	U/S of Highway 528 crossing	09/22/76	0.2		27	3040	
USGS	6175580	48.01446	-105.71000	Sand Creek	U/S of Highway 528 crossing	10/21/76	0.25		24	2960	
USGS	6175580	48.01446	-105.71000	Sand Creek	U/S of Highway 528 crossing	03/30/77	19		12	942	
USGS	6175580	48.01446	-105.71000	Sand Creek	U/S of Highway 528 crossing	06/16/77	7.1		20	1900	
USGS	6175580	48.01446	-105.71000	Sand Creek	U/S of Highway 528 crossing	07/12/77	0.2		32	3230	
USGS	6175580	48.01446	-105.71000	Sand Creek	U/S of Highway 528 crossing	09/14/77	0.2		16	1290	
USGS	6177400	47.35000	-105.58333	Mccune Creek	Mccune Creek near Circle MT	06/20/84	0.06			638	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/21/74	0.03		15	3900	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	11/18/74	0.11		14	3820	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	12/16/74	0.07		14	4130	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/20/75	0.07		12	4430	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	02/24/75	0.05		12	4800	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/18/75	0.26		10	3100	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/14/75	22		6	2520	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/21/75	3.9		7	3230	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/18/75	0.91		8	3400	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	07/22/75	2.6		8	3250	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	08/19/75	0.09		11	4400	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	09/25/75	0.14		13	4200	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/29/75	0.18		11	3500	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	11/20/75	0.24		11	3750	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	12/10/75	0.29		10	3800	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/27/76	0.96		8	3050	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	02/25/76	12		4	1800	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/19/76	7.2		6	2060	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/29/76	2.2		8	3330	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/26/76	2.4		10	3800	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/14/76	16		6	2320	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	07/20/76	0.32		7	2940	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	08/18/76	0.83		9	3200	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	09/22/76	0.14		11	3710	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/20/76	0.09		12	3480	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	11/17/76	0.07		11	3850	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	12/21/76	0.11		11	4100	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/18/77	0.05		11	3800	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	02/17/77	0.11		10	2980	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/08/77	3.3		8	3320	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/22/77	0.96		9	3610	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/19/77	0.67		10	3600	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/14/77	0.11		12	3850	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	07/13/77	0.07		9	2350	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	09/12/77	0.09		14	3180	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/19/77	0.09		13	3350	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	11/07/77	0.11		13	3410	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	12/13/77	0.1		12	3900	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/12/78	0.1		11	3900	

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Agency Code	Station ID	Latitude	Longitude	Station Name	Site Description	Activity Start Date	Instantaneous Discharge (cfs)	Total Dissolved Solids (mg/L)	Sodium Adsorption Ratio (SAR)	Specific Conductance (uS/cm)	Sulfate-S (mg/L)
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/22/78	1060		0.9	336	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/25/78	7.1		6	3000	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/09/78	15		8	3680	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/08/78	21		10	3290	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	07/12/78	30		4	1980	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	08/09/78	2.6		8	3410	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	09/14/78	3.6				
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/11/78	4.2		9	3620	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	11/13/78	3.6		9	4110	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	12/13/78	2.6		10	4990	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/08/79	0.3		10	4410	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	02/20/79	0.6		11	5700	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/19/79	143		2	820	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/11/79	489		3	1290	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/09/79	50		7	4000	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/05/79	13		7	4500	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	07/10/79	2.4		8	4600	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	08/21/79	0.89		11	4680	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	09/12/79	0.18		12	4620	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/17/79	0.28		12	4220	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	11/06/79	0.96		11	5000	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	12/04/79	1.8		10	5600	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/08/80	0.35		11	5800	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	02/19/80	0.91		12	5780	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/26/80	5.5		7	3150	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/22/80	1.7		7	3730	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/13/80	0.35		10	4400	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/10/80	0.1		12	4420	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	07/28/80	0.01		14	5000	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	08/27/80	0.02		15	4600	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	09/17/80	0.01		15	4650	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/21/80	0.02		17	4330	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	11/19/80	0.08		16	4300	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	12/17/80	0.28		11	4820	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/20/81	0.58		13	5190	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	02/18/81	1		11	4390	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/10/81	0.61		9	4100	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/28/81	0.24		11	4760	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/21/81	0.13		12	4830	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/29/81	0.08		17	4680	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/30/81	0.08		16	5820	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	12/03/81	0.01		17	6200	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/04/82	6.2		6	1860	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/22/82	3		8	3580	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/26/82	6.2		9	4100	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/22/82	3		9	4600	

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Agency Code	Station ID	Latitude	Longitude	Station Name	Site Description	Activity Start Date	Instantaneous Discharge (cfs)	Total Dissolved Solids (mg/L)	Sodium Adsorption Ratio (SAR)	Specific Conductance (uS/cm)	Sulfate-S (mg/L)
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	08/24/82	0.05		14	5030	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	09/21/82	0.03		16	2420	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/19/82	0.06			4250	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	11/29/82	0.31			4780	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/11/83	11			2120	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	02/23/83	17			890	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/12/83	2			3620	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/24/83	2.7			4100	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/28/83	0.04			4100	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	08/22/83	0.01			4750	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	09/27/83	0.01			5200	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/17/83	0.04			4790	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	11/28/83	0.06			4000	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/11/84	0.1			3620	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	02/01/84	0.01			3600	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/05/84	0.62			4210	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/15/84	0.08			4100	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/20/84	60			982	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/27/84	14			2120	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	09/19/84	0.04			4820	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/25/84	0.1			3940	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	12/12/84	0.11			4200	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	02/27/85	5.3			2030	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/13/85	1.6			2750	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/24/85	0.14			4200	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	08/21/85	0.02			4950	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	09/26/85	0.02			5150	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	11/13/85	0.02			4250	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/24/86	11			2890	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/01/86	4.3			4300	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/04/86	1.9			5000	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	08/04/86	5.8			2730	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	09/24/86	9.3			3900	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/30/86	8.2			4350	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/19/87	12			4050	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/03/87	27			4250	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/28/87	36			5800	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	08/20/87	0.33			5150	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	12/09/87	1.7			5250	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/06/88	3			3850	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/25/88	0.44			3600	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	07/13/88	0.12			4800	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	09/21/88	0.1			6100	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/25/88	0.06			5200	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	12/07/88	0.1			4650	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/25/89	0.06			4100	

Table 1.5 Surface Water Salinity – Unlisted Segments

Agency Code	Station ID	Latitude	Longitude	Station Name	Site Description	Activity Start Date	Instantaneous Discharge (cfs)	Total Dissolved Solids (mg/L)	Sodium Adsorption Ratio (SAR)	Specific Conductance (uS/cm)	Sulfate-S (mg/L)
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/09/89	8.1			610	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/23/89	21			2350	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/05/89	7.9			2520	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	07/19/89	0.21			5000	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	08/31/89	111			2400	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	09/18/89	0.48			2720	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/24/89	0.17			3900	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	12/04/89	0.53			3930	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/23/90	1.2			4100	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/06/90	6.1			2580	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/03/90	2.2			2630	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/24/90	4.5			3080	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/27/90	0.07			3680	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	12/06/90	0.02			6400	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/04/91	0.16			4370	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/21/91	0.58			4830	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/25/91	51			3850	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/26/91	178			1850	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	08/06/91	0.22			4050	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	09/19/91	0.14			4370	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/21/91	0.17			4220	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	11/20/91	0.24			4100	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/09/92	0.44			5150	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/03/92	0.61			2780	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/09/92	0.52			4430	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/20/92	19			4580	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/12/92	0.84			5000	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/24/92	0.06			5100	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	07/29/92	0.38			4350	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/06/92	0.24			4150	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	12/02/92	0.13			4050	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	02/02/93	0.06			4890	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/05/93	164			575	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/07/93	537			327	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/10/93	54			760	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/16/93	5.5			1450	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/23/93	5.5			2090	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	08/31/93	2.1			4510	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/06/93	0.63			4760	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	12/01/93	2			4390	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	02/01/94	0.79			4440	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/25/94	20			2400	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/23/94	4.9			5710	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/22/94	1.7			5600	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/03/94	0.15			5160	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	11/16/94	1.3			4610	

Table 1.5 Surface Water Salinity – Unlisted Segments

Agency Code	Station ID	Latitude	Longitude	Station Name	Site Description	Activity Start Date	Instantaneous Discharge (cfs)	Total Dissolved Solids (mg/L)	Sodium Adsorption Ratio (SAR)	Specific Conductance (uS/cm)	Sulfate-S (mg/L)
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	12/20/94	1.5			4860	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	02/02/95	24			3880	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/14/95	37			2050	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/26/95	0.03			4910	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	09/14/95	0.02			5070	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	11/01/95	0.04			4100	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/12/96	0.92			5890	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	02/12/96	231			281	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/12/96	2160			402	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/15/96	132			684	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/19/96	34			1380	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/02/96	8.7			2820	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/25/96	6.5			3660	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/17/96	2			1190	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	07/23/96	0.09			4410	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	08/29/96	0.02			4950	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/25/96	0.05			4350	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	11/19/96	0.25			5180	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/07/97	7.3			6320	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/20/97	29			2260	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/24/97	0.19			4370	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	08/21/97	0.05			5370	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/02/97	0.03			5040	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	11/25/97	0.01			4620	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/06/98	0.57			6120	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/04/98	1.4			4910	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/27/98	11			4090	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	08/18/98	0.01			5580	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	11/17/98	0.09			4280	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/13/99	0.4			5560	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	02/23/99	13			2070	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/12/99	6.2			2370	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/28/99	2.8			4620	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/24/99	0.31			4790	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	08/03/99	0.02			4770	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/12/99	0.2			4590	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/21/00	0.15			1300	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/02/00	1.2			4710	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/29/00	0.66			4640	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/01/00	0.17			5320	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	07/07/00	1.2			4000	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/08/01	0.11			4280	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	02/27/01	0.06			4670	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/06/01	38			1440	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/19/01	5.7			1650	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/23/01	2.2			1990	

Table 1.5 Surface Water Salinity – Unlisted Segments

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USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/24/01	0.46			3590	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	06/14/01	1.7			4560	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	10/01/01	1			4610	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	11/08/01	0.1			4450	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	12/11/01	0.09			4470	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	01/30/02	0.14			5130	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	03/28/02	26			3580	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/08/02	3.2			2680	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	04/24/02	1.1			3300	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	05/20/02	0.44			4290	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	07/01/02	0.17			5120	
USGS	6177500	47.41418	-105.57555	Redwater River	Redwater River at Circle MT	08/16/02	0.07			5680	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	10/25/79	3.3		12	3600	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	05/25/82	17		11	3120	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	06/22/82	10		11	3700	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	08/24/82	1.1		15	4020	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	09/20/82	1.2		15	3850	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	10/19/82	2.7			3380	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	11/30/82	2.6			4000	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	01/11/83	21			1440	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	02/23/83	70			750	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	03/09/83	27			1840	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	04/12/83	5.8			2580	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	05/24/83	9.4			3400	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	06/27/83	1.2			3680	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	08/22/83	0.06			4140	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	09/26/83	0.03			4400	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	10/17/83	0.06			3680	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	11/28/83	1.6			3920	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	02/01/84	0.36			3600	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	02/29/84	2.2			3000	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	04/04/84	3.5			3220	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	05/16/84	3.3			3620	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	06/28/84	31			1720	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	07/20/84	2.6			3400	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	08/08/84	0.08			3420	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	08/30/84	0.01			4640	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	09/20/84	0.06			4650	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	10/26/84	2.2			3400	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	12/12/84	1.7			4180	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	02/27/85	20			1970	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	03/08/85	6.5			2780	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	03/12/85	7.5			2280	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	03/21/85	9.4			1910	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	04/30/85	3.3			3400	
USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	05/24/85	1.3			3820	

Table 1.5 Surface Water Salinity – Unlisted Segments

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USGS	6177650	47.63085	-105.32860	Redwater River	Redwater River near Richey MT	09/26/85	0.12			4400	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	10/15/75	6.8		12	3100	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	11/21/75	5.1		13	3300	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	12/30/75	3.4		14	3600	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	01/28/76	3.2		13	4250	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	02/26/76	164		5	1020	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	03/22/76	163		4	990	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	04/30/76	20		11	3120	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	05/26/76	11		11	2940	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	06/13/76	982		4	812	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	07/20/76	28		8	2130	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	08/19/76	5.9		13	2750	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	09/21/76	3.1		12	2780	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	10/20/76	3.3		12	2900	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	11/18/76	5.1		12	3300	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	12/21/76	4		12	3550	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	01/17/77	0.3		12	3290	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	02/09/77	1		12	3120	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	03/07/77	18		11	2920	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	04/21/77	9.9		12	3260	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	05/19/77	24		13	3150	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	06/16/77	15		15	3290	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	07/13/77	0.94		16	3850	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	09/13/77	0.6		17	4000	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	10/20/77	1.4		12	2880	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	11/07/77	2		13	3050	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	12/12/77	0.66		14	4050	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	03/22/78	2830		2	430	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	04/28/78	32		9	2580	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	05/10/78	38		10	2720	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	06/09/78	92		8	3310	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	07/13/78	175		5	1650	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	08/10/78	17		9	2620	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	09/15/78	19		10	2450	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	10/23/78	16		10	2730	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	11/14/78	15		11	3300	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	12/13/78	7.9		14	4380	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	01/10/79	2.3		14	4390	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	02/21/79	1.6		12	4000	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	03/28/79	400		4	1250	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	04/10/79	4560		2	630	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	05/10/79	223		8	3380	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	06/06/79	54			3700	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	07/11/79	18		10	3400	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	08/01/79	12		11	3500	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	09/12/79	5.8		13	3480	

Table 1.5 Surface Water Salinity – Unlisted Segments

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USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	10/17/79	8		10	2870	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	11/07/79	7.8		11	3220	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	12/05/79	9.9		13	3820	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	01/09/80	1.8		14	4290	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	02/20/80	1.4		12	4100	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	03/27/80	33		9	2450	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	04/23/80	15		10	3190	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	05/19/80	7		15	4950	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	06/09/80	2.4		13	3690	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	07/28/80	0.03		17	4350	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	08/27/80	1		12	3400	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	09/17/80	1.6		12	3500	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	10/21/80	4		13	3160	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	11/18/80	6.1		13	3400	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	12/18/80	4			3360	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	01/19/81	4.1		14	3720	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	02/17/81	42		7	1360	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	03/30/81	9.4		11	2910	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	04/28/81	3.9		13	3420	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	05/21/81	2.2		14	3580	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	06/29/81	4.6		18	4220	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	07/30/81	2.2		14	3300	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	08/13/81	23		7	1460	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	09/24/81	0.73		14	3290	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	11/02/81	2.8		13	3080	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	12/03/81	3		12	3500	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	01/25/82	0.15		13	4440	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	03/03/82	56		4	909	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	04/21/82	37		9	2660	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	05/24/82	44		11	3080	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	06/23/82	17		13	3850	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	08/24/82	2.1		15	3620	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	09/20/82	1.8		15	3400	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	10/19/82	5.6			3030	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	11/30/82	4.9			4300	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	01/11/83	14			2920	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	03/09/83	60			1660	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	04/11/83	27			2620	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	05/24/83	16			3800	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	06/27/83	2.9			3620	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	09/26/83	0.02			4250	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	10/17/83	0.22			5000	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	11/28/83	2.1			3290	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	01/09/84	0.77			4180	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	02/01/84	5.1			4100	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	02/29/84	6.4			2780	

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USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	04/04/84	9.4			3290	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	05/14/84	4			3420	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	06/28/84	122			1220	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	08/06/84	2.2			2750	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	09/20/84	0.4			3900	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	10/26/84	1.4			3150	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	12/15/84	1.2			3730	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	02/27/85	85			1240	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	03/01/85	56			1370	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	03/08/85	14			2320	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	03/12/85	20			2450	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	03/21/85	20			1880	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	04/08/85	32			2720	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	05/23/85	1.5			3700	
USGS	6177825	47.90196	-105.21554	Redwater River	Redwater River near Vida MT	09/27/85	0.08			5000	
USGS	470511105542301	47.08639	-105.90639	Redwater River	T15N R46E S4 NW	10/21/77			0.5	1320	
USGS	470512105473701	47.08667	-105.79361	Lisk Creek	T15N R47E S5 NE	09/19/80			0.9	2820	
USGS	470717105563601	47.12139	-105.94333	Redwater River	T16N R46E S30 NE	10/12/77			13	3360	
USGS	471035105484701	47.17639	-105.81306	West Duck Creek	T16N R47E S6 NE	09/20/80			2	2750	
USGS	471038105514601	47.17722	-105.86278	Lisk Creek	T16N R46E S2 NE	10/08/77			34	2780	
USGS	471114105525001	47.18722	-105.88056	Redwater River	T17N R46E S32 SE	09/17/80			18	3180	
USGS	471229105554300	47.20806	-105.92861	Redwater River	T17N R45E S25 NW	07/29/75			0.3	1270	
USGS	471324105570900	47.22333	-105.95250	Trail Creek	T17N R45E S23 NW	07/22/75			18	3700	
USGS	471447105562800	47.24639	-105.94111	Trail Creek	T17N R45E S11 NE	07/28/75			2	2150	
USGS	471448105485201	47.24667	-105.81444	Duck Creek	T17N R46E S11 NE	09/17/80			24	3650	
USGS	471521105521101	47.25583	-105.86972	Redwater Trib	T17N R46E S4 SW	09/17/80			5	2340	
USGS	471521105551200	47.25583	-105.92000	Trail Creek	T17N R45E S1 SE	07/28/75			0.1	897	
USGS	471548105435801	47.26320	-105.73300	Ash Creek	T17N R47E S4 NE	09/16/80			1	960	
USGS	471626105580001	47.27389	-105.96667	Trail Creek	T18N R45E S34 SE	07/18/75			28	3080	
USGS	471631105575700	47.27528	-105.96583	Dirty Creek	T18N R45 S34 NE	07/18/75			34	3310	
USGS	471648105493300	47.28000	-105.82583	Redwater Trib	T18N R46E S35 NW	08/04/75			24	4640	
USGS	471708105333001	47.28556	-105.55833	Dry Ash Creek	T18N R48E S26 SE	09/16/80			2	4050	
USGS	471710105572900	47.28611	-105.95806	Dirty Creek	T18N R45E S27 SE	07/18/75			0.6	1240	
USGS	471714105281801	47.28722	-105.47167	Mccune Creek Trib	T18N R49E S27 SE	09/18/80			34	1930	
USGS	471908105342801	47.31889	-105.57444	McCune Creek	T18N R48E S14 SW	09/16/80			8	2750	
USGS	471912105214401	47.32000	-105.36222	Berry Creek	T18N R50E S16 SW	10/29/77			7	1800	
USGS	471920105424001	47.32222	-105.71111	Stoney Butte Creek	Stoney Butte Creek near Brockway MT	04/01/77	0.28		10	3020	
USGS	472010105421601	47.33611	-105.70444	Stony Butte Creek	T18N R47E S10 NE	09/16/80			53	2300	
USGS	472020105163501	47.33889	-105.27639	Sioux Creek	T18N R51E S7 NW	10/27/77			1	3110	
USGS	472120105524100	47.35556	-105.87806	Cotter Creek	T19N R46E S32 SE	07/23/75			0.1	621	
USGS	472120105532900	47.35556	-105.89139	Cotter Creek	T19N R46E S32 SW	07/23/75			2	1010	
USGS	472204105270500	47.36778	-105.45139	Buffalo Springs Creek	T19N R49E S34 NE	10/29/75			4	1760	
USGS	472225105501900	47.37361	-105.83861	Stony Butte Creek	T19N R46E S27 SE	07/23/75			0.3	1000	
USGS	472233105530000	47.37583	-105.88333	Cotter Creek	T19N R46E S29 SW	07/23/75			0.5	857	
USGS	472259105513500	47.38306	-105.85972	Cotter Creek	T19N R46E S28 NE	07/23/75			3	1820	
USGS	472302105275901	47.38389	-105.46639	Buffalo Springs Creek	T19N R49E S27 NW	07/27/82			2	1460	

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USGS	472330105445102	47.39167	-105.74750	Antelope Creek	T19N R47E S20 NE	07/29/75			10	2370	
USGS	472339105283901	47.39417	-105.47750	Gyp Creek	T19N R49E S21 NE	07/27/82			54	2150	
USGS	472351105150101	47.39750	-105.25028	Corral Creek	T19N R51E S20 NW	10/24/77			0.9	1920	
USGS	472356105395200	47.39889	-105.66444	Redwater Trib	T19N R47E S13 SE	07/28/75			2	2060	
USGS	472409105505700	47.40250	-105.84917	Stony Butte Creek	T19N R46E S15 SW	07/22/75			130	3920	
USGS	472414105522200	47.40389	-105.87278	Stony Butte Creek	T19N R46E S17 SE	07/22/75			6	2610	
USGS	472414105522500	47.40389	-105.87361	Stony Butte Creek	T19N R46E S17 SE	07/22/75			0.7	706	
USGS	472423105225501	47.40639	-105.38194	Sioux Creek	T19N R50E S17 NW	10/24/77			2	1680	
USGS	472444105400900	47.41222	-105.66917	Redwater Trib	T19N R47E S13 NE	07/28/75			6	4310	
USGS	472448105451000	47.41305	-105.74976	Antelope Creek	T19N R47E S8 SE	07/29/75			3	2000	
USGS	472448105454900	47.41333	-105.76361	Antelope Creek	T19N R47E S8 SW	07/29/75			1	1980	
USGS	472448105503800	47.41333	-105.84389	Stony Butte Creek	T19N R46E S10 SW	07/20/75			20	3260	
USGS	472448105530300	47.41333	-105.88417	Stony Butte Creek	T19N R46E S8 SW	07/22/75			2	991	
USGS	472450105354501	47.41389	-105.59583	Redwater River	T19N R48E S10 SW	07/29/82			86	1820	
USGS	472453105350301	47.41472	-105.88417	Redwater Trib	T19N R48E S10 SE	10/03/75			95	1550	
USGS	472453105530300	47.41472	-105.88417	Stony Butte Creek	T19N R46E S8 SW	07/22/75			35	2670	
USGS	472505105171001	47.41806	-105.28611	Corral Creek	T19N R50E S12 SE	10/22/77			7	2100	
USGS	472506105424300	47.41833	-105.71194	Redwater Trib	T19N R47E S10 SE	07/28/75			10	4160	
USGS	472510105424300	47.41944	-105.71194	Redwater Trib	T19N R47E S10 SE	07/28/75			39	3660	
USGS	472515105423600	47.42083	-105.71000	Redwater Trib	T19N R47E S10 NE	07/28/75			2	3200	
USGS	472515105524100	47.42083	-105.87806	Stony Butte Creek	T19N R46E S8 NE	07/22/75			0.3	1020	
USGS	472537105324300	47.42694	-105.54528	Cottonwood Creek	T19N R48E S12 NW	11/18/75			4	1230	
USGS	472555105341700	47.43194	-105.57139	Redwater Trib	T19N R48E S2 SW	11/18/75			32	2320	
USGS	472634105270500	47.44278	-105.45139	Redwater Trib	T20N R49E S34 SE	11/18/75			53	5070	
USGS	472653105303501	47.44806	-105.50972	Gyp Creek	T20N R49E S32 SW	07/29/82			21	7750	
USGS	472704105304201	47.45111	-105.51167	Redwater River	T20N R49E S32 NW	07/30/82			60	2300	
USGS	472741105305101	47.46139	-105.51417	Redwater River	T20N R49E S30 SE	07/29/82			28	2750	
USGS	472747105254801	47.46306	-105.43000	Cottonwood Creek	T20N R49E S26 SE	07/27/82			22	11500	
USGS	472806105265500	47.46833	-105.44861	Redwater Trib	T20N R49E S27 NE	11/21/75			2	1890	
USGS	472810105354300	47.46944	-105.59528	Redwater Trib	T20N R48E S22 SW	09/27/75			10	3090	
USGS	472853105252801	47.48139	-105.42444	Cottonwood Creek	at Highway 200	06/22/82	0.02			1290	
USGS	472905105315001	47.48472	-105.53056	Lost Creek	T20N R49E S18 SW	05/06/76			26	3400	
USGS	472905105315001	47.48472	-105.53056	Lost Creek	T20N R49E S18 SW	08/08/79			27	2290	
USGS	472907105315501	47.48528	-105.53194	Lost Creek	Lost Cr at Highyway 13 North of Circle MT	06/22/82	0.06			7300	
USGS	473035105390800	47.50972	-105.65222	Lost Creek	T20N R48E S7 NW	09/12/75			4	1340	
USGS	473038105022001	47.51056	-105.03889	Sullivan Creek	T20N R52E S12 NW	10/17/77			1	3350	
USGS	473052105253901	47.51444	-105.42750	Redwater River	Redwater River near Circle MT	06/22/82	7.7		10	3750	
USGS	473052105253901	47.51444	-105.42750	Redwater River	Redwater River near Circle MT	08/24/82	0.41		16	4500	
USGS	473052105253901	47.51444	-105.42750	Redwater River	Redwater River near Circle MT	10/19/82	1.1			3800	
USGS	473052105285701	47.51444	-105.48250	Buffalo Creek, South Fork	T20N R49E S4 SW	07/28/82			3	1620	
USGS	473135105320701	47.52639	-105.53528	Buffalo Creek, South Fork	T20N R48E S1 NE	07/28/82			50	2680	
USGS	473343105280200	47.56194	-105.46722	Spring Creek	T21N R49E S20 SW	09/18/75			21	4180	
USGS	473447105084800	47.57972	-105.14667	Sullivan Creek Trib	T21N R51E S14 SW	09/24/75			7	3230	
USGS	473450105040001	47.58056	-105.06667	Pasture Creek	T21N R52E S17 SE	09/08/76			3	865	

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USGS	473542104562701	47.58060	-105.06667	Lisk Creek, South Fork	T21N R53E S8 NE	05/04/76			0.7	2630	
USGS	473556105303800	47.59500	-104.94083	Duck Creek	T21N R48E S12 NW	09/19/75			57	2980	
USGS	473557105534100	47.59889	-105.51056	Middle Fork McGuire Creek	T21N R45E S12 NW	09/10/65			58	16500	
USGS	473641105205001	47.59920	-105.89470	Duck Creek	Duck Cr at Road Crossing nr Mouth nr Circle MT	06/22/82	0.11			3900	
USGS	473641105205001	47.61139	-105.34722	Duck Creek	Duck Cr at Road Crossing nr Mouth nr Circle MT	10/19/82	0.01			6250	
USGS	473719105491400	47.62190	-105.82060	East Fork Prarie Elk Creek	T22N R46E S33 SE	09/05/75			59	3460	
USGS	473743105502900	47.62860	-105.84140	East Fork Prarie Elk Creek	T22N R46E S32 NE	09/10/65			51	18700	
USGS	473750105172201	47.63056	-105.28944	Sullivan Creek	Sullivan Creek near Mouth near Richey MT	06/22/82	0.04			2950	
USGS	473750105172201	47.63139	-105.09194	Sullivan Creek	Sullivan Creek near Mouth near Richey MT	10/19/82	0.01			3940	
USGS	473753105053100	47.63140	-105.09194	Pasture Creek, East Fork	T22N R52E S30 SE	09/30/75			0.6	1140	
USGS	473757105200900	47.63250	-105.33583	Redwater River	T22N R50E S29 SW	09/17/75			6	1650	
USGS	473806104594500	47.63500	-104.99583	Lisk Creek, South Fork	T22N R52E S25 SW	10/10/75			39	5310	
USGS	473816105200001	47.63778	-105.33333	Cow Creek	Cow Creek at Mouth near Richey MT	06/22/82	0.51			4900	
USGS	473816105200001	47.63778	-105.33333	Cow Creek	Cow Creek at Mouth near Richey MT	10/19/82	0.15			4850	
USGS	473822105442300	47.63944	-105.73972	Cow Creek	T22N R47E S30 NW (S25)	02/02/65			64	4000	
USGS	473829105032401	47.64139	-105.05667	Lisk Creek, South Fork	T22N R52E S28 NW	10/03/75			84	1650	
USGS	473845105415302	47.64583	-105.69806	Cow Creek	T22N R47E S21 SW	08/13/75			0.5	1500	
USGS	473912104542700	47.65333	-104.90750	Kuester Reservoir trib	T22N R53E S22 NW	10/08/75			9	3700	
USGS	474058105085600	47.65750	-105.79310	Sullivan Creek Trib	T22N R51E S10 NE	09/24/75			60	2600	
USGS	474059105265800	47.68306	-105.44944	Cow Creek	T22N R49E S8 NE	09/19/75			4	1570	
USGS	474150105062200	47.69722	-105.10611	Sullivan Creek Trib	T22N R51E S1 NE	11/21/75			2	1700	
USGS	474206105362800	47.70167	-105.60778	Cow Creek	T22N R48E S6 NE	09/16/75			0.3	680	
USGS	474226105150301	47.70720	-105.25083	Pasture Creek	Pasture Creek near Mouth near Richey MT	06/23/82	0.48			4820	
USGS	474226105150301	47.70722	-105.25083	Pasture Creek	Pasture Creek near Mouth near Richey MT	10/19/82	0.25			3800	
USGS	474256105150401	47.71556	-105.25111	Redwater River	Redwater River Northwest of Richey MT	06/23/82	14		11	3350	
USGS	474256105150401	47.71556	-105.25111	Redwater River	Redwater River Northwest of Richey MT	08/24/82	1.2		13	3400	
USGS	474256105150401	47.71556	-105.25111	Redwater River	Redwater River Northwest of Richey MT	10/19/82	4.9			3200	
USGS	474312105425601	47.72000	-105.71556	Cow Creek	T23N R47E S29 SE	09/25/80			3	2200	
USGS	474335105225001	47.72639	-105.38056	Hay Creek	T23N R49E S25 NW	09/26/78			64	3500	
USGS	474355104024001	47.73194	-104.04444	Redwater Trib	T23N R52E S28 NE	08/30/78			68	3250	
USGS	474423105015400	47.73972	-105.03167	Lisk Creek, South Fork	T23N R52E S22 NW	10/23/75			2	1340	
USGS	474427105211700	47.74083	-105.35472	Hay Creek	T23N R50E S19 NW	06/16/52				123000	
USGS	474450105235601	47.74722	-105.39889	Hay Creek	T23N R49E S14 SW	09/23/80			0.1	1160	
USGS	474506105161200	47.75167	-105.27000	Gold Gulch	T23N R50E S14 SW	09/25/75			10	2170	

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USGS	474507105161200	47.75194	-105.27000	Gold Gulch	T23N R50E S14 SW	09/25/75			11	2370	
USGS	474520105054500	47.75556	-105.09583	Redwater Trib	T23N R52E S18 NW	11/21/75			46	4090	
USGS	474523105055300	47.75639	-105.09806	Redwater Trib	T23N R52E S18 NW	10/21/75			66	1940	
USGS	474535105531001	47.75970	-105.88610	Prairie Elk Creek Trib	T23N R45E S12 SE	09/27/78			67	5800	
USGS	474540105064500	47.76111	-105.11250	Sullivan Creek Trib	T23N R51E S13 NE	10/21/75			20	2560	
USGS	474625105510701	47.77362	-105.85251	Prairie Elk Creek	near Weldon MT	04/01/77	0.4		15	3950	
USGS	474635105481001	47.77640	-105.80280	Tony Coulee	T23N R46E S03 SW	09/27/78			72	3900	
USGS	474724105104600	47.79000	-105.17944	Sullivan Creek Trib	T23N R51E S4 NE	10/27/75			12	2290	
USGS	474810105464001	47.80280	-105.77780	Garton Coulee	T24N R46E S26 SW	10/07/78			91	2880	
USGS	474812105393501	47.80330	-105.65970	Middle Fork Sand Creek	T24N R47E S35 NW	10/20/85				1870	
USGS	474815105393601	47.80420	-105.66000	Middle Fork Sand Creek	T24N R47E S35 NW	09/28/80			30	4350	
USGS	474918105141001	47.82167	-105.23611	Lisk Creek	Lisk Creek at Mouth near Vida MT	06/22/82	0.02			6350	
USGS	474918105141001	47.82167	-105.23611	Lisk Creek	Lisk Creek at Mouth near Vida MT	10/19/82	0.02			5500	
USGS	474957105145701	47.83250	-105.24917	Redwater River	Redwater River East of Vida MT	06/22/82	16		12	3580	
USGS	474957105145701	47.83250	-105.24917	Redwater River	Redwater River East of Vida MT	08/24/82	1.2		15	3500	
USGS	474957105145701	47.83250	-105.24917	Redwater River	Redwater River East of Vida MT	10/19/82	5.4			3160	
USGS	475006105505201	47.83500	-105.84780	Sadie Coulee	T24N R46E S17 SW	09/29/80			40	3050	
USGS	475016105443700	47.83780	-105.74360	Remuda Creek	T24N R47E S18 SW	11/20/66				73200	
USGS	475117106001601	47.85470	-106.00440	Shade Creek	T24N R44E S12 SE	09/30/80			77	3150	
USGS	475145105532501	47.86250	-105.89030	Prairie Elk Creek Trib	T24N R45E S01 NW	10/05/78			47	1900	
USGS	475226105142301	47.87389	-105.23972	Redwater River	T25N R50E S35 SE	09/02/80			78	2570	
USGS	475324105485401	47.89000	-105.81500	Prairie Elk Creek Trib	T25N R46E S29 SW	09/01/80			65	5500	
USGS	475326105415901	47.89060	-105.69970	West Fork Sand Creek	T25N R47E S30 NE	09/26/80			15	5600	
USGS	475347104593302	47.89639	-104.99250	Duplisse Creek	T25N R52E S27 NW	11/12/75			2	1150	
USGS	475402105165001	47.90056	-105.28056	Redwater Trib	T25N R50E S21 SW	09/23/80			79	2330	
USGS	475425105465501	47.90694	-105.78194	Brown's Coulee	T25N R46E S21 NE	10/07/78			81	3590	
USGS	475519105503601	47.92194	-105.84333	Big Mud Creek	T25N R45E S13 NE	09/27/80			62	3150	
USGS	475525105225001	47.92361	-105.38056	Sheep Creek	T25N R49E S15 NW	10/06/78			72	2990	
USGS	475633105022601	47.94250	-105.04056	Long Grass Creek	T25N R52E S5 SW	09/03/80			4	2800	
USGS	475838105415301	47.97720	-105.69810	Crow Creek	T26N R47E S30 NE	09/26/80			27	2250	
USGS	475848105193501	47.98000	-105.32639	Sheep Creek	Sheep Cr at Road Crossing nr Mouth nr Vida MT	06/23/82	0.15			3410	
USGS	475848105193501	47.98000	-105.32639	Sheep Creek	Sheep Cr at Road Crossing nr Mouth nr Vida MT	10/20/82	0.09			2500	
USGS	480111105182001	48.01972	-105.30556	Redwater River	Redwater River 2 Miles South of Nickwall MT	10/25/79	9.4		10	3000	
USGS	480111105182001	48.01972	-105.30556	Redwater River	Redwater River 2 Miles South of Nickwall MT	06/23/82	25		12	3120	
USGS	480111105182001	48.01972	-105.30556	Redwater River	Redwater River 2 Miles South of Nickwall MT	08/24/82	2.2		14	3200	
USGS	480111105182001	48.01972	-105.30556	Redwater River	Redwater River 2 Miles South of Nickwall MT	10/19/82	7.7			2700	
USGS	480315105125001	48.05417	-105.21389	Redwater River	Redwater River 0.75 Mi at Mouth nr Poplar MT	10/25/79	7.4		12	3100	

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USGS	480315105125001	48.05417	-105.21389	Redwater River	Redwater River 0.75 Mi at Mouth nr Poplar MT	06/23/82	25		12	3310	
USGS	480315105125001	48.05417	-105.21389	Redwater River	Redwater River 0.75 Mi at Mouth nr Poplar MT	08/24/82	2.3		15	3400	
USGS	480315105125001	48.05417	-105.21389	Redwater River	Redwater River 0.75 Mi at Mouth nr Poplar MT	10/20/82	7.4			2890	
MONT-DEQ	2D	47.39604	-105.59789	Redwater River	At Union Bridge	05/25/99		4880	9.98		
21MTHDWQ	5185PA01	47.70800	-105.25140	Pasture Creek	At mouth	08/23/95			149.822		
21MTHDWQ	5480PR01	47.99944	-105.86472	Prairie Elk Creek	100 feet upstream from Highway 528 crossing	08/10/95			95.657		
21MTHDWQ	5481SA01	48.01420	-105.71440	Sand Creek	At mouth	08/21/95			35.779		
MONT-DEQ	G010001	47.69250	-105.49333	Cow Creek	At Highway 13 Bridge, Near Circle, MT.	03/01/76				1130	
21MTHDWQ	G010002	47.69250	-105.49330	Cow Creek	At Highway 13 Bridge, Near Circle, MT.	03/16/76				1190	
21MTHDWQ	G040001	47.79220	-104.86830	Jeffrey Creek		06/15/76				8220	
MONT-DEQ	G040002	47.79222	-104.86833	Jeffrey Creek		06/01/76				8000	
21MTHDWQ	G050001	47.49080	-105.53640	Lost Creek	At Highway 13 Bridge, Near Circle, MT.	03/16/76				2094	
MONT-DEQ	G050002	47.49083	-105.53639	Lost Creek	At Highway 13 Bridge, Near Circle, MT.	03/01/76				2040	
21MTHDWQ	G050003	47.53580	-105.62920	Lost Creek	Noname Reservoir, Near Lost Creek	08/29/75				4600	
MONT-DEQ	G050004	47.53583	-105.62917	Lost Creek	D/S of reservoir T21N, R47E, Sec. 36	08/01/75				4100	
MONT-DEQ	G070001	47.70640	-105.24560	Pasture Creek	At mouth	06/20/03					
21MTHDWQ	G070004	47.70810	-105.25140	Pasture Creek	At mouth	08/23/95			149.822		
MONT-DEQ	G080001	47.22056	-105.86722	Redwater River	At County Road, Near Mouth	10/01/74				8401	
MONT-DEQ	G080004	47.40220	-105.58640	Redwater River	Fairgrounds - RW-1	08/06/03				6090	
MONT-DEQ	G080004	47.40220	-105.58640	Redwater River	Fairgrounds - RW-1	08/13/03		5180		6220	
MONT-DEQ	G080004	47.40220	-105.58640	Redwater River	Fairgrounds - RW-1	08/20/03		5410		6480	
MONT-DEQ	G080004	47.40220	-105.58640	Redwater River	Fairgrounds - RW-1	08/27/03		5640		6650	
MONT-DEQ	G080004	47.40220	-105.58640	Redwater River	Fairgrounds - RW-1						
MONT-DEQ	G080005	47.41360	-105.57300	Redwater River	Cemetary Rd. - RW-2	08/06/03				5870	
MONT-DEQ	G080005	47.41360	-105.57300	Redwater River	Cemetary Rd. - RW-2	08/13/03		4750		5970	
MONT-DEQ	G080005	47.41360	-105.57300	Redwater River	Cemetary Rd. - RW-2	08/20/03		4710		5970	
MONT-DEQ	G080005	47.41360	-105.57300	Redwater River	Cemetary Rd. - RW-2	08/27/03		4870		6010	
MONT-DEQ	G080005	47.41360	-105.57300	Redwater River	Cemetary Rd. - RW-2						
21MTHDWQ	G080007	47.41640	-105.57190	Redwater River	At USGS Gaging Station, Near Circle, MT.	03/16/76				2445	
21MTHDWQ	G080007	47.41640	-105.57190	Redwater River	At USGS Gaging Station	08/15/78				3630	
21MTHDWQ	G080007	47.41640	-105.57190	Redwater River	At USGS Gaging Station	03/26/79				977	
21MTHDWQ	G080007	47.41640	-105.57190	Redwater River	At USGS Gaging Station	07/13/79				4652	
21MTHDWQ	G080007	47.41640	-105.57190	Redwater River	At USGS Gaging Station	10/15/79				4107	
MONT-DEQ	G080008	47.42370	-105.56890	Redwater River	Below airport - RW-3	08/06/03				5240	
MONT-DEQ	G080008	47.42370	-105.56890	Redwater River	Below airport - RW-3	08/13/03		3880		5140	
MONT-DEQ	G080008	47.42370	-105.56890	Redwater River	Below airport - RW-3	08/20/03		4010		5320	
MONT-DEQ	G080008	47.42370	-105.56890	Redwater River	Below airport - RW-3	08/27/03		4210		5510	
MONT-DEQ	G080008	47.42370	-105.56890	Redwater River	Below airport - RW-3						
MONT-DEQ	G080009	47.43490	-105.55770	Redwater River	HWY 13 - RW-4	08/06/03				5040	
MONT-DEQ	G080009	47.43490	-105.55770	Redwater River	HWY 13 - RW-4	08/13/03		3720		4850	
MONT-DEQ	G080009	47.43490	-105.55770	Redwater River	HWY 13 - RW-4	08/20/03		3770		4960	
MONT-DEQ	G080009	47.43490	-105.55770	Redwater River	HWY 13 - RW-4	08/27/03		3810		4960	

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MONT-DEQ	G080009	47.43490	-105.55770	Redwater River	HWY 13 - RW-4						
21MTHDWQ	G080011	47.42370	-105.56890	Redwater River	Downstream from Highway 201	08/23/90				3990	
21MTHDWQ	G080011	47.42370	-105.56890	Redwater River	Downstream from Highway 201	08/20/91				3450	
21MTHDWQ	G080012	48.05360	-105.21890	Redwater River	At County Road, Near Mouth	07/10/73				2200	
21MTHDWQ	G080012	48.05360	-105.21890	Redwater River	At County Road	10/22/74				3203	
21MTHDWQ	G080012	48.05360	-105.21890	Redwater River	At County Road	08/15/78				2689	
21MTHDWQ	G080012	48.05360	-105.21890	Redwater River	At County Road	03/25/79				1047	
21MTHDWQ	G080012	48.05360	-105.21890	Redwater River	At County Road	07/11/79				3294	
21MTHDWQ	G080012	48.05360	-105.21890	Redwater River	At County Road	10/15/79				3084	
MONT-DEQ	G080013	48.05361	-105.21889	Redwater River	At County Road	07/01/73				2200	
MONT-DEQ	G080013	48.05361	-105.21889	Redwater River	At County Road	10/01/74				3203	
21MTHDWQ	G090001	47.95720	-105.51390	Sheep Creek	Near Wolf Point, MT.	03/16/76				1656	
MONT-DEQ	G090002	47.95722	-105.51389	Sheep Creek	D/S of Highway 13 crossing	03/01/76				1620	
MONT-DEQ	M31TMBRC03	47.34720	-106.15400	Timber Creek	2.6 stream miles D/S of Highway 200 crossing	06/17/08	0.26			10510	5300
MONT-DEQ	M31TMBRC03	47.34720	-106.15400	Timber Creek	2.6 stream miles D/S of Highway 200 crossing	08/29/08	0			19935	11000
MONT-DEQ	M31TMBRC04	47.26160	-106.15430	Timber Creek	3.6 stream miles U/S of Skull Creek Road crossing	06/16/08	0.1			12200	5500
MONT-DEQ	M48PSTRC01	47.70640	-105.24560	Pasture Creek	1500 m Upstream of Mouth	06/20/03		3590	17		
MONT-DEQ	M48PSTRC01	47.70640	-105.24560	Pasture Creek	near mouth	06/20/03					
MONT-DEQ	M48PSTRC01	47.70640	-105.24560	Pasture Creek	1500 m Upstream of Mouth	06/17/08	0.14	4000		5514	
MONT-DEQ	M48PSTRC02	47.63970	-105.16180	Pasture Creek	1250 m Upstream of Bridge NW 1/4 S27T22NR51E	06/20/03		5980	15		
MONT-DEQ	M48PSTRC03	47.64585	-105.16706	Pasture Creek	Access road crossing ¼ mile north of Delp residence	06/18/08	0.127	6560		7916	
MONT-DEQ	M49PREKC01	47.95020	-105.89480	Prairie Elk Creek	Near Mouth	06/03/03		6020	14		
MONT-DEQ	M49PREKC01	47.95020	-105.89480	Prairie Elk Creek	near mouth	06/03/03				2500	
MONT-DEQ	M49PREKC02	47.76250	-105.84760	Prairie Elk Creek	T23N, R46E, SW¼ Sec.8	06/03/03		9530	26		
MONT-DEQ	M49PREKC02	47.76250	-105.84760	Prairie Elk Creek	T23N, R46E, SW¼ Sec.8	06/03/03				5600	
MONT-DEQ	M49PREKC02	47.76250	-105.84760	Prairie Elk Creek	T23N, R46E, SW¼ Sec.8	06/18/08	0.001			4170	
MONT-DEQ	M49PREKC03	47.72306	-105.83806	Prairie Elk Creek	at Garoutte's	07/12/03				4700	
MONT-DEQ	M49PREKC04	47.80944	-105.86917	Prairie Elk Creek	at B. Taylors	07/12/03				2900	
MONT-DEQ	M49PREKC05	48.00139	-105.86444	Prairie Elk Creek	near mouth at Hutterite colony	07/12/03				1100	
MONT-DEQ	M49PREKC06	47.67277	-105.84521	Prairie Elk Creek	Arnston Ranch Corral Complex	06/18/08	0			11560	
MONT-DEQ	M49PREKC07	47.62644	-105.81458	Prairie Elk Creek	Gibbs Ranch, 904 WELDON ROAD	06/18/08	0			9500	
MONT-DEQ	M49SANDC01	48.01610	-105.71500	Sand Creek	downstream of county bridge crossing	06/04/03				1900	
McConeCD	M49SANDC01	48.01610	-105.71500	Sand Creek	near mouth (d/s of bridge crossing)	06/04/03		5830	5.2		
MONT-DEQ	M49SANDC01	48.01610	-105.71500	Sand Creek	near mouth (d/s of bridge crossing)	06/18/08	1.17			1909	540
MONT-DEQ	M49SANDC01	48.01610	-105.71500	Sand Creek	near mouth (d/s of bridge crossing)	08/28/08	0.22			3844	800
MONT-DEQ	M49SANDC02	48.01611	-105.71444	Sand Creek	near mouth at Pipals	07/12/03				1500	
MONT-DEQ	M49SANDC02	48.01611	-105.71444	Sand Creek	near mouth at Pipals	06/18/08				732	180
MONT-DEQ	M49SANDC03	47.90579	-105.65429	Sand Creek	U/S of Hubbard Road crossing	06/18/08	0.32			7174	3000
MONT-DEQ	M49SANDC03	47.90579	-105.65429	Sand Creek	U/S of Hubbard Road crossing	08/28/08	0.3			7660	
MONT-DEQ	MCNPREK 06	48.00080	-105.85870	Prairie Elk Creek	At mouth	07/12/03		3470		1100	
MONT-DEQ	MCNPREK-01	47.72050	-105.83620	Prairie Elk Creek	¼ mile D/S Sally Coulee Confluence	07/12/03		3470		4700	
MONT-DEQ	MCNPREK-01	47.72050	-105.83620	Prairie Elk Creek	¼ mile D/S Sally Coulee Confluence	07/12/03		2090		4700	

Table 1.5 Surface Water Salinity – Unlisted Segments

Agency Code	Station ID	Latitude	Longitude	Station Name	Site Description	Activity Start Date	Instantaneous Discharge (cfs)	Total Dissolved Solids (mg/L)	Sodium Adsorption Ratio (SAR)	Specific Conductance (uS/cm)	Sulfate-S (mg/L)
MONT-DEQ	MCNPREK-01	47.72050	-105.83620	Prairie Elk Creek	¼ mile D/S Sally Coulee Confluence	07/12/03					
MONT-DEQ	MCNPREK-02	47.76250	-105.84760	Prairie Elk Creek	T23N, R46E, SW¼ Sec.8	07/12/03				5600	
MONT-DEQ	MCNPREK-03	47.80930	-105.87050	Prairie Elk Creek	T24N, R46E, SW¼ Sec. 30	07/12/03		2090		2900	
MONT-DEQ	MCNPREK-03	47.80930	-105.87050	Prairie Elk Creek	T24N, R46E, SW¼ Sec. 30	07/12/03					
MONT-DEQ	MCNPREK-04	47.84310	-105.86450	Prairie Elk Creek	At Pass Road Crossing	10/06/03				4380	
MONT-DEQ	MCNPREK-05	47.91370	-105.88430	Prairie Elk Creek	D/S of Highland Road crossing.	07/12/03				1300	
MONT-DEQ	MCNPREK-06	48.00080	-105.85870	Prairie Elk Creek	Near mouth- aka PRELK-06	07/12/03		536		1100	
MONT-DEQ	MCNPREK-06(near mouth)	48.00080	-105.85870	Prairie Elk Creek	At mouth	07/12/03		536			
MONT-DEQ	MCNPREK-3A	47.82790	-105.87830	Prairie Elk Creek	At Shade Creek confluence	10/06/03		3040		3820	
MONT-DEQ	MCNPREK-4(above Pass Croosing)	47.84310	-105.86450	Prairie Elk Creek	U/S Pass Road Crossing	10/06/03					
MONT-DEQ	MCNPREK-4A	47.86820	-105.87100	Prairie Elk Creek	Prairie Elk Creek, 2 miles D/S Pass Road crossing	09/16/03				3500	
MONT-DEQ	MCNPREK-4A	47.86820	-105.87100	Prairie Elk Creek	Prairie Elk Creek, 2 miles D/S Pass Road crossing	10/06/03				3440	
MONT-DEQ	MCNPREK-4A	47.86820	-105.87100	Prairie Elk Creek	Prairie Elk Creek, 2 miles D/S Pass Road crossing	10/06/03		2650			
MONT-DEQ	MCNPREK-4A	47.86820	-105.87100	Prairie Elk Creek	Prairie Elk Creek, 2 miles D/S Pass Road crossing	10/06/03		2340			
MONT-DEQ	MCNPREK-4A	47.86820	-105.87100	Prairie Elk Creek	Prairie Elk Creek, 2 miles D/S Pass Road crossing	10/06/03					
MONT-DEQ	MCNPREK-4A	47.86820	-105.87100	Prairie Elk Creek	Prairie Elk Creek, 2 miles D/S Pass Road crossing	06/18/08	0.6				
MONT-DEQ	MCNPREK-4B	47.88980	-105.86890	Prairie Elk Creek	U/S of Highland Rd. crossing	10/06/03				3280	
MONT-DEQ	MCNPREK-4B	47.88980	-105.86890	Prairie Elk Creek	U/S of Highland Rd. crossing	10/06/03		2250			
MONT-DEQ	MCNPREK-5A	47.92500	-105.88490	Prairie Elk Creek	At mouth of Bermuda Creek	10/06/03		1970		2210	
MONT-DEQ	MCNPREK-5B	47.95080	-105.89500	Prairie Elk Creek	D/S of Bermuda Creek mouth	10/06/03		5410		2880	
MONT-DEQ	MCNPREK-5B	47.95080	-105.89500	Prairie Elk Creek	D/S of Bermuda Creek mouth	10/06/03					
MONT-DEQ	MCNREDW-01	47.40220	-105.58640	Redwater River	Redwater River -Fairgrounds - aka RW-1	08/06/03				6090	
MONT-DEQ	MCNREDW-01	47.40220	-105.58640	Redwater River	Redwater River -Fairgrounds - aka RW-1	08/06/03		5050			
MONT-DEQ	MCNREDW-01	47.40220	-105.58640	Redwater River	Redwater River -Fairgrounds - aka RW-1	08/13/03				6220	
MONT-DEQ	MCNREDW-01	47.40220	-105.58640	Redwater River	Redwater River -Fairgrounds - aka RW-1	08/13/03		5180			
MONT-DEQ	MCNREDW-01	47.40220	-105.58640	Redwater River	Redwater River -Fairgrounds - aka RW-1	08/20/03				6480	
MONT-DEQ	MCNREDW-01	47.40220	-105.58640	Redwater River	Redwater River -Fairgrounds - aka RW-1	08/27/03		5640		6650	
MONT-DEQ	MCNREDW-01	47.40220	-105.58640	Redwater River	Redwater River -Fairgrounds - aka RW-1	05/05/04		4240		5240	
MONT-DEQ	MCNREDW-01	47.40220	-105.58640	Redwater River	Redwater River -Fairgrounds - aka RW-1	05/13/04		4350		5300	
MONT-DEQ	MCNREDW-01	47.40220	-105.58640	Redwater River	Redwater River -Fairgrounds - aka RW-1	05/27/04		4540		5370	
MONT-DEQ	MCNREDW-01	47.40220	-105.58640	Redwater River	Redwater River -Fairgrounds - aka RW-1	08/05/04		4650		5900	
MONT-DEQ	MCNREDW-01	47.40220	-105.58640	Redwater River	Redwater River -Fairgrounds - aka RW-1	08/16/04		4870		5800	
MONT-DEQ	MCNREDW-01	47.40220	-105.58640	Redwater River	Redwater River -Fairgrounds - aka RW-1	08/23/04		4990		5930	
MONT-DEQ	MCNREDW-01	47.40220	-105.58640	Redwater River	Redwater River -Fairgrounds - aka RW-1	08/30/04		5060		5950	
MONT-DEQ	MCNREDW-01	47.40220	-105.58640	Redwater River	Redwater River -Fairgrounds - aka RW-1	06/16/08	0.0097			5710	
MONT-DEQ	MCNREDW-01	47.40220	-105.58640	Redwater River	Redwater River -Fairgrounds - aka RW-1	08/02/08	0			7977	
MONT-DEQ	MCNREDW-02	47.41360	-105.57300	Redwater River	Redwater River -Cemetary Rd.	08/06/03		4710		5870	
MONT-DEQ	MCNREDW-02	47.41360	-105.57300	Redwater River	Redwater River -Cemetary Rd.	08/06/03		4750			
MONT-DEQ	MCNREDW-02	47.41360	-105.57300	Redwater River	Redwater River -Cemetary Rd.	08/13/03		4870		5970	

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MONT-DEQ	MCNREDW-02	47.41360	-105.57300	Redwater River	Redwater River -Cemetary Rd.	08/13/03		4750			
MONT-DEQ	MCNREDW-02	47.41360	-105.57300	Redwater River	Redwater River -Cemetary Rd.	08/20/03				5970	
MONT-DEQ	MCNREDW-02	47.41360	-105.57300	Redwater River	Redwater River -Cemetary Rd.	08/27/03				6010	
MONT-DEQ	MCNREDW-02	47.41360	-105.57300	Redwater River	Redwater River -Cemetary Rd.	05/05/04		3970		4990	
MONT-DEQ	MCNREDW-02	47.41360	-105.57300	Redwater River	Redwater River -Cemetary Rd.	05/13/04		4040		5000	
MONT-DEQ	MCNREDW-02	47.41360	-105.57300	Redwater River	Redwater River -Cemetary Rd.	05/20/04		3920		4940	
MONT-DEQ	MCNREDW-02	47.41360	-105.57300	Redwater River	Redwater River -Cemetary Rd.	05/27/04		3870		4820	
MONT-DEQ	MCNREDW-02	47.41360	-105.57300	Redwater River	Redwater River -Cemetary Rd.	08/05/04		5090		6490	
MONT-DEQ	MCNREDW-02	47.41360	-105.57300	Redwater River	Redwater River -Cemetary Rd.	08/16/04		4930		6030	
MONT-DEQ	MCNREDW-02	47.41360	-105.57300	Redwater River	Redwater River -Cemetary Rd.	08/23/04		4910		6150	
MONT-DEQ	MCNREDW-02	47.41360	-105.57300	Redwater River	Redwater River -Cemetary Rd.	08/30/04		4880		6170	
MONT-DEQ	MCNREDW-02	47.41360	-105.57300	Redwater River	Redwater River -Cemetary Rd.	06/07/05		4010		690	
MONT-DEQ	MCNREDW-02	47.41360	-105.57300	Redwater River	Redwater River -Cemetary Rd.	06/16/08	0.28			4810	
MONT-DEQ	MCNREDW-02	47.41360	-105.57300	Redwater River	Redwater River -Cemetary Rd.	08/27/08	0.15			7454	
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	08/06/03		4210		5240	
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	08/06/03					
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	08/13/03		3710		5140	
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	08/13/03		3880			
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	08/20/03				5320	
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	08/27/03				5510	
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	05/05/04				4780	
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	05/13/04		3700		4750	
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	05/20/04		3640		4680	
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	05/27/04		3690		4680	
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	06/23/04		3630		4990	
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	08/05/04				5110	
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	08/16/04		3730		4910	
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	08/23/04		3880		5070	
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	08/30/04		3670		8830	
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	10/06/04		4010		4300	
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	06/23/05		3880		3530	
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	06/16/08	0.162			4560	
MONT-DEQ	MCNREDW-03	47.42370	-105.56890	Redwater River	Redwater River- Below airport	08/27/08	0.056			5479	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	08/06/03				5040	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	08/06/03		4040			
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	08/13/03				4850	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	08/13/03		3720			
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	08/20/03		3770		4960	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	08/27/03		3810		4960	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	09/15/03					
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	11/09/03				5800	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	12/09/03				4840	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	01/15/04				4150	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	02/16/04				4150	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	03/25/04				2140	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	04/20/04				4250	

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MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	05/05/04		3740		4770	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	05/13/04		3730		4760	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	05/20/04		3790		4150	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	05/27/04		4340		5360	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	08/05/04		3840		5290	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	08/16/04		4000		5190	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	08/30/04		4050		5170	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	09/22/04				4560	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	10/18/04				4760	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	11/15/04				9470	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	12/15/04				4870	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	02/08/05				4480	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	03/07/05				3330	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	04/07/05				5180	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	06/07/05				1080	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	06/17/08	0.25			5458	
MONT-DEQ	MCNREDW-04	47.43490	-105.55770	Redwater River	Redwater River -HWY 13	08/27/08	0.0013			6650	
MONT-DEQ	MCNREDW-1-8	47.30528	-105.76694	Redwater River	At Brockway	06/07/05				474	
MONT-DEQ	MCNREDW-2C	47.54528	-105.37889	Redwater River	T21N, R49E, SW ¼ Sec. 25	06/23/04				4170	
MONT-DEQ	MCNREDW-2C	47.54528	-105.37889	Redwater River	T21N, R49E, SW ¼ Sec. 25	10/06/04				4250	
MONT-DEQ	MCNREDW-3A	47.71611	-105.24722	Redwater River	D/S or Pasture Creek mouth	06/23/04				3940	
MONT-DEQ	MCNREDW-3A	47.71611	-105.24722	Redwater River	D/S or Pasture Creek mouth	10/06/04				3750	
MONT-DEQ	MCNREDW-3A	47.71611	-105.24722	Redwater River	D/S or Pasture Creek mouth	06/22/05				2780	
MONT-DEQ	MCNREDW-3D	48.04694	-105.21639	Redwater River	T27N, R50E, SE ¼ Sec. 35	06/24/04				3420	
MONT-DEQ	MCNREDW-3D	48.04694	-105.21639	Redwater River	T27N, R50E, SE ¼ Sec. 35	10/06/04				3500	
MONT-DEQ	MCN-REDW-3D	48.04694	-105.21639	Redwater River	T27N, R50E, SE ¼ Sec. 35	06/22/05				2450	
MONT-DEQ	MCNREDW-3G	47.92917	-105.25980	Redwater River	T25N, R50E, SE ¼ Sec. 9	06/24/04				3730	
MONT-DEQ	MCNREDW-3G	47.92917	-105.25980	Redwater River	T25N, R50E, SE ¼ Sec. 9	10/06/04				3650	
MONT-DEQ	MCNREDW-3G	47.92917	-105.25980	Redwater River	T25N, R50E, SE ¼ Sec. 9	06/22/05				2960	
MONT-DEQ	MCNSAND-01	48.01600	-105.71470	Sand Creek	At the mouth	07/12/03		983		1500	
MONT-DEQ	MCNSAND-02	47.90340	-105.65940	Sand Creek	T25N, R47E, NE¼ Sec. 21	09/16/03				17880	
MONT-DEQ	MCNSAND-03	47.86850	-105.64060	Sand Creek	T25N, R47E, SE¼ Sec. 34	09/16/03		12400		13400	
MONT-DEQ	MCNSAND-2A	47.97620	-105.65630	Sand Creek	T26N, R47E, SE¼ Sce. 28	09/16/03		2440		3550	
MONT-DEQ	MCNTMBR-01	47.16950	-106.12030	Timber Creek	1.5 miles U/S of Last Chance Road crossing	07/10/03				7440	
MONT-DEQ	MCNTMBR-01	47.16950	-106.12030	Timber Creek	1.5 miles U/S of Last Chance Road crossing	07/10/03		7680			
MONT-DEQ	MCNTMBR-02	47.26200	-106.15270	Timber Creek	3.6 stream miles U/S of Skull Creek Road crossing	07/10/03				21000	
MONT-DEQ	MCNTMBR-04	47.13770	-106.16670	Timber Creek	1 mi U/S from HWY 200 crossing	07/10/03		6760		11400	
MONT-DEQ	MCNTMBR-05	47.39420	-106.16490	Timber Creek	1.7 miles U/S of Highway 24 crossing	07/10/03				8070	
MONT-DEQ	MCNTMBR-06	47.45890	-106.22260	Timber Creek	400 m D/S of Shed Creek confluence	07/10/03				4520	
MONT-DEQ	MCNTMBR-06	47.45890	-106.22260	Timber Creek	400 m D/S of Shed Creek confluence	07/10/03		3260			
	Prairie Elk PE-01	47.72050	-105.83620	Prairie Elk Creek				2630	13.7		
	Redwater (3-A)	47.71611	-105.24722	Redwater River				2050	8.22		
	Redwater (3-D)	48.04694	-105.21639	Redwater River				2030			
	Redwater (RW-03)	47.42370	-105.56890	Redwater River				2730	8.15		

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	Redwater 1-8	47.30528	-105.76694	Redwater River		06/07/05		444	1.7		
	Redwater RW-02A	47.41300	-105.58334	Redwater River		06/07/05		614			
	Redwater RW-04	47.43490	-105.55770	Redwater River		06/07/05		656	3.54		
	Site 2D	47.39583	-105.59722	Redwater River		05/26/99	1.25	4910	10.3		
	Site 2F	47.42500	-105.57250	Redwater River		05/26/99	1.3	4580	10.7		
	Site 3A	47.71611	-105.24722	Redwater River		05/25/99	2.5	2970	10.8		
	Site 3B	47.70790	-105.25184	Pasture Creek		05/25/99	2.5	3760	12.7		
	Site 3D Nickwall Crossing	48.04694	-105.21639	Redwater River		05/25/99	25	3280	12.2		
	Site 3EF	47.89889	-105.20528	Redwater River		05/26/99	4	4010	16.5		
	Site 3H,Reach 1	47.77833	-105.23389	Redwater River		05/25/99	3	10400	16.7		
	Site 8, Reach 1	47.30500	-105.76694	Redwater River		05/26/99	0.75	6560	10.7		
	Site2B	47.57778	-105.35583	Redwater River		05/24/99	2.25	3450	11.3		

Table 1.6 Redwater TPA Ground Water Quality

SUBBASIN NAME	SAMPLE ID	GWIC ID	LAT	LONG	SAMPLE DATE	TWNSHP	RNG	SEC	TRACT	AQUIFER	TOTAL DEPTH (ft)	TEMP (ºC)	PH (SU)	SC (µmhos/cm)	CA (mg/L)	MG (mg/L)	NA (mg/L)	K (mg/L)	FE (mg/L)	MN (mg/L)	HCO3 (mg/L)	SO4 (mg/L)	CL (mg/L)	NO3_N (mg/L)
LOWER REDWATER	1952Q0005	895035	47.74080	-105.35470	6/16/1952	23N	50E	19	BDC	337MSNC	0.0		9.00	0	1800.0	280.0	46000 k		0.00		280	4200	72000.00	0.00
TIMBER CREEK	1975Q0917	2348	47.35410	-106.16660	7/15/1975	19N	44E	31	CCDA	125TGRV	78.0	9.5	7.00	3437	78.0	66.0	700.0	6.30	0.00	0.08	911	1223	8.00	1.00
TIMBER CREEK	1975Q0918	2347	47.37440	-106.14860	7/15/1975	19N	44E	29	CBBB	125TGRV	90.0	10.0	8.00	2092	3.0	1.0	514.0	1.90	0.00	<.01	751	460	22.00	1.00
NELSON	1975Q0919	2343	47.43380	-106.04660	7/15/1975	19N	44E	1	ADCD	125TGRV	60.0	9.0	8.00	1906	98	66	295.0	4.80	0.00	0.14	566	660	6.00	0.00
TIMBER CREEK	1975Q0923	2345	47.39610	-106.16720	7/17/1975	19N	44E	19	BBAB	125LEBO	141.0	0.0	8.00	2233	4.0	2.0	592.5	2.00	0.00	<.01	1053	325	43.00	3.00
TIMBER CREEK	1975Q0924	2207	47.30580	-106.16000	7/16/1975	18N	44E	19	BDAD	125TGRV	100.0	0.0	8.00	2648	7.0	4.0	627.5	2.40	0.00	0.01	627	847	18.00	2.00
TIMBER CREEK	1975Q0925	2206	47.31160	-106.12610	7/16/1975	18N	44E	16	CCCB	125TGRV	123.0	0.0	9.00	4635	9.0	28.0	1075.0	4.80	0.00	0.01	315	1994	21.00	4.00
UPPER REDWATER	1975Q1016	2357	47.41330	-105.84380	7/21/1975	19N	46E	10	CDCA	125TGRV	108.0	0.0	8.00	3264	43.0	44.0	765.0	4.90	0.00	0.10	1174	965	10.00	2.00
UPPER REDWATER	1975Q1017	2356	47.41330	-105.88410	7/22/1975	19N	46E	8	CDDB	125TGRV	135.0	12.0	8.00	991	50.0	46.0	97.0	5.40	0.00	0.01	531	99	2.00	0.00
UPPER REDWATER	1975Q1019	2354	47.42080	-105.87800	7/22/1975	19N	46E	8	ACDA	125TGRV	63.0	9.0	7.00	1020	128.0	57.0	15.4	3.20	0.00	0.01	661	36	4.00	6.00
UPPER REDWATER	1975Q1020	2360	47.40380	-105.87360	7/22/1975	19N	46E	17	DAAC	125TGRV	135.0	0.0	7.00	706	48.0	50.0	29.4	3.20	0.00	0.04	393	68	3.00	1.00
TIMBER CREEK	1975Q1024	2208	47.29000	-106.16270	7/17/1975	18N	44E	30	BDCA	125TGRV	140.0	0.0	8.00	3272	10.0	7.0	825.0	3.10	0.00	0.01	985	1028	7.00	1.00
UPPER REDWATER	1975Q1029	2143	47.22330	-105.95250	7/22/1975	17N	45E	23	BBAB	125TGRV	130.0	0.0	8.00	3705	50.0	65.0	810.0	7.90	0.00	0.06	1430	969	7.00	2.00
TIMBER CREEK	1975Q1030	2139	47.26300	-105.99250	7/22/1975	17N	45E	4	BDBB	125TGRV	140.0	10.0	7.00	4135	136.0	116.0	792.5	9.50	0.00	0.08	1176	1525	3.00	4.00
TIMBER CREEK	1975Q1031	2126	47.25190	-106.05130	7/22/1975	17N	44E	12	ABBC	125TGRV	100.0	0.0	8.00	3828	166.0	131.0	707.5	9.10	0.00	0.58	1260	1445	6.00	2.00
TIMBER CREEK	1975Q1032	2124	47.26360	-106.04800	7/22/1975	17N	44E	1	ACAA	125TGRV	72.0	0.0	7.00	3047	175.0	142.0	440.0	11.40	0.00	0.10	1062	1100	6.00	2.00
UPPER REDWATER	1975Q1180	2362	47.37360	-105.83860	7/23/1975	19N	46E	27	DBCA	125TGRV	48.0	9.0	7.00	1005	108.0	66.0	18.0	4.00	0.00	0.20	422	240	5.00	0.00
UPPER REDWATER	1975Q1183	2366	47.35550	-105.87800	7/23/1975	19N	46E	32	DCDD	125TGRV	56.0	9.5	6.00	621	84.0	29.0	3.4	2.20	0.00	<.01	372	26	4.00	1.00
UPPER REDWATER	1975Q1184	2376	47.39880	-105.66440	7/28/1975	19N	47E	13	DDCB	125TGRV	33.0	9.0	7.00	2055	171.0	138.0	139.0	6.40	0.00	0.60	904	510	1.00	1.00
UPPER REDWATER	1975Q1185	2375	47.41220	-105.66910	7/28/1975	19N	47E	13	ABBA	125TGRV	50.0	9.0	7.00	4308	299.0	230.0	532.5	9.60	0.00	0.70	785	2126	8.00	4.00
UPPER REDWATER	1975Q1186	2374	47.41830	-105.71190	7/28/1975	19N	47E	10	DBBD	125TGRV	60.0	8.0	7.00	4160	119.0	173.0	765.0	10.90	0.00	0.06	667	1987	6.00	3.00
UPPER REDWATER	1975Q1188	2372	47.42080	-105.71000	7/28/1975	19N	47E	10	ACDC	110ALVM	20.0	8.0	7.00	3198	237.0	248.0	230.0	2.70	0.00	<.01	379	1706	4.00	7.00
HORSE	1975Q1189	2367	47.44020	-105.66660	7/28/1975	19N	47E	1	ABAD	125TGRV	100.0	0.0	7.41	2976	87.3	83.8	514.0	4.80	0.01	<.01	628.7	1094.40	6.55	1.20
HORSE	1975Q1190	2368	47.43750	-105.68580	7/28/1975	19N	47E	2	ADBB	125TGRV	63.1	9.0	7.74	1638	28.6	41.3	287.0	4.70	0.01	<.01	500.4	454.60	3.25	1.00
HORSE	1975Q1191	2369	47.43750	-105.68580	7/28/1975	19N	47E	2	ADBB	125TGRV	90.0	10.0	7.67	3227	104.4	83.4	566.0	5.60	0.01	<.01	854	1083.20	6.70	4.00
UPPER REDWATER	1975Q1192	2370	47.41330	-105.76360	7/29/1975	19N	47E	8	CCDC	125TGRV	85.0	10.0	7.00	1980	183.0	139.0	92.0	3.80	0.00	<.01	495	667	45.00	20.00
UPPER REDWATER	1975Q1193	2371	47.41330	-105.75270	7/29/1975	19N	47E	8	DCDC	125TGRV	61.0	8.0	7.00	2001	112.0	119.0	199.0	8.10	0.00	0.07	938	429	4.00	4.00

Table 1.6 Redwater TPA Ground Water Quality

SUBBASIN NAME	SAMPLE ID	GWIC ID	LAT	LONG	SAMPLE DATE	TWNSHP	RNG	SEC	TRACT	AQUIFER	TOTAL DEPTH (ft)	TEMP (°C)	PH (SU)	SC (µmhos/cm)	CA (mg/L)	MG (mg/L)	NA (mg/L)	K (mg/L)	FE (mg/L)	MN (mg/L)	HCO3 (mg/L)	SO4 (mg/L)	CL (mg/L)	NO3_N (mg/L)
UPPER REDWATER	1975Q1194	2377	47.39160	-105.74750	7/29/1975	19N	47E	20	ADDC	125TGRV	20.0	5.5	7.00	2369	63.0	66.0	445.0	5.40	0.00	0.08	878	673	6.00	1.00
HORSE	1975Q1195	2488	47.46830	-105.86130	8/12/1975	20N	46E	28	ABBC	125TGRV	120.2	12.0	6.94	1435	99.0	91.0	116.0	6.30	0.06	0.14	639.2	351.60	3.85	0.20
UPPER REDWATER	1975Q1198	2140	47.24630	-105.94110	7/28/1975	17N	45E	11	ACDD	125TGRV	65.0	0.0	7.00	2152	161.0	136.0	168.5	7.50	0.00	0.01	840	636	4.00	1.00
UPPER REDWATER	1975Q1199	2142	47.24770	-105.93300	7/28/1975	17N	45E	12	BCBD	125TGRV	105.0	0.0	7.00	1063	113.0	68.0	17.4	4.30	1.00	0.19	318	319	11.00	0.00
UPPER REDWATER	1975Q1200	2138	47.25580	-105.92000	7/28/1975	17N	45E	1	DCAA	125TGRV	50.0	10.0	7.00	897	122.0	49.0	6.6	2.80	0.00	0.60	500	105	1.00	0.00
TIMBER CREEK	1975Q1201	2137	47.18910	-106.04800	7/29/1975	17N	44E	36	ACDD	125TGRV	95.0	9.0	8.00	3193	45.0	35.0	712.5	6.80	0.00	0.05	1107	879	7.00	2.00
TIMBER CREEK	1975Q1202	2062	47.17880	-106.04770	7/29/1975	16N	45E	5	AABC	125TGRV	76.0	13.0	8.00	3411	16.0	12.0	848.0	4.00	0.00	<.01	944	1146	8.00	1.00
UPPER REDWATER	1975Q1203	2144	47.20800	-105.92860	7/29/1975	17N	45E	25	BABC	125TGRV	86.0	0.0	7.00	1269	143.0	86.0	21.1	4.70	0.00	0.10	811	103	2.00	1.00
UPPER REDWATER	1975Q1204	2216	47.28110	-105.82500	8/4/1975	18N	46E	35	BBAD	125TGRV	144.0	11.0	8.00	4645	80.0	56.0	1167.5	7.40	0.00	0.05	1811	1404	21.00	2.00
MCGUIRE CREEK	1975Q1205	2615	47.56910	-106.04250	8/7/1975	21N	44E	23	BBDC	125LEBO	123.0	11.0	8.00	4990	28.0	11.0	1230.0	4.70	0.00	0.02	1284	1660	15.00	3.00
LOWER REDWATER	1975Q1206	2755	47.64580	-105.69800	8/13/1975	22N	47E	21	CDCC	125TGRV	70.0	8.5	7.00	1443	134.0	121.0	34.4	4.10	0.00	0.89	605	398	4.00	0.00
MCGUIRE CREEK	1975Q1283	2619	47.54020	-105.93580	8/18/1975	21N	45E	34	BBDA	110ALVM	17.0	8.0	7.00	6542	164.0	311.0	1116.0	19.20	0.00	0.11	915	3172	44.00	26.00
MCGUIRE CREEK	1975Q1287	2620	47.53660	-105.91500	8/20/1975	21N	45E	35	BCDC	125TGRV	119.0	9.5	7.00	3487	26.0	32.0	787.5	5.30	0.00	0.04	1125	975	10.00	0.00
MCGUIRE CREEK	1975Q1290	2753	47.64160	-105.99550	9/3/1975	22N	45E	30	BADC	125LEBO	150.0	13.0	7.00	4720	35.0	18.0	1117.5	4.60	0.00	0.03	1294	1445	11.00	3.00
TIMBER CREEK	1975Q1380	2125	47.26130	-106.08800	7/23/1975	17N	44E	3	ADCD	125TGRV	34.0	10.0	8.00	2144	193.0	81.0	230.0	6.20	0.00	1.45	718	681	6.00	2.00
TIMBER CREEK	1975Q1381	2128	47.23750	-106.13880	7/23/1975	17N	44E	17	BAAD	125TGRV	46.0	9.0	8.00	2863	120.0	103.0	448.0	6.00	0.00	<.01	722	1078	8.00	0.00
TIMBER CREEK	1975Q1388	2059	47.17830	-106.12110	7/24/1975	16N	44E	2	BABB	110ALVM	26.0	9.0	8.00	4173	70.0	47.0	936.0	8.00	0.00	0.00	976	1566	6.00	3.00
TIMBER CREEK	1975Q1389	2136	47.18410	-106.08800	7/24/1975	17N	44E	34	DDBA	125TGRV	126.0	10.5	9.00	3530	10.0	44.0	776.0	7.50	0.00	<.01	517	1364	12.00	1.00
MCGUIRE CREEK	1975Q1538	2752	47.64580	-106.03190	8/7/1975	22N	44E	23	DDBC	125LEBO	37.0	7.0	8.00	1567	91.0	60.0	193.0	3.70	0.00	0.01	448	522	7.00	0.00
HORSE	1975Q1543	2487	47.52160	-105.81250	8/8/1975	20N	46E	2	ADCD	125TGRV	29.5	7.0	8.08	1021	78.4	63.0	51.0	3.60	<.01	<.01	277.6	278.90	48.20	0.80
PASTURE CREEK	1975Q1546	2760	47.68270	-105.14880	9/24/1975	22N	51E	10	ADDA	125TGRV	111.0		9.00	2601	4.0	3.0	617.5	2.20	0.00	<.01	665	691	13.00	1.00
LOWER REDWATER	1975Q1647	2624	47.56190	-105.46720	9/18/1975	21N	49E	20	CCBA	125TGRV	76.0	0.0	8.00	4179	57.0	60.0	935.0	7.20	0.00	0.09	1220	1368	7.00	2.00
PASTURE CREEK	1975Q1648	2625	47.57970	-105.14660	9/24/1975	21N	51E	14	CBBB	125TGRV	138.0	12.0	8.00	3232	163.0	124.0	495.0	8.40	0.00	0.15	726	1368	5.00	2.00
LOWER REDWATER	1975Q1649	2494	47.48750	-105.39610	10/1/1975	20N	50E	18	CDDA	125TGRV	120.0		8.00	1283	98.0	69.0	98.5	5.10	0.00	0.02	405	386	3.00	1.00
EAST REDWATER	1975Q1650	3008	47.81630	-105.05860	10/7/1975	24N	52E	28	BBAD	110ALVM	33.0	10.0	8.00	2252	49.0	115.0	317.0	2.00	0.00	0.00	443	811	27.00	23.00
LOWER REDWATER	1975Q1651	2758	47.63250	-105.33580	9/17/1975	22N	50E	29	CCDB	110ALVM	25.0		9.00	1653	26.0	68.0	250.0	5.10	0.00	<.01	348	354	111.00	0.00
LOWER REDWATER	1975Q1652	2906	47.75190	-105.27000	9/25/1975	23N	50E	14	CACB	110ALVM	39.0		8.00	23740	51.0	46.0	460.0	4.80	0.00	<.01	772	677	8.00	3.00
LOWER REDWATER	1975Q1653	2907	47.75160	-105.27000	9/25/1975	23N	50E	14	CACC	110ALVM	26.0		8.00	2173	59.0	43.0	436.0	4.60	0.00	0.04	806	612	5.00	1.00

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PASTURE CREEK	1975Q1654	2762	47.63130	-105.09190	9/30/1975	22N	52E	30	DCCD	125TGRV	60.0		8.00	1137	68.0	100.0	37.0	7.20	0.00	<.01	464	240	12.00	13.00
EAST REDWATER	1975Q1694	3010	47.83380	-104.91130	10/13/1975	24N	53E	15	CCCD	110ALVM	30.0	0.0	8.00	1235	115.0	83.0	46.0	3.00	0.00	0.00	405	385	3.00	3.00
EAST REDWATER	1975Q1698	2915	47.75440	-104.82910	10/17/1975	23N	54E	18	ADDA	125TGRV	51.0	9.0	8.00	600	85.0	31.0	3.0	2.00	0.00	0.00	395	30	2.00	1.00
EAST REDWATER	1975Q1736	3063	47.89630	-104.99410	11/12/1975	25N	52E	27	BABB	110ALVM	40.0	0.0	8.00	1708	159.0	102.0	131.0	4.00	0.00	0.00	475	648	4.00	4.00
UPPER REDWATER	1975Q1781	2379	47.42690	-105.54520	11/18/1975	19N	48E	12	BAAB	125TGRV	80.2	10	7.77	1234	55.7	43.5	162.0	3.80	0.01	0.05	429	308	6.30	0.30
TIMBER CREEK	1975Q1782	2203	47.33110	-106.21580	9/8/1975	18N	43E	10	DABD	125LEBO	110.0	11.0	8.00	2200	190.0	176.0	91.0	6.00	0.00	0.00	581	748	44.00	21.00
LOWER REDWATER	1975Q1784	2759	47.69720	-105.10610	11/21/1975	22N	51E	1	ADDA	125TGRV	40.0	7.5	7.00	1699	111.0	120.0	116.0	4.90	6.00	0.15	446	642	6.00	0.00
LOWER REDWATER	1975Q1785	2910	47.75550	-105.09580	10/21/1975	23N	52E	18	BDAC	125TGRV	88.0	0.0	8.00	4091	15.0	14.0	1025.0	5.00	0.00	0.00	1415	1148	12.00	2.00
LOWER REDWATER	1975Q1788	2378	47.43190	-105.57130	11/18/1975	19N	48E	2	CBDA	125TGRV	109.0	10.5	8.00	2321	9.0	9.0	584.0	3.20	0.00	0.01	1191	344	17.00	0.00
EAST REDWATER	1975Q1806	3067	47.87380	-104.88440	11/21/1975	25N	53E	33	CABA	125TGRV	72.0	0.0	8.00	1330	178.0	81.0	18.0	4.00	0.00	0.00	504	387	7.00	1.00
MCGUIRE CREEK	1976Q1087	2614	47.57630	-106.07750	9/3/1976	21N	44E	16	DBCD	110ALVM	15.0	10.5	8.00	772	55.0	39.0	59.0	3.00	0.00	<.01	292	148	10.00	5.00
PASTURE CREEK	1976Q1157	2626	47.57860	-105.07880	9/8/1976	21N	52E	17	CABC	125TGRV	38.0		8.00	888	39.0	45.0	108.0	3.40	3.00	0.08	552	62	18.00	0.00
LOWER REDWATER	1976Q5000	143805	47.59500	-104.94040	5/4/1976	21N	53E	8	DABB	125TGRV	68.0	11.0	0.00	0	270.0	240.0	67.0	8.50	1.00	0.46	651	1200	6.00	0.00
LOWER REDWATER	1979Q3206	2491	47.48470	-105.53050	8/8/1979	20N	49E	18	CCDC	125TGRV	120.0	26.8	9.00	3428	28.0	22.0	789.0	4.60	0.00	0.02	1157	830	10.00	0.00
NELSON	1979Q3207	2483	47.47050	-106.00330	8/11/1979	20N	45E	20	DDBC	125TGRV	120.0	26.0	8.00	4081	41	26	960.0	5.40	0.00	0.03	987	1400	9.00	2.00
NELSON	1979Q3208	2484	47.46330	-106.02910	8/11/1979	20N	45E	30	DBAB	125TGRV	57.0	26.0	2.00	2288	99	79	344.0	5.40	5.00	0.24	293	1005	10.00	5.00
UPPER REDWATER	1980Q2477	2218	47.31880	-105.57440	9/16/1980	18N	48E	14	CBBA	125TGRV	88.0	8.0	7.00	2819	111.0	84.0	458.0	5.20	4.00	0.64	559	1113	12.00	0.00
UPPER REDWATER	1980Q2478	2219	47.28550	-105.55830	9/16/1980	18N	48E	26	DDBA	125TGRV	140.0	13.0	7.00	4127	435.0	392.0	182.0	11.80	6.00	0.31	876	2313	14.00	0.00
UPPER REDWATER	1980Q2479	2146	47.24660	-105.81440	9/17/1980	17N	46E	11	ADCC	125TGRV	72.0	8.0	8.00	3830	40.0	34.0	848.0	4.60	0.00	0.04	871	1323	18.00	1.00
UPPER REDWATER	1980Q2480	2145	47.25580	-105.86970	9/17/1980	17N	46E	4	CCAC	125TGRV	80.0	9.0	8.00	2411	144.0	118.0	339.0	8.90	2.00	0.12	801	901	8.00	3.00
UPPER REDWATER	1980Q2481	2147	47.18720	-105.88050	9/17/1980	17N	46E	32	DBAB	125TGRV	50.0	9.0	8.00	3444	48.0	41.0	721.0	5.50	0.00	0.03	867	1108	17.00	0.00
UPPER REDWATER	1980Q2484	2148	47.26330	-105.73270	9/16/1980	17N	47E	4	ACBA	125TGRV	67.0	9.0	8.00	1468	124.0	94.0	78.6	5.70	0.00	0.05	372	533	9.00	0.00
UPPER REDWATER	1980Q2485	2217	47.33610	-105.70440	9/16/1980	18N	47E	10	ADAA	125TGRV	114.0	14.0	9.00	2360	4.0	3.0	560.0	1.80	0.00	0.01	805	492	18.00	0.00
UPPER REDWATER	1980Q2490	2063	47.17630	-105.81300	9/20/1980	16N	47E	6	ADAA	125TGRV	72.0	10.0	7.00	0	216.0	230.0	166.0	6.00	0.00	0.01	411	1450	20.00	3.00
UPPER REDWATER	1980Q2492	1987	47.08660	-105.79360	9/19/1980	15N	47E	5	ADCD	125TGRV	83.0	8.5	8.00	2931	262.0	283.0	89.0	9.00	4.00	0.07	736	1390	7.00	2.00
LOWER REDWATER	1980Q2497	2904	47.74720	-105.39880	9/23/1980	23N	49E	14	CDCC	125TGRV	75.0	9.0	8.00	1172	191.0	45.0	8.3	9.70	0.00	0.06	515	253	7.00	0.00
LOWER REDWATER	1980Q2502	3005	47.83190	-105.45970	9/24/1980	24N	49E	20	BAAD	125LEBO	65.0	10.0	8.00	1219	119.0	79.0	45.4	5.00	1.00	0.18	628	209	8.00	0.00
LOWER REDWATER	1980Q2503	2902	47.72000	-105.71550	9/25/1980	23N	47E	29	DCBB	125TGRV	50.0	8.0	8.00	2284	189.0	124.0	190.0	5.00	0.00	0.03	562	880	16.00	2.00
LOWER	1980Q2508	3218	47.97520	-105.31050	9/23/1980	26N	50E	30	DBBD	125TLCK	42.0	8.5	8.00	5792	96.0	45.0	1371.0	8.40	9.00	0.21	1142	2341	35.00	0.00

Table 1.6 Redwater TPA Ground Water Quality

SUBBASIN NAME	SAMPLE ID	GWIC ID	LAT	LONG	SAMPLE DATE	TWNSHP	RNG	SEC	TRACT	AQUIFER	TOTAL DEPTH (ft)	TEMP (°C)	PH (SU)	SC (µmhos/cm)	CA (mg/L)	MG (mg/L)	NA (mg/L)	K (mg/L)	FE (mg/L)	MN (mg/L)	HCO3 (mg/L)	SO4 (mg/L)	CL (mg/L)	NO3_N (mg/L)
REDWATER																								
LOWER REDWATER	1980Q2513	3004	47.82880	-105.51110	9/24/1980	24N	48E	24	BCBC	125LEBO	65.0	8.0	8.00	3364	376.0	193.0	234.0	5.50	0.00	0.01	684	1610	29.00	9.00
LOWER REDWATER	1980Q2515	3006	47.81110	-105.39580	9/24/1980	24N	49E	26	CAAA	125LEBO	34.0	9.5	8.00	2405	132.0	87.0	320.0	5.10	0.00	0.11	528	825	24.00	16.00
SAND CREEK	1980Q2516	3057	47.89050	-105.69970	9/26/1980	25N	47E	30	ACCD	112DRFT	36.0	10.0	8.00	5300	115.0	137.0	1030.0	5.90	0.00	0.01	770	2240	21.00	16.00
SAND CREEK	1980Q2517	3208	47.97720	-105.69800	9/26/1980	26N	47E	30	ACCD	211FHHC	76.0	12.0	8.00	2191	17.0	7.0	526.0	2.50	0.00	0.03	1042	335	8.00	0.00
LOWER REDWATER	1980Q2526	3007	47.83300	-105.32080	9/2/1980	24N	50E	20	AAAA	125LEBO	83.0	10.0	8.00	4543	57.0	47.0	1076.0	5.90	0.00	0.05	1333	1500	38.00	0.00
PRAIRIE ELK CREEK	1980Q2530	2998	47.80860	-105.89080	9/1/1980	24N	45E	25	CACC	211HLCK	73.0	9.0	8.00	4291	13.0	5.0	1059.0	2.00	0.00	0.01	1226	1320	11.00	1.00
EAST REDWATER	1980Q2591	3062	47.94250	-105.04050	9/3/1980	25N	52E	5	CCAC	112DRFT	42.0	8.0	8.00	2777	218.0	137.0	275.0	6.00	0.00	3.00	672	1120	17.00	1.00
EAST REDWATER	1981Q0094	3014	47.79362	-104.82395	3/3/1981	24N	54E	32	C	125FRUN	70.0	0.0	8.00	964	85.0	63.0	14.0	3.00	0.00	0.00	436	120	4.00	1.00
TIMBER CREEK	1981Q1700	2210	47.32830	-105.97800	9/14/1981	18N	45E	10	CCBB	125TGRV	138.0	10.5	8.00	3064	108.0	99.0	524.0	8.60	1.00	0.07	924	994	8.00	0.00
TIMBER CREEK	1981Q1701	2350	47.35500	-106.23050	9/15/1981	19N	44E	35	DDDD	125TGRV	140.0	11.0	8.00	3827	13.0	8.0	975.0	2.20	0.00	0.01	1190	1010	8.00	0.00
TIMBER CREEK	1981Q1702	2349	47.36190	-106.11520	9/15/1981	19N	44E	33	ACCD	125TGRV	60.0	10.0	8.00	4391	24.0	16.0	1102.0	3.10	0.00	0.03	1330	1260	21.00	0.00
UPPER REDWATER	1982Q0032	2141	47.24830	-105.93550	1/19/1982	17N	45E	12	BCBC	110ALVM	18.0	12.0	8.00	2255	239.0	165.0	100.0	3.70	0.00	0.51	417	1110	12.00	2.00
UPPER REDWATER	1982Q0040	2215	47.27080	-105.84380	1/19/1982	18N	46E	34	CD	125TGRV	140.0	7.0	8.00	3300	38.0	28.0	719.0	5.80	0.00	0.05	1108	936	5.00	0.00
LOWER REDWATER	1982Q0041	2381	47.41750	-105.28750	1/1/1900	19N	50E	12	CD	125FRUN	100.0		8.00	2192	91.0	78.0	327.0	6.40	1.00	0.05	638	759	5.00	0.00
LOWER REDWATER	1982Q0042	2382	47.41750	-105.28800	1/1/1900	19N	50E	12	CD	125FRUN	80.0		8.00	2183	94.0	86.0	308.0	6.50	6.00	0.08	734	716	3.00	0.00
UPPER REDWATER	1982Q0047	2064	47.16330	-105.75160	1/19/1982	16N	47E	10	AACA	125TGRV	90.0		8.00	2652	10.0	6.0	618.0	2.00	0.00	0.01	637	848	8.00	0.00
NELSON	1982Q0301	2485	47.46500	-106.02830	5/7/1982	20N	45E	30	DBAB	125TGRV	57.0	10.0	6.00	2214	95	77	335.0	4.70	4.00	0.22	290	1020	10.00	0.00
EAST REDWATER	1995Q0321	37875	47.90220	-105.16970	11/6/1994	25N	51E	20	CBDB	110ALVM	28.0	9.0	7.00	3660	103.0	97.0	794.0	6.00	0.00	0.00	971	1500	7.00	0.00
TIMBER CREEK	1995Q0633	132726	47.05160	-105.98300	6/20/1995	15N	45E	14	DACD	125TGRV	84.0	17.5	7.00	3490	238.0	198.0	553.0	10.00	5.00	0.48	848	1750	11.00	0.00
LOWER REDWATER	1995Q0639	143805	47.59500	-104.94040	6/17/1995	21N	53E	8	DABB	125TGRV	68.0	10.3	7.00	2850	367.0	293.0	67.0	5.70	0.00	0.26	481	1800	23.00	0.00
EAST REDWATER	1995Q0647	36271	47.76160	-104.89270	6/18/1995	23N	53E	10	DDDD	125TGRV	78.0	10.0	8.00	2800	66.0	41.0	676.0	5.00	0.00	0.00	1025	1000	5.00	0.00
LOWER REDWATER	1995Q0651	32531	47.41630	-105.28250	6/17/1995	19N	50E	12	DDBA	125TGRV	37.0	9.5	8.00	2310	134.0	128.0	295.3	9.30	1.00	0.06	666	1000	5.00	0.00
LOWER REDWATER	2000Q1093	143805	47.59500	-104.94040	5/8/2000	21N	53E	8	DABB	125TGRV	68.0	11.5	7.00	3350	413.0	324.0	79.1	5.59	0.00	0.11	434	2059	21.00	0.00
TIMBER CREEK	2005Q0085	132738	47.12400	-106.06390	8/10/2004	16N	45E	20	CBDB	125FRUN	145.0	10.9	8.00	3470	51.0	40.0	802.0	6.00	0.00	0.08	795	1376	13.00	0.00
SAND CREEK	2005Q0087	3001	47.80430	-105.65900	8/11/2004	24N	47E	35	BBBA	125LEBO	101.0	11.3	8.00	1870	3.0	2.0	426.0	6.51	1.00	0.01	1043	7	82.00	0.00
UPPER REDWATER	2005Q0089	138134	47.41800	-105.58210	8/11/2004	19N	48E	10	DBDA	125FRUN	150.0	10.9	8.00	3130	24.0	19.0	775.0	3.87	0.00	0.03	830	1059	0.00	0.00
TIMBER CREEK	2005Q0090	132737	47.12400	-106.06380	8/10/2004	16N	45E	20	CBDB	125FRUN	145.0	10.8	8.00	3590	66.0	48.0	855.0	5.00	1.00	0.05	861	1483	12.00	0.00

APPENDIX C
REFERENCE CONDITION APPROACH

This appendix presents details about the general and statistical methods used for development of reference conditions.

C.1 Reference Condition

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

C.1.1 Reference Condition as Defined in DEQ's Standard Operating Procedure for Water Quality Assessment (2006b)

DEQ applies the reference condition approach for making beneficial use-support determinations for certain pollutants (such as nutrients) that have narrative standards. Montana's WQS do not contain specific provisions addressing nutrients, yet nutrients are known to adversely affect beneficial uses under certain conditions or combination of conditions. The reference condition approach is used to determine if beneficial uses are supported when nutrients are present.

Waterbodies used to determine reference condition are not necessarily pristine or perfectly suited to giving the best possible support to all possible beneficial uses. Reference condition also does not reflect an effort to turn the clock back to conditions that may have existed before human settlement, but is intended to accommodate natural variations in biological communities, water chemistry, etc. due to climate, bedrock, soils, hydrology, and other natural physiochemical differences. The intention is to differentiate between natural conditions and widespread or significant alterations of biology, chemistry, or hydrogeomorphology due to human activity. Therefore, reference conditions should reflect minimum impacts from human activities. A reference approach attempts to identify the potential condition that could be attained (given historical land use) by the application of reasonable land, soil, and water conservation practices. DEQ realizes that presettlement water quality conditions usually are not attainable.

Comparison of conditions in a waterbody to reference waterbody conditions must be made during similar seasons and/or hydrologic conditions for both waters. For example, the Total Phosphorus (TP) concentration in a stream at base flow during the summer should not be compared to the TP reference condition that would occur during a spring runoff event. In addition, a comparison should not be made to the lowest or highest TP values of a reference site, which represent the outer boundaries of reference conditions.

The following approaches may be used to determine reference conditions:

Primary Approach
- Comparing conditions in a waterbody to baseline data from minimally impaired waterbodies that are in a nearby watershed or in the same region having similar geology, hydrology, morphology, and/or riparian habitat.
- Evaluating historical data relating to condition of the waterbody in the past.
- Comparing conditions in a waterbody to conditions in another portion of the same waterbody, such as an unimpaired segment of the same stream.

Secondary Approach
- Reviewing literature containing reports of aquatic life or macroinvertebrate assessments or studies using other indicators of stream health that were conducted on similar waterbodies that are minimally impaired.
- Seeking expert opinion (e.g. from a regional fisheries biologist who has a good understanding of the waterbody's fisheries health or potential).
- Applying quantitative modeling (e.g. applying a nutrient loading model to determine how much nitrogen or phosphorus is entering a stream based on land use and land cover characteristics).

DEQ uses the primary approach for determining reference condition if adequate regional reference data are available and uses the secondary approach to estimate reference condition when there are no regional data. DEQ often uses more than one approach to determine reference condition, especially when regional reference condition data are sparse or nonexistent.

C.1.2 Use of Statistics for Developing Reference Values or Ranges

Reference value development must consider natural variability as well as variability that can occur as part of field measurement techniques. Statistical approaches are commonly used to help incorporate variability. One statistical approach is to compare stream conditions to the mean (average) value of a reference data set to see if the stream condition compares favorably to this value or falls within the range of one standard deviation around the reference mean. The use of these statistical values assumes a normal distribution, whereas water resources data tend to have a non-normal distribution (He1sel and Hirsch 1995). For this reason, another approach is to compare stream conditions to the median value of a reference data set to see if the stream condition compares favorably to this value or falls within the range defined by the 25th and 75th percentiles of the reference data. This is a more realistic approach than using one standard deviation since water quality data often include observations considerably higher or lower than most of the data. Very high and low observations can have a misleading impact on the statistical summaries if a normal distribution is incorrectly assumed, whereas statistics based on non-normal distributions are less influenced by such observations.

Figure C-1 is an example boxplot type presentation of the median, 25th and 75th percentiles, and minimum and maximum values of a reference data set. In this example, the reference stream results are stratified by two different stream types. Typical stratifications for reference stream data may include stream gradient categories, stream size ranges, or geomorphic settings. If the parameter being measured is one where low values are undesirable and can cause harm to aquatic life (such as dissolved oxygen), then measured values in the potentially impaired stream that fall below the 25th percentile of reference data are not desirable and can be used to indicate impairment. If the parameter being measured is one where high values are undesirable (such as nutrient concentrations), then measured values above the 75th percentile can be used to indicate impairment.

The use of a non-parametric statistical distribution for interpreting narrative WQS or developing numeric criteria is consistent with EPA's guidance for determining nutrient criteria (EPA 2000). Furthermore, the selection of the applicable 25th or 75th percentile values from a reference data set is consistent with ongoing DEQ guidance development for interpreting narrative WQS where it is determined that there is "good" confidence in the quality of the reference sites and resulting information (Suplee 2004). If there is only a "fair" confidence in the quality of the reference sites, then the 50th percentile or median value is preferred. If there is "very high" confidence, then the 90th percentile of the reference data set should be used. Most available sets of reference data for TMDL target development tend to be of "fair" to "good" quality. This is primarily due to the limited number of available reference data points after applying geographic and seasonal stratifications. Reference data quality can also be affected by field crew experience, sampling methods, short-term land use changes and other annual stream system changes not often accounted for in an individual data set.

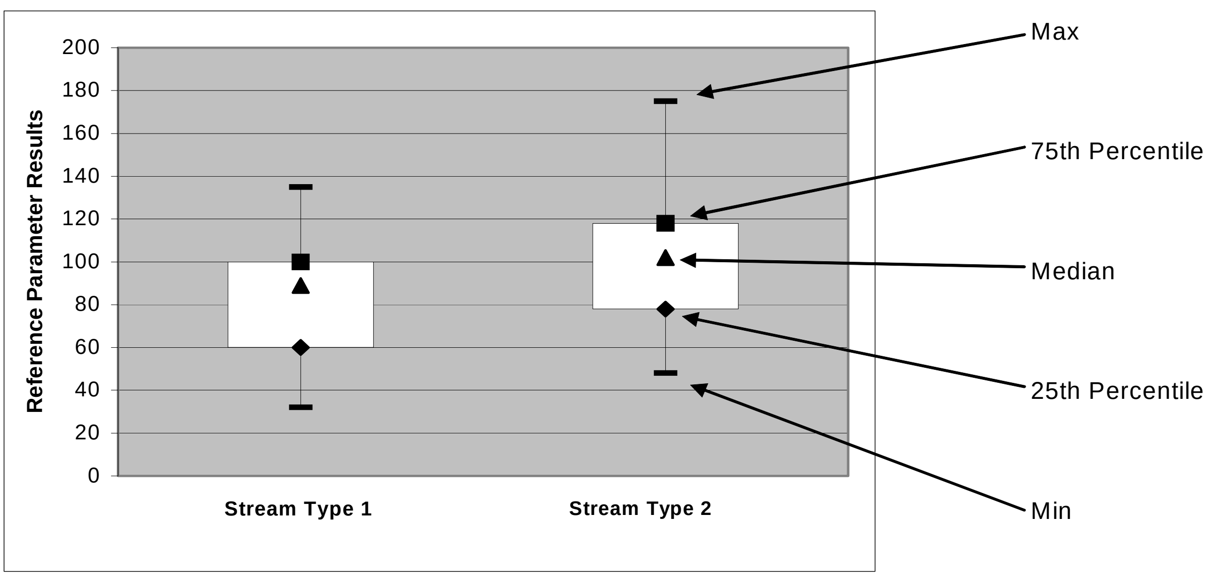

Figure C-1. Boxplot Example for Reference Data.

The above 25th – 75th percentile statistical approach has several notable considerations:

1. It is a simple approach that is easy to apply and understand.
2. About 25 percent of all streams would naturally fall into the impairment range. Thus, it should not be applied unless there is some linkage to human activities that could lead to the observed conditions. Where applied, it must be noted that the stream's potential may prevent it from achieving the reference range as part of an adaptive management plan.

3. About 25 percent of all streams would naturally have a greater water quality potential than the minimum water quality bar represented by the 25^{th} to 75^{th} percentile range. This may represent a condition where the stream's potential has been significantly underestimated. Adaptive management can also account for these considerations.
4. Obtaining reference data that represents a naturally occurring condition can be difficult because all reasonable land, soil, and water conservation practices may not be extensively in use. Even if these practices are in place, the proposed reference stream may not have fully recovered from past activities, such as continuous, season-long livestock grazing that does not represent application of all reasonable land, soil, and water conservation practices.
5. A stream should not be considered impaired unless there is causal linkage between the parameter of concern and beneficial use support. That is, if the reference range for a water quality parameter is not met, negative impacts to beneficial uses are likely. Causal relationships between target parameters and beneficial uses can justify impairment conclusions based on the above statistical approach.

There are two types of errors that can occur due to this or similar statistical approaches where a reference range or reference value is developed: (1) A stream could be considered impaired even though the naturally occurring condition for that stream parameter does not meet the desired reference range or (2) a stream could be considered not impaired for the parameter(s) of concern because the results for a given parameter fall just within the reference range, whereas the naturally occurring condition for that stream parameter represents much higher water quality and beneficial uses could still be negatively impacted. The application of adaptive management helps to minimize a sustained error of either type.

Options When Regional Reference Data is Limited or Does Not Exist

In some cases, there is very limited reference data and applying the above statistical approaches is not possible. Under these conditions the limited information can be used to develop a reference value or range, with the need to note the greater level of uncertainty and perhaps a greater level of future monitoring as part of the adaptive management approach. These conditions can also lead to more reliance on secondary type approaches for reference development as described above in **Section C.1.1**.

An alternative approach is to develop summary statistics for a given parameter from all streams within a watershed or region of interest (EPA 2000). The boxplot distribution of all the data for a given parameter is still useful to help determine potential target values, realizing that most or all of the streams being evaluated are either impaired or have a reasonable probability of having significant water quality impacts. Under these conditions one would apply the median and the 25^{th} or 75^{th} percentiles as potential target values, but you would use the 25^{th} and 75^{th} percentiles in a way opposite from their use as a true regional reference distribution. Where the distributional statistics summarize the entire data set, one could reasonably assume that as many as 50% to 75% of the results represent questionable water quality.

Figure C-2 below illustrates an example of a statistical distribution for which higher values represent better water quality. In this case, the median and 25^{th} percentiles may represent potential target values, versus the median and 75^{th} percentiles discussed above for a higher quality reference distribution. Justification for use of the median, the 25^{th} percentile, or both should be based on an assessment of the level of impact to all measured streams in the watershed.

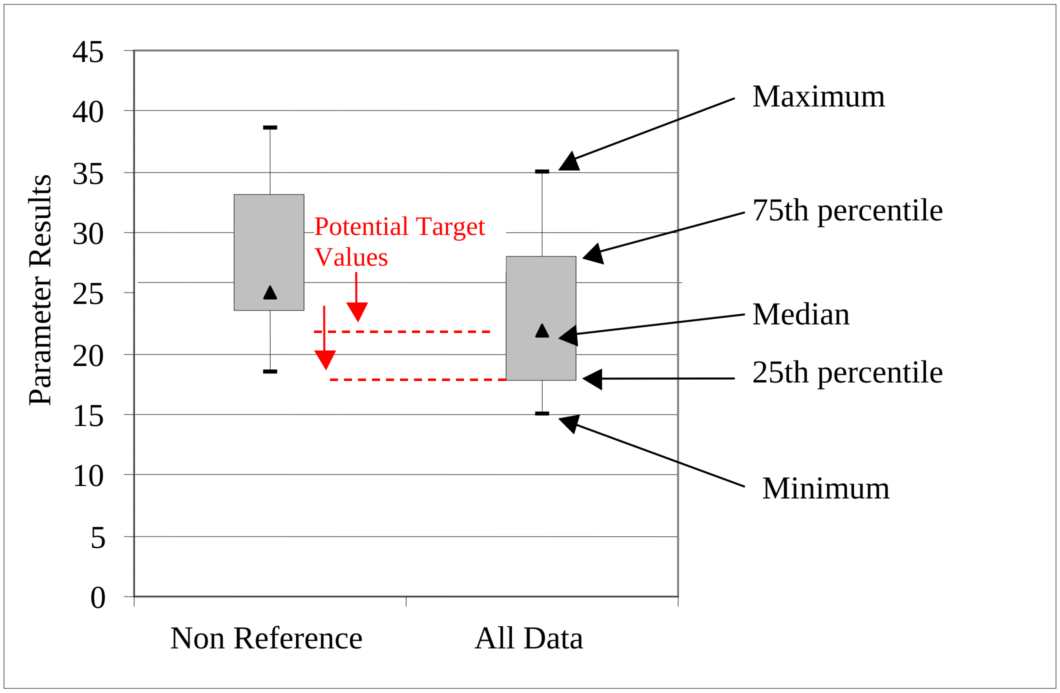

Figure B-2. Boxplot example for the use of all data to set targets.

Focused consideration of target achievability is important when using this approach. There may also be a need to rely on secondary reference development methods to modify how one applies the target or what one selects as the final target value. The level of certainty in impairment conclusions may be lower using the all-data approach, and adaptive management may have a larger role in TMDL implementation.

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APPENDIX D
REDWATER RIVER NUTRIENT MODELING REPORT

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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

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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.

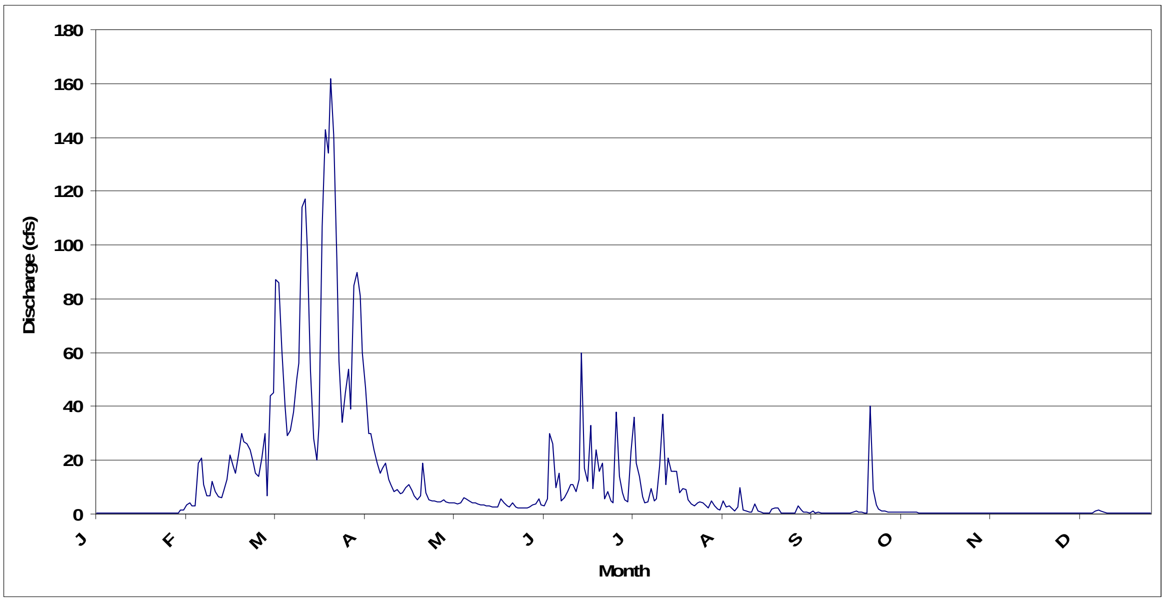

Figure 2-2. Mean Daily Discharge (cfs) at USGS Station 06177825, Redwater River near Vida, MT, for 10 years of record.

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.

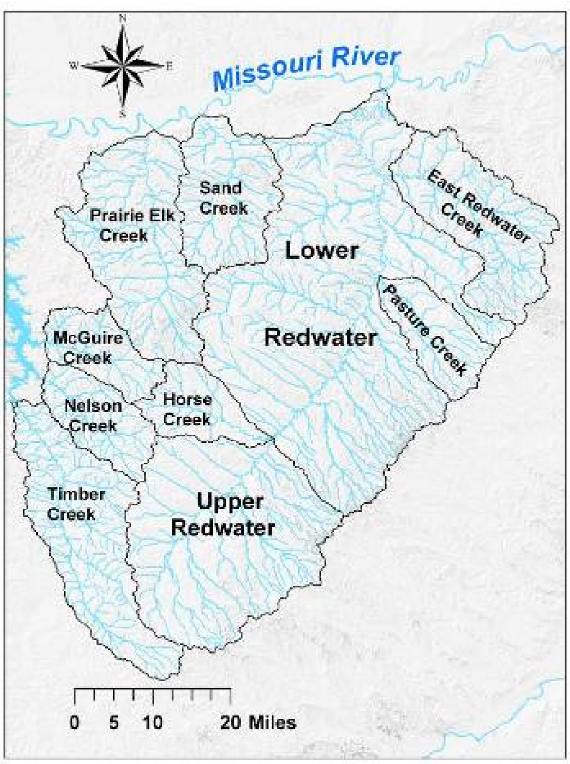

Figure 4-1. Modeled STEPL Subbasins in the Redwater TPA

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.

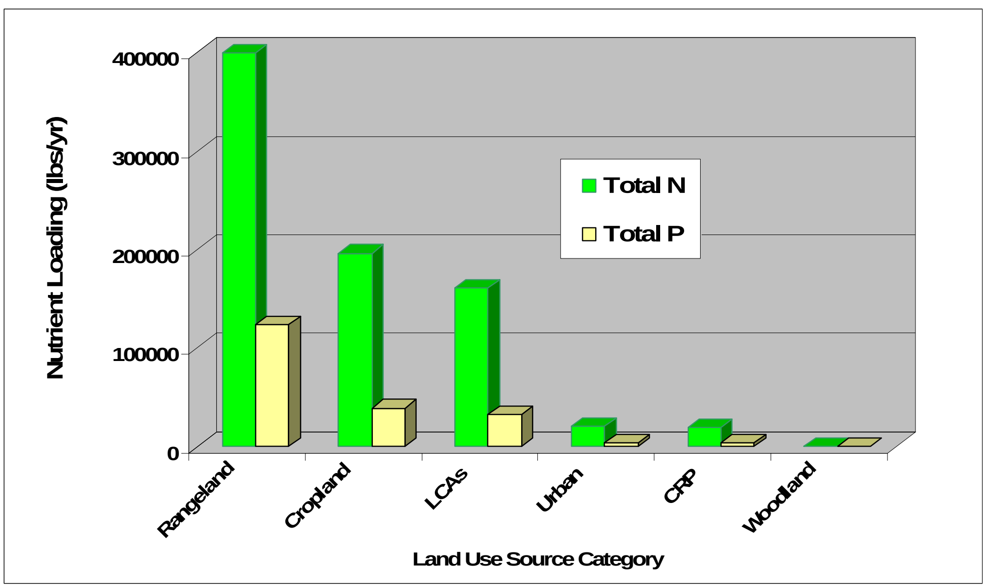

Figure 5-1. Total Annual Nutrient Load By Land Use Category

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.

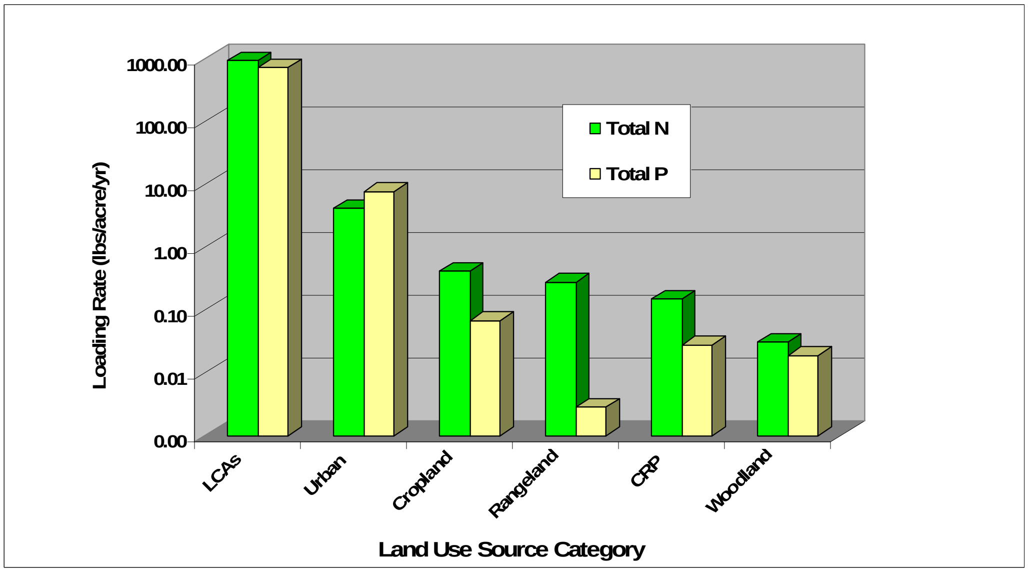

Figure 5-2. Annual Nutrient Load Rates of Land Use Categories

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.

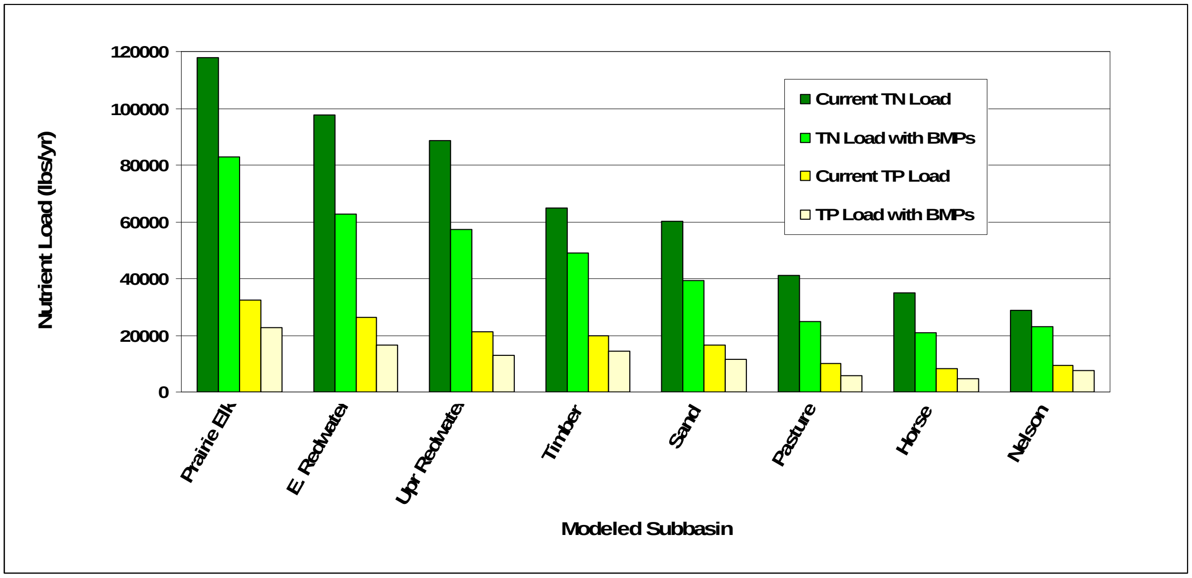

Figure 5-3. Current Condition TN and TP Loads and Load Reductions with BMPs for the Eight Redwater Subbasins Where BMPs Were Applied.

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.

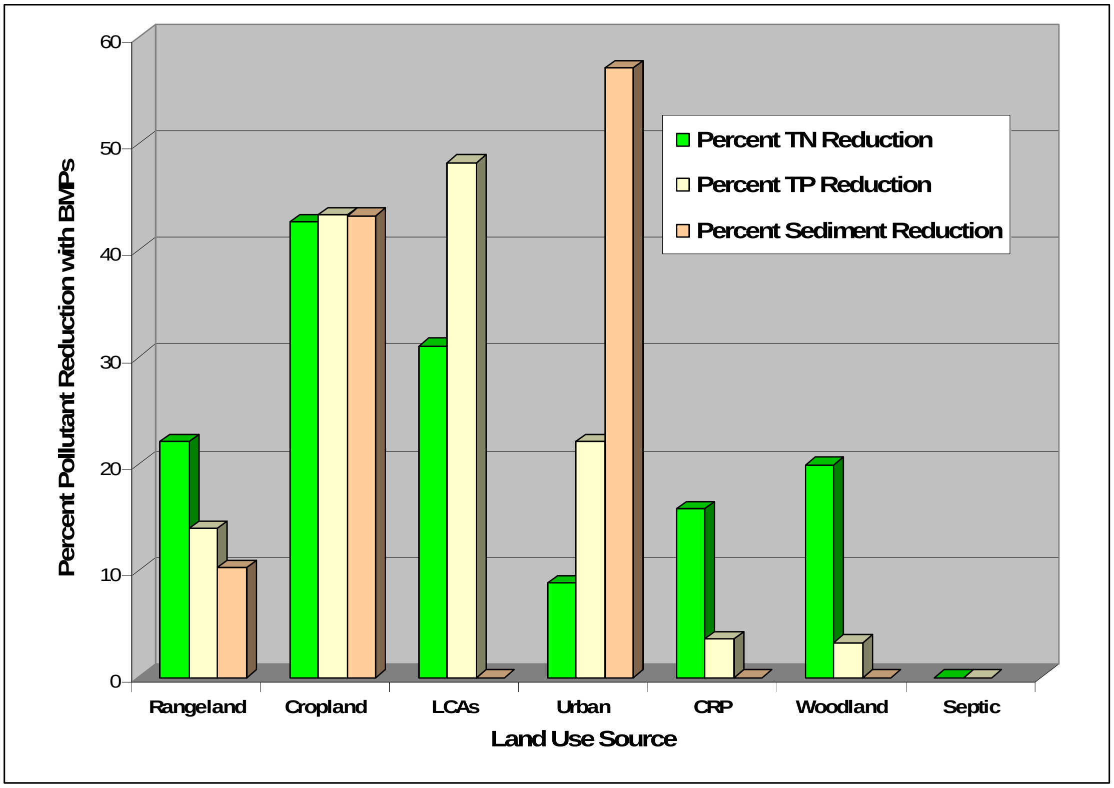

Figure 5-4. Modeled Pollutant Load Reductions by Land Use Source

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.

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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

APPENDIX E
NITRATE SENSITIVITY ANALYSIS

Table E-1. Nitrogen Loading Analysis Before Waste Water Treatment Plant Upgrade

Site Name:	Circle WWTP, Pre-Upgrade Loading
County:	McCone
Notes:	Public, Two-celled System, constructed 1954

Effluent Seepage Rate from Pond System	**Value**	**Units**	**Notes**
Pond Seepage Discharge (Q) = KIA = 99.3 m^3/day ~ 11,601 ft^3/day	99.3	m^3/day	(3,507 ft^3/day)
Where:			
K = hydraulic conductivity of clay liner = 10^{-9} m/sec	2.34E-09	m/sec	From estimated seepage rate of 9,611,500 gal/yr (Interstate Engineering 2004)
I = Hydraulic gradient = pond operating depth+liner thickness/liner thickness =6+1 ft/1 ft	7	NA	(Interstate Engineering 2004)
A = Pond area 17.34 acres (70,173 m^2)	70173.000	m^2	(Interstate Engineering 2004)

Nitrogen Concentration of Effluent-Affected Groundwater Reaching the Redwater River				
VARIABLES	**Description**	**Value**	**Units**	**Notes**
K	Aquifer Hydraulic Conductivity	0.283	ft/day	Silty Sand at 10^{-5} cm/s (Freeze and Cherry 1979)
I	Hydraulic Gradient	0.003	ft/ft	From local wells U/S of system
D	Mixing Zone Thickness (usually constant)	15.000	ft	Assumed mixing depth in the alluvial aquifer
L	Mixing Zone Length (see ARM 17.30.517(1)(d)(viii)	300.000	ft	Measured median distance from edge of pond system to Redwater River bank
Y	Width of Source Perpendicular to Ground Water Flow	1000.000	ft	Per system plan map
Ng	Background Nitrate (as Nitrogen) Concentration in Ground Water	1.600	mg/L	Average for 53 wells "MCN" GWIC, WQ, Total Depth < 150 ft.
Nr	Nitrate (as Nitrogen) Concentration in Precipitation (usually constant)	1.000	mg/L	Default
Ne	Nitrate (as Nitrogen) Concentration in Effluent	10.600	mg/L	Circle DMR mean for TN
#l	Facility Operated as a single system discharge	1.000		
Ql	Effluent Seepage Rate	3,507	ft^3/day	
P	Precipitation	13.380	in/year	Circle weather station mean annual precipitation
V	Percent of Precipitation Recharging Ground Water (usually constant)	0.200		
EQUATIONS	**Description**	**Value**	**Units**	**Notes**
W	Width of Mixing Zone Perpendicular to Ground Water Flow = (0.175)(L)+(Y)	1052.500	ft	Assumes 5° dispersion angle from each side of the source
Am	Cross Sectional Area of Aquifer Mixing Zone = (D)(W)	15787.500	ft^2	
As	Surface Area of Mixing Zone = (L)(W)	315750.000	ft^2	

Table E-1. Nitrogen Loading Analysis Before Waste Water Treatment Plant Upgrade

Qg	Ground Water Flow Rate = (K)(I)(Am)	13.404	ft^3/day	
Qr	Precipitation Recharge Flow Rate = (As)(P/12/365)(V)	192.910	ft^3/day	
Qe	Effluent Flow Rate = (#l)(Ql)	3,507	ft^3/day	
SOLUTION	**Description**	**Value**	**Units**	**Notes**
Nt	Nitrate (as Nitrogen) Concentration entering Redwater River =((Ng)(Qg)+(Nr)(Qr)+(Ne)(Qe)) / ((Qg)+(Qr)+(Qe))	10.069	mg/L	
Surface Water-Effluent Seepage Mixing				
	Description	**Value**	**Units**	**Notes**
Nsw	Background Nitrate (as Nitrogen) Concentration in Surface Water	1.241	mg/L	Average growing season concentration for stations MCNREDW-01, MCNREDW-02 & 6177500
Qsw	Baseflow Surface Water Discharge Rate	28912.000	ft^3/day	Baseflow average (0.335 cfs)
Ngw	Concentration of Effluent-affected Groundwater	10.073	mg/L	C45Above
	Cross Sectional Area of Aquifer Mixing Zone = (D)(W)	15787.500	ft^2	C38 Above
	Aquifer Gradient	0.003	NA	C22 Above
	Aquifer Hydraulic Conductivity	0.283	ft/day	Silty Sand at 10^{-5} cm/s (Freeze and Cherry 1979)
Qgw		13.404	ft^3/day	
Qsw		28912.000	ft^3/day	
	Concentration of mixed surface water and effluent	2.527	mg/L	
Loading Contributions From Treatment System vs Upstream Sources				
	Baseflow Surface Water Discharge Rate (cfs)	0.335	cfs	Growing season baseflow average
	Upstream Nitrogen Concentration in Surface Water (mg/L)	1.241	mg/L	Mean of upstream growing season TN concentration
	Upstream Nitrogen Loading rate (lbs/day)	2.245	lbs/day	Flow (cfs)*concentration (mg/L*conversion factor (5.4)
	Effluent Discharge Rate (cfs)	0.041	cfs	C42/86400 sec/day
	Effluent Nitrogen Concentration (mg/L)	10.600	mg/L	
	Treatment System Loading Rate (lbs/day)	2.3	lbs/day	
	Treatment System Percentage of Total Load	51		
	Upstream Percentage of Nitrogen Load	49		

Table E-2. Nitrogen Loading Analysis After Waste Water Treatment Plant Upgrade

Site Name:	Circle WWTP, Post Upgrade Loading
County:	McCone
Notes:	Public, Three-celled System, constructed 2009

Effluent Seepage Rate from Pond System	**Value**	**Units**	**Notes**
Pond Seepage Discharge (Q) = KIA = 0.152^3/day ~ 5.4 ft^3/day	0.152	m^3/day	(5.4 ft^3/day)
Where:			
K = hydraulic conductivity of clay liner = 10^{-11} m/sec	4.600E-11	m/sec	
I = Hydraulic gradient = 1.2 m operating depth	1.200	NA	(Interstate Engineering 2004)
A = Pond area 7.9 acres (31,970 m^2)	31970.000	m^2	(Interstate Engineering 2004)

Nitrogen Concentration of Effluent-Affected Groundwater Reaching the Redwater River

VARIABLES	**Description**	**Value**	**Units**	**Notes**
K	Aquifer Hydraulic Conductivity	0.283	ft/day	Silty Sand at 10^{-5} cm/s (Freeze and Cherry 1979)
I	Hydraulic Gradient	0.003	ft/ft	From local wells U/S of system
D	Mixing Zone Thickness (usually constant)	15.000	ft	Assumed mixing depth in the alluvial aquifer
L	Mixing Zone Length (see ARM 17.30.517(1)(d)(viii)	900.000	ft	Measured median distance from edge of pond system to Redwater River bank
Y	Width of Source Perpendicular to Ground Water Flow	750.000	ft	Per system plan map
Ng	Background Nitrate (as Nitrogen) Concentration in Ground Water	1.600	mg/L	Average for 53 wells "MCN" GWIC, WQ, Total Depth < 150 ft.
Nr	Nitrate (as Nitrogen) Concentration in Precipitation (usually constant)	1.000	mg/L	Default
Ne	Nitrate (as Nitrogen) Concentration in Effluent	10.600	mg/L	Circle DMR mean for TN
#l	Facility Operated as a single system discharge	1.000		
Ql	Effluent Seepage Rate	5.385	ft^3/day	
P	Precipitation	13.380	in/year	Circle weather station mean annual precipitation
V	Percent of Precipitation Recharging Ground Water (usually constant)	0.200		
EQUATIONS	**Description**	**Value**	**Units**	**Notes**
W	Width of Mixing Zone Perpendicular to Ground Water Flow = (0.175)(L)+(Y)	907.500	ft	Assumes 5° dispersion angle from each side of the source
Am	Cross Sectional Area of Aquifer Mixing Zone = (D)(W)	13612.500	ft^2	
As	Surface Area of Mixing Zone = (L)(W)	816750.000	ft^2	
Qg	Ground Water Flow Rate = (K)(I)(Am)	11.557	ft^3/day	

Table E-2. Nitrogen Loading Analysis After Waste Water Treatment Plant Upgrade

Qr	Precipitation Recharge Flow Rate = (As)(P/12/365)(V)	499.001	ft^3/day	
Qe	Effluent Flow Rate = (1#)(Q1)	5.385	ft^3/day	
SOLUTION	**Description**	**Value**	**Units**	**Notes**
Nt	Nitrate (as Nitrogen) Concentration entering Redwater River =((Ng)(Qg)+(Nr)(Qr)+(Ne)(Qe)) / ((Qg)+(Qr)+(Qe))	1.114	mg/L	
Surface Water-Effluent Seepage Mixing				
	Description	**Value**	**Units**	**Notes**
Nsw	Background Nitrate (as Nitrogen) Concentration in Surface Water	1.231	mg/L	Mean of upstream growing season TN concentration
Qsw	Baseflow Surface Water Discharge Rate	28912.000	ft^3/day	Baseflow average-0.335 cfs
Ngw	Concentration of Effluent-affected Groundwater	1.114	mg/L	C47Above
	Cross Sectional Area of Aquifer Mixing Zone = (D)(W)	13612.500	ft^2	C37 Above
	Aquifer Gradient	0.003	NA	C19 Above
	Aquifer Hydraulic Conductivity	0.283	ft/day	Silty Sand at 10^{-5} cm/s (Freeze and Cherry 1979)
Qgw		11.557	ft^3/day	
Qsw		28912.000	ft^3/day	
	Concentration of mixed surface water and effluent	1.233	mg/L	
Loading Contributions From Treatment System vs Upstream Sources				
	Baseflow Surface Water Discharge Rate (cfs)	0.335	cfs	Growing season baseflow average
	Upstream Nitrogen Concentration in Surface Water (mg/L)	1.200	mg/L	C49 above
	Upstream Nitrogen Loading rate (lbs/day)	2.171	lbs/day	Flow (cfs)*concentration (mg/L*conversion factor (5.4)
	Effluent Discharge Rate (cfs)	0.00006	cfs	
	Effluent Nitrogen Concentration (mg/L)	10.600	mg/L	
	Treatment System Loading Rate (lbs/day)	0.004	lbs/day	
	Treatment System Percentage of Total Load	0.1641		
	Upstream Percentage of Nitrogen Load	100		

Table E-3. Nitrogen Loading Analysis Sludge Disposal Loading

Site Name:	Circle WWTP
County:	McCone
Notes:	Loading from Sludge Disposal Area of Former Two-Celled System

Effluent Seepage Rate from Sludge Disposal Area	**Value**	**Units**	**Notes**
Annual precipitation = (0.20)* (13.38) = 2.68 in/year (0.223 ft/year)	13.380	inches	Circle weather station
Sludge disposal area is 500,000 ft2	500000.000	ft^2	GIS area measurement tool
Volume of annual precipitation within disposal area	557500.000	ft^3	
Precipitation infiltration fraction	0.200		
Mean daily volume of precipitation entering local aquifer from disposal area	305.479	ft^3/day	

Nitrogen Concentration of Effluent-Affected Groundwater Reaching the Redwater River

VARIABLES	**Description**	**Value**	**Units**	**Notes**
K	Aquifer Hydraulic Conductivity	2.830	ft/day	Silty Sand at 10-5 cm/s (Freeze and Cherry 1979)
I	Hydraulic Gradient	0.003	ft/ft	From local wells U/S of system
D	Mixing Zone Thickness (usually constant)	15.000	ft	Default
L	Mixing Zone Length (see ARM 17.30.517(1)(d)(viii))	800.000	ft	Median distance from edge of sludge disposal area to Redwater River bank
Y	Width of Drainfield Perpendicular to Ground Water Flow	1000.000	ft	Per system plan map
Ng	Background Nitrate (as Nitrogen) Concentration in Ground Water	1.600	mg/L	Average for 53 wells "MCN" GWIC, WQ, Total Depth < 150 ft.
Nr	Nitrate (as Nitrogen) Concentration in Precipitation (usually constant)	1.000	mg/L	Default
Ne	Nitrate (as Nitrogen) Concentration in Effluent	10.600	mg/L	Circle DMR mean for TN
#l	Number of Single Family Homes on the Drainfield	1.000		Source is a single system
Ql	Quantity of Affected Seepage Entering Local Groundwater	305.479	ft^3/day	Calculated for clay-lined cell
P	Precipitation	13.380	in/year	
V	Percent of Precipitation Recharging Ground Water (usually constant)	0.200		
EQUATIONS	**Description**	**Value**	**Units**	**Notes**
W	Width of Mixing Zone Perpendicular to Ground Water Flow = (0.175)(L)+(Y)	1140.000	ft	
Am	Cross Sectional Area of Aquifer Mixing Zone = (D)(W)	17100.000	ft^2	
As	Surface Area of Mixing Zone = (L)(W)	912000.000	ft^2	
Qg	Ground Water Flow Rate = (K)(I)(Am)	145.179	ft^3/day	

Table E-3. Nitrogen Loading Analysis Sludge Disposal Loading

Qr	Precipitation Recharge Flow Rate = (As)(P/12/365)(V)	557.195	ft^3/day	
Qe	Effluent Flow Rate = (#l)(Ql)	305.479	ft^3/day	
SOLUTION	**Description**	**Value**	**Units**	**Notes**
Nt	Nitrate (as Nitrogen) Concentration at end of Mixing Zone =((Ng)(Qg)+(Nr)(Qr)+(Ne)(Qe)) / ((Qg)+(Qr)+(Qe))	3.996	mg/L	
Surface Water-Effluent Mixing				
	Description	**Value**	**Units**	**Notes**
Nsw	Background Nitrate (as Nitrogen) Concentration in Surface Water	1.241	mg/L	Average growing season concentration for stations MCNREDW-01, MCNREDW-02 & 6177500
Qsw	Baseflow Surface Water Discharge Rate	28912.000	ft^3/day	Baseflow average-0.3 cfs
Ngw	Concentration of Effluent-affected Groundwater	3.996	mg/L	C41 Above
	Cross Sectional Area of Aquifer Mixing Zone = (D)(W)	17100.000	ft^2	C34 Above
	Aquifer Gradient	0.003	NA	C19 Above
	Aquifer Hydraulic Conductivity	2.830	ft/day	Silty Sand at 10-5 cm/s (Freeze and Cherry 1979)
Qgw		145.179	ft^3/day	
Qsw		28912.000	ft^3/day	
	Concentration of mixed surface water and effluent	1.353		
Loading Contributions From Treatment System vs Upstream Sources				
	Baseflow Surface Water Discharge Rate (cfs)	0.330		
	Upstream Nitrogen Concentration in Surface Water (mg/L)	1.241		
	Upstream Nitrogen Loading rate (lbs/day)	2.211		
	Effluent Discharge Rate (cfs)	0.004		
	Effluent Nitrogen Concentration (mg/L)	10.600		
	Treatment System Loading Rate (lbs/day)	0.202		
	Treatment System Percentage of Total Load	8.385		
	Upstream Percentage of Nitrogen Load	91.615		

APPENDIX F
RESPONSE TO PUBLIC COMMENTS

The formal public comment period for *The Redwater River Nutrient and Salinity TMDLs and Framework Water Quality Improvement Plan* was initiated on October 26th, 2010 and concluded on November 26th, 2010. A public meeting was held in Circle, MT on November 3, 2010. Comment letters were received from the McCone Conservation District and two individuals. Excerpts from the comment letters are provided below. Responses prepared by DEQ follow each of the individual comments and where applicable, the text of the document has been modified to address these comments. Original comment letters are held on file at the DEQ and may be viewed upon request.

Comment #1:
Page 16 2.2.1 Vegetation; I question basin wildrye. There may be some, if any. Don't think this should be one of the grasses listed. Inland salt grass should be listed as this is common on all the creeks. You have not listed any rushes as creeping spike rush, three square bulrush, also alkali cordgrass and smooth brome are common along the creek banks in the planning area. Other grasses that should be listed is foxtail barley in the wet zone and Kentucky blue grass in the dry uplands that are common.

DEQ Response to Comment #1:
The first paragraph of **Section 2.2.1** has been edited to include mention of the plant species listed in the comment.

Comment #2:
Page 12 & 13 Geology, Soils and Water (Surface & Groundwater) I believe DEQ needs to do a more thorough job on looking into the geology, soils and the groundwater. A water resource survey was completed for McCone County and published in 1971. It gives a lot of insite to the soils, the geology and the water in the planning area and feel it could shed some light on why the streams have the salinity, high TDS and sulfates. "Horse Creek and Lost Creek rise on the Big Dry Creek-Redwater River Divide flow southeast and enter the Redwater. The high bottom lands are saline for some distance above their mouths." (McCone Water Resource Survey 1971) There are several statements in the survey relating the salinity and salts in the soils.

DEQ Response to Comment #2:
The watershed characterization section (**Section 2**) of the document is intended to give the reader a broad understanding of the physical and cultural setting of the planning area. The inherent salinity of the area for both the mainstem Redwater River and tributaries is explicitly illustrated in **Figures 6-1** and **6-2,** that graph changes in specific conductivity with changes in flow. The salinity target development discussion (**Section 6.4**) repeatedly points out the elevated dissolved solids concentration of planning area surface waters relative to other areas of the state for which salinity TMDL targets have been developed. The target departure discussion for Nelson Creek (**Section 6.5.3**) recommends, due to the inherent high salinity of Nelson Creek surface water and lack of cropland salinity source areas, that the salinity impairment be reassessed. The DEQ's understanding of inherent salinity in the planning area is adequately demonstrated in these discussions. The more elaborate descriptions of salinity sources in the McCone County Water

Resource Survey are appropriate for a document published to assess the county's historical water use and identify areas suitable for irrigation development. The detailed discussions of salinity sources and the limitations to irrigation development are beyond the more general scope of **Section 2**.

Comment #3:
On Page 2; you talk about "the water chemistry monitoring during the 1970s and 1980s and it states commonly included corresponding flow measurements". Then it goes on to say that "these are lacking in the more recent monitoring efforts that occurred from 2003-2005". Then you go on to talk about using mean daily flows to generate flow duration curves for each stream.

If you don't have flow with each nutrient sample or wasn't taken because there was no flow and use a mean daily flow, this is allowing for HUGE ERROR. I do know that the sampling that was done between 2003-2005 as the district helped DEQ with the sampling that there were a lot of those sample sites had NO flow. It was also documented in the field visit sheets.

DEQ Response to Comment #3:
All impairment evaluations were based on water column nutrient concentrations, which may include measurements both with and without corresponding measured stream flows. This approach is consistent with stream assessments completed throughout eastern Montana during development of a reference data set for nutrients in wadeable prairie streams. Although we acknowledge the value of data obtained during flow conditions, paired flow and water chemistry data are not critical for development of the nutrient TMDLs. The existing chemistry data has sufficient corresponding flow measurements to provide a reasonable understanding of water column nutrient conditions and associated impacts. This information provides adequate estimates of the overall load reductions needed and does not represent a source of significant error, despite including results measured during summer flow conditions commonly encountered in the Redwater planning area.

We used flow duration curves to provide additional analyses. These curves help illustrate the seasonal flow variability. Individual measured loads that appear on the graphs of load duration curves for specific streams are those that correspond to a measured or estimated flow at the time of sampling. The loads illustrated as open circles on the load duration curves in **Section 5.0** are for actual sample results having corresponding measured or estimated flows. Results obtained under non-flowing conditions or samples collected without measured or estimated flows do not appear on the graphs. This method of illustrating loading shows the loads associated with specific sample results in the context of the stream's annual loading pattern, and illustrates the TMDL over the annual range of estimated flows. This approach provides more information than a simple comparison of measured loads versus the TMDL for a single flow condition. The individual loads shown on the curves as open circles are only those having corresponding flows. The same results would be obtained if each concentration was multiplied by the corresponding flow and compared to the target value multiplied by the same flow.

The flow duration curves are constructed from gage records. Where gage records are not available, the curves were estimated from similar streams by multiplying the total annual runoff of the stream in question by a daily proportion of total annual runoff calculated for the gaged stream. The total annual runoff values for the stream in question were estimated using the equations of Omang and Parrott (1984). This process is described in the third paragraph of **Section 5.3.1**. Estimated mean daily flows, multiplied by nutrient target concentrations, are then used to construct load duration curves. Therefore, there is inherent error in estimating mean daily flows for an ungaged stream. This flow estimation error does not significantly affect overall TMDL calculations since, as discussed above, the basic loading reduction conclusions are derived from the measured nutrient concentrations and their departures from target values The level of uncertainty in nutrient TMDLs using this approach is well within that acknowledged in protocols developed by EPA where load allocations can range “from reasonably accurate estimates to gross allotments” (USEPA 1999).

Comment #4:
Did you use any of the data Aquatic Life Uses in the Redwater River Based on Periphytron Composition Report and the Biological Integrity of the Redwater River Of the Benthic Algae Community Report that was completed by Loren Bahls in December 11 2000 on the 8 miles of Redwater segment? Was this compared to the samples you took in 2008? The 2 reports were prepared for DEQ.

DEQ Response to Comment #4:
Table 5-13 contains diatom inferred DO values generated for all algae samples collected within the listed reach. These included the samples collected in 2000 and 2003 and assessed by Bahls in reports for streams in the Redwater TPA. The values derived for 2008 samples are also in the table for comparative purposes. The average of the inferred DO values for 2008 is 5.4 mg\L; the mean for the earlier samples is 6.4 mg/L.

Of the various indices referenced in the reports by Bahls, the DEQ currently focuses on one of these indices to help assess water quality health related to nutrients. This is the oxygen tolerance index (OTI) used to derive the inferred DO values in **Table 5-13**. Therefore, other indices discussed by Bahls are not incorporated into the document. Other indices may be appropriate for future assessment of impairments due to causes other than nutrients. The criteria for selection of the algae tolerance indices is discussed in detail in **Sections 2.8** and **2.9** of **Appendix A** of the document entitled “Scientific and Technical Basis of the Numeric Nutrient Criteria of Montana’s Wadeable Streams and Rivers” (Suplee 2008) that describes the development of nutrient criteria.

Comment #5:
Paragraph five of Section 5.4.1 states that “Nitrate appears specifically as an impairment cause in the assessment records for East Redwater and Nelson Creek. Nitrate is a common form of nitrogen found in agricultural fertilizers applied to croplands etc”. Nelson Creek is about 90% rangeland.

DEQ Response to Comment #5:
Section 5.4.1 provides some general information on potential nitrate sources. Even relatively small percentages of a land use can contribute to elevated pollutant loading depending on many specific factors. The statement referenced above was included in the discussion as a justification for including targets for NO_3+NO_2-N in the nutrient target suite, rather than a specific statement regarding its applicability in Nelson Creek. The data record for NO_3+NO_2-N in Nelson Creek

suggests that target exceedences are a high flow phenomenon. Recent Nelson Creek sampling events did not occur under high flow conditions. In light of this uncertainty, a NO_3+NO_2-N TMDL was developed, since there was not enough data to remove this form of impairment from Montana's 303(d) list. Future high flow NO_3+NO_2-N sampling in Nelson Creek during the growing season may confirm or dispute the NO_3+NO_2-N impairment cause. The adaptive management process can accommodate justifiable future adjustments to impairment causes in Nelson Creek or other locations in the Redwater River TPA.

Comment #6:
The document states on page 7 the DO concentration standard for C-3 streams. Again there has been no ground truthing to determine if all these streams are C-3 streams. The assessment that was done for the entire Redwater in 1998-2000 determined that not all of the stream was a C-3 stream some parts of the Redwater was an E channel.

DEQ Response to Comment #6:
The "C-3" designation is a *water use* classification category within the Montana Water Quality Standards (ARM 17.30.629), rather than a Rosgen or other type of *stream channel* classification. The classification of the Redwater River as a C-3 stream is contained in ARM 17.30.610(i). Waters classified as C-3 are to be maintained suitable for bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers. The quality of these waters is naturally marginal for drinking, culinary, and food processing purposes, agriculture, and industrial water supply.

Comment #7:
It states "Although the diatom index and meter readings are linked to aquatic life use support through the standards, the inherent uncertainty in both measures makes them more suitable as supplemental indicators of nutrient enrichment". Also were all DO reading taken the same time of the day when samples were collected? That is also a huge factor your DO reading can change throughout the day.

DEQ Response to Comment #7:
The optimum time for DO readings that would be compared to the minimum criteria described in **Section 5.4.2** is during the pre-dawn hours, before photosynthetic oxygen generation by aquatic plants. The readings associated with sampling and assessments in the Redwater TPA were generally taken during daylight hours. Such reading are useful for identifying acutely limiting DO conditions but are less than optimum for standards comparisons. Therefore, the DO readings are used as supplemental indicators of nutrient enrichment. Where DO values are lower than the supplemental indicator value, one can conclude that pre-dawn conditions would be even worse and the information indicates a water quality concern. Where DO values satisfy the supplemental indicator value, stream health is still uncertain since pre-dawn measures could be less than the indicator value. This is further explained in paragraph six of **Section 5.7**.

Comment #8:
Page 8, second paragraph; the exceedence of one or more targets or supplemental indicators does not automatically equate to beneficial use impairment. The number of target exceedences, as well as the magnitude of the target departures is considered by following the methodology of

Suplee and Sada de Suplee (2010) for water quality assessment. The combination of target analysis, meaningful qualitative observations and sound professional judgment is applied in each assessment of TMDL development needs.

I don't believe this is the best way to determine impairments by observations and sound professional judgment. Who's professional judgment? Do you allow only DEQ's judgment calls? What about NRCS or landowners. Landowners have to take care of the land or they won't have the land to produce food or keep them in business. There is a lot of professional judgment put into there operations or they won't be in business long. NRCS is technically trained with guidelines to follow and to help protect the natural resources. Best way is by ground truthing the entire reach of a stream and personally knowing the area.

DEQ Response to Comment #8:
The TMDL process is not static. The process occurs in the context of adaptive management, where adjustments to loading estimates and allocations can be made based on updated water quality data and an objective investigation of source contributions. Planning area stakeholders, therefore, have the opportunity for a continuing consultation role in water quality management. The nutrient targets used to assess impairment are the most up-to-date values.

The Montana Water Quality Act directs the DEQ to monitor and assess the quality of state waters and identify surface waters not meeting standards. In addition, it specifies a consultation role for conservation districts and watershed advisory groups in DEQ assessments and TMDL development responsibilities. In the Redwater River TPA, this role has been realized through a series of meetings attended by DEQ, Conservation District, NRCS and private landowner representatives. The agendas for these meetings have focused on describing assessment methods, summarizing assessment results and explaining impairment conclusions. Conservation district and NRCS personnel have reviewed and commented on draft sampling and analysis plans and draft document sections.

We agree that the understanding of water quality and the assessment of pollutant loading improves with first hand knowledge of field conditions. All TMDL development is a compromise between further data collection and finalizing required TMDL documentation to help move toward continued implementation of water quality protection. Finding that balance is difficult and there will tend to be differing opinions.

Comment #9:
Page 9 Table 5-4 Do any of the sample results in Table 5-4 have a flow reading with them? Don't see that in the document.

DEQ Response to Comment #9:
The nutrient water quality data are assembled in **Appendix B**, **Table 1.3**. Flow values, if measured, are included in the table.

Comment #10:
Page 9; All 11 TN results exceed the applicable TN target and seven of 11 TP results (64%) exceed the applicable TP target. Only one NO3+2-N result of 12 exceeded the 20 µg/L target for

the glaciated portion of the watershed. The 76 µg/L NO3+2-N target was met in all samples collected within the unglaciated portion of the watershed. This contradicts the statement on the previous page "The exceedence of one or more targets or supplemental indicators does not automatically equate to beneficial use impairment".

DEQ Response to Comment #10:
Section 5.4.3.1 of the document was edited to address this comment during the stakeholder review and the above referenced sentence was removed because it does not adequately describe target application in all situations. Regarding the NO_{3+2}-N listing, the results are summarized for each of the two ecoregions. The results are summarized for each of the two ecoregions. The NO_{3+2}-N impairment is due to one exceedence in 10 results for the glaciated ecoregion.

The original 2006 NO_3+_2-N listing for East Redwater Creek stems from a the interpretation of a 70 µg/L result as being excessive compared to a level of 20 µg/L that was the use support threshold at the time. With later development of the 76 µg/L target for the unglaciated ecoregion, the 70 µg/L result no longer is a target exceedence. A concentration of 30 µg/L in a sample from the glaciated area (site 5288NO01), where the 20 µg/L target does apply, is the target exceedence resulting in the current NO_3+_2-N listing.

Comment #11:
Page 10 Table 5-5 I don't see any of the samples taken in May of 2004 for the four sites in the 8 miles of Redwater. Samples were taken in May. Samples were collected once a week for 4 weeks as it was collected in August, that would demonstrate best -case conditions and worst -case conditions. Again do all samples have a flow?

DEQ Response to Comment #11:
For the purpose of determining nutrient impairment, the numeric targets in **Table 5-3** apply during the growing season for algae (mid-June through September). The target departure comparisons include algae growing season results only. **Table 5-5** contains only those results for samples collected during mid-June through September. **Appendix B** contains the results for all seasons, including the May 2004 information, and flow values when measured.

Comment #12:
Table 5-6 Again only one sample I thought that one samples doesn't warrant it to be a factor.

DEQ Response to Comment #12:
Table 5-6 contains comparisons with diatom-inferred DO, a supplemental indicator for assessing nutrient impairment. Although only one result had a value less than the 7-day mean minimum standard, all of the results in lower Horse Creek indicate low DO supply. This condition, together with the numeric target comparisons indicates use impairment and need for a TMDL.

Comment #13:
Table 5-7 Nelson Creek; What about all the sampling that was done on Nelson Creek by Golder & Associates that was completed for 3 years and was done year round. Flow was taken year around plus groundwater sampling. Again do all samples have flow?

DEQ Response to Comment #13:
This comment was also addressed in the stakeholder review and the available Nelson Creek data for Nelson Creek collected by Golder and Associates, have been inserted into **Table 5-7** and **Appendix B**.

Comment #14:
Page 14 Table 5-11 Sampling that was done in October 2003 that DEQ collected isn't listed in Table 5-11 here. Again do all these samples have flow?

DEQ Response to Comment #14:
Per the above response to Comment #12, the month of October is not within the growing season and so is not included in the analysis. The October data is included, with flow when measured, in **Appendix B**.

Comment #15:
Page 15; Table 5-13 May sampling is missing on 8 miles of Redwater DEQ states that the growing season is from mid June to September. The samples that the district took in May, in the 8 miles of the Redwater had algae blooms on the water. Photos were taken during this sample period. Other creeks sampled during this time also had algae. Our growing season is from April 1 to October 1. Why is the growing season set from June to September? Our main run-off is in March first part of April. We are dealing with prairie streams that don't have mountain snow run-off in June. Dept of Ag has the growing season as May-October. The growing season needs to be corrected in this document. By June we have landowners cutting hay. If water has a different growing season from plants, then why was there algae growing in May in the creeks in the planning area?

DEQ Response to Comment #15:
Optimum growing conditions for algae are different from those of crop plants. Seasonal variation in stream nutrient concentrations is not only influenced by factors such as runoff patterns, but also by biological uptake and release by organisms, including aquatic plants. Aquatic plant growth (including algae growth) is also influenced by light availability and air temperature which are climate factors. Optimum growing conditions for crop plants likely determine growing season designations established by the U.S. Department of Agriculture. The growing season period used in the Redwater analysis is an expansion of those developed for level III Great Plains ecoregions. The June 30th start of the growing season was expanded to include the last half of June. Further expansion of the growing season into May would best be evaluated by temporally targeted chlorophyll sampling that is not currently available for specific planning areas.

The observations you provide regarding algal growth during May are helpful in understanding systems such as the Redwater, and such observations of spring algal growth in other prairie regions of the state have been noted. The algal growing season is based on the season where such growth is most likely to occur.

Comment #16:
Page 17 Table5-14 Were these samples compared to the samples taken in 2000 by Loren Bahls report? Table 5-15 Where is the June 3 2003 samples? Did all samples have flow?

DEQ Response to Comment #16:
Table 5-14 contains diatom inferred DO values generated for all algae samples collected within the nutrient listed reach of the Redwater River for the period mid-June through September. These included the samples collected in 2000 and 2003 and assessed by Bahls in reports for streams in the Redwater TPA. The diatom-inferred DO values in the table are developed from the species composition of the samples and are independent of flow condition. Diatom samples collected on June 4, 2003 were from sampling sites on Horse Creek. These results are given in **Appendix B** since June 4 is outside of the algae growing season. Water quality samples from the listed reach of the Redwater River that have corresponding flow measurements are also given in **Appendix B**, **Table 1.3**.

Comment #17:
On all the DO tables What time of the day were the samples taken Samples that were done in June and the ones done in August; Were they all at the same time of day?

DEQ Response to Comment #17:
The DO readings associated with sampling and assessments in the Redwater TPA were taken between 8:00 AM and 8:00 PM. Refer to the response to Comment #7 above for information on the optimum timing of field DO readings under current protocols.

Comment #18:
Page 19 Table 5-19 On the sample 8/29/08 Is this sample site the one that is on the State section? And have you consider the rest area upstream at Flowing Well Rest Area that has its own septic system and the ground water well that the public use in the rest area has tested positive for e-coli. This is documented in the public water reports. This area is all rangeland. Also was there flow with this sample or was this an isolated pool?

DEQ Response to Comment #18:
Site M31TMBRC03, sampled on 8/29/08 is located in Section 6, Township 18 North, Range 44 East, on the portion of the section owned by the State of Montana. The measurement was taken in a channel pool. Flow at the time of the reading was not measureable.

A query of the bacterial sampling record for the public supply at the Flowing Wells rest area (PWSID# MT0001964) from April 1995 through July 2010 contains two positive detections for coliform bacteria that occurred in July of 2006. The DEQ program record for this system for the above period contains no detections for E. Coli.

The Montana Department of Transportation operates the Flowing Wells rest area that discharges about 380 gallons of domestic wastewater per day from a septic drain field operated each year from April through November. The nitrogen concentration in rest area septic effluent is estimated at 180 mg/L. The system discharges about 0.6 lbs of TN/day (180mg/L*0.0006 cfs*5.39 =0.58 lbs/day), minus the amount lost through denitrification. The low water table gradient (0.002) and fine-textured (silty clay) sediments receiving the discharge makes for a sufficiently long travel time between the drain field and the stream channel to allow denitrification of the entire load. Therefore, the TN allocation for Timber Creek is to natural background sources and composite agricultural sources.

Furthermore, the August 2008 sample containing 8,700 µg/L TN also contained a total ammonia concentration of 2,390 µg/L. This level of ammonia could not have been delivered from a single, drain field located several miles upstream. Throughout this stream distance, nearly all ammonia would have been converted to nitrate nitrogen and consumed during the growing season by aquatic plants. The high ammonia result suggests a more immediate and perhaps transient loading source that may include livestock in and along the Timber Creek channel near the sample site.

Comment #19:
On table 5-19 With the ONE low reading, Was this sample taken the same time of day as the others?

DEQ Response to Comment #19:
The DO reading at site M31TMBRC03 was taken at 8:45 AM. Dissolved oxygen readings taken during the 2008 field work, as well as any previous field sampling effort, were taken during daylight hours rather than a specific time slot for each site visited. Refer to the response to Comment #7 above for information on the optimum timing of field DO readings under current protocols.

Comment #20:
Page 20; 5.5, You talk about the percentage of land use in the planning area. What is the amount of acres of each land use? I don't see that in this planning document. This would give a more accurate picture of what type of land use there is and just how many acres you are actually talking about.

DEQ Response to Comment #20:
The land use acreages are given in **Section 2.3.3**, **Table 2-6**.

Comment #21:
Page 22 second paragraph; Kemp and Dodds (2001) studied TN concentrations in streams draining two undeveloped native tall grass prairie watersheds. They reported a TN range from 200 to 400 µg/L. Corresponding samples from stream transects through tilled cropland had a mean TN concentration of 1,200 µg/L. The study reported a positive correlation between stream discharge and nitrogen concentration in grassland streams, compared to a negative correlation with data from tilled cropland. The increase in nitrogen with decreasing stream flow resulted from base flow groundwater loading beneath fertilized cropland (Kemp and Dodds 2001). Dodds and Oakes (2004) used regression models to identify the land use and population density predictors of TN and TP using surface water data from central and eastern Kansas, as well as a nationwide USGS dataset. Why are you using surface water data set from central and eastern Kansas? Why not use data set according to Montana glaciated and unglaciated regions as in the Redwater planning area. Using central and eastern Kansas is a lot different than Montana.

DEQ Response to Comment #21:
Literature reports of research into the relationship between and land cover and surface water nutrient concentration is relevant as a check on the results reported for studies in Montana. The data from Kansas are presented as supporting evidence of the effects of crop nutrient additions on local water quality. The paragraphs following the discussion of work by Dodds clearly state that nutrient targets are based on studies conducted in Montana.

Comment #22:
This statement is very troublesome; Assembly of a true reference dataset for the Redwater TPA is problematic due to the large extent of agricultural land use.

DEQ Response to Comment #22:
Even with agricultural use within a watershed, there is potential to obtain reference data. The nutrient targets are developed from reference data collected from many areas that include agricultural land uses. Due to a lack of data from streams where long-term land uses are consistent with the application of all reasonable land, soil and water conservation practices, the ability to assemble additional reference data from the Redwater TPA is limited. The discussion in the document regarding the quality of reference data from the planning area has been edited to replace the word "problematic" with the word "challenging." The nutrient targets within this document are a logical and appropriate translation of the State's narrative water quality standard for nutrients.

Comment #23:
Page 23; Agricultural nutrient sources in the Redwater TPA were inventoried through combined interpretation of 2005 National Agricultural Imagery Program (NAIP) aerial photography (USDA 2005) and the 2001 USGS land cover dataset (Homer et al. 2004) in a geographic information system (GIS). The land cover raster data (30-meter resolution) were used to quantify the acreage of rangeland, cropland, woodland and urban land use areas. The CRP program acreage was calculated from percent cropland enrollment figures provided by the McCone County UDSA, Farm Service Agency. Percent cropland enrollment figures for McCone County were extrapolated to cropland in the other four planning area counties. Acreage in the CRP program was subtracted from the raster-based estimate of cropland acreage. "Feedlot" area was measured using GIS tools applied to seasonal livestock confinement polygons identified on NAIP photography. The assessment identified 102 confinement areas ranging from 0.1 to 6.5 acres. Figure 5-2 illustrates a confinement area from the inventory.

Aerial photography does not tell the whole picture in order to tell exactly what is going on. You need to ground truth. That has been proven by other TMDL work that was done by aerial photography. For instance on Big Spring Creek, DEQ hired a contractor to do a riparian assessment. They used aerial photos. The Fergus Conservation District did not agree with what they reported. They hired consultants to assess the stream (walking the whole length of the creek)

Another example is last month the District went out with DEQ and the Keystone Pipeline people to look at creeks that would require a 310 permit for the pipeline. After assessing the crossings on the ground instead of going just by what the aerial imagery, they actually found that some *areas were better to cross in a different area then what computer model suggested. Other comments made were that some of the streambanks weren't has steep has the aerial imagery suggested. The aerial photos did not warrant what was there and the ground truthing gave a more accurate picture.*

DEQ Response to Comment #23:
Interpretation of aerial photo and satellite imagery is a common source assessment tool in TMDL development. As discussed above in the response to Comment #9, ground truth work can be desirable but not necessary to meet our TMDL development goals and level of detail requirements. "Walking the whole length of the creek" is an unrealistic approach to nutrient TMDL development, a quantitative analytical process that occurs in the context of time constraints, limited availability of field personnel and financial limitations. Given the extent and variety of nutrient sources and loading pathways, observation of the physical conditions along listed stream channels does not produce a complete source inventory at the watershed scale, where loading contributions are common from upland and tributary sources. Opportunities are available to further refine and document our understanding of source loading through TMDL reviews and development of local watershed plans during TMDL implementation.

Comment #24:
From the feedlots points that you sent the district I have pulled up every feedlot that you identified. Some of the so called feedlots indentified by aerial photos (the district well aware of who owns livestock and who don't) some of the feedlots listed do not own livestock. Another problem we are having is with some of the feedlots, they are a considerable distance from the creeks. One area that we measured had a 385 feet of buffer before it would be a direct source to the creek plus it was perennial coverage. This buffer was the closes distance if you actually measured where the corals are and then where the runoff would drain the distance is even greater. The other problem is just with the runoff from these corals; Have you check with the landowners to see if the corrals are ultilized for more then 45 days? By looking at the aerial photo can you determine if the corral has been cleaned out and has a minimal amount of manure? Or what if they only have two livestock compared to a producer that may have 100 livestock for the same acreage? Wouldn't your amount or source of nutrients be different for that area?

By using the work sheet guide in the STEPL model it states:
Function ; Calculates pollutant load from the feedlots based on animal types, weight and average rainfall.
Under hidden tables;
Feedlot load calculation
Ratio of nutrients produced by animals relative to 10001b. of slaughter steer.

Another point is the numbers of livestock put in the data for the STEPL model are incorrect. The District checked with the McCone County Assessor and for an example in the Appendix D, Table A-2 it has listed 7215 sheep in the planning area. All of McCone County as of February 1, 2010 has 2606. In McGuire it list 242 and Nelson list 276.1 talked with the 2 landowners that had big sheep numbers and they told me they no longer have sheep. They have sold all there sheep due to problems with coyotes. I don't believe there is 5000 sheep in the sub-watershed for the East

Redwater and Pasture Creek. For the hogs the County has 2760. 2744 of those hogs are out of the planning area and are a permitted operation. The total for McCone County in the planning area is 16 hogs. This is a big difference from 440 swine listed in the STEPL model. The other livestock numbers are also incorrect.

According to the STEPL model this method has two assumptions l)if the feedlot is adjacent to receiving hydrological system without any buffering areas; and 2) installing the animal waste BMP will reduce pollutants from the lot from reaching the hydrologic system. Feedlots that cannot show impact to the hydrologic system being protected should not be evaluated with this computation. See notes below.

Notes: An animal lot refers to an open lot 01 combination of open lots intended lor confined feeding, breeding, raising or holding animals. It is specifically designed as a confinement area in which manure accumulates or where the concentration of animals is such [hat vegetation cannot be maintained The purpose of these calculations if to represent nitrogen (N), phosphorus [P], and Biological Oxygen Demand [BOD] reductions after an animal waste BMP is installed. This method has two assumptions: 1] the feedlot is Adjacent to a receiuing hydrological system without any buffering areas; and 2] installing the animal waste BMP will reduce pollutants from the lot from reaching the hydrologic system. Feedlots that cannot show impact to the hydrologic system being protected should not be evaluated with this computation.

In the FAQ's section of the STEPL model information it states that the numbers that in the data charts should not be changed and it caution the users. It also states that the model should not be used to set criteria only used as a guide.

You state; "In Appendix D, D-24 4.4.3 These totals were then distributed by the proportion of grazing land within each of the 10 modeled watersheds". If this is the case how can any of the data that is being used give you a true picture or even come close to what is actually in the watershed?

DEQ Response to Comment #24:
The STEPL model was used to broadly identify nutrient source categories and to determine whether the application of common BMPs would cause loading reductions similar to those suggested by target departures. The model results were not used to develop nutrient targets, quantify TMDLs, or quantify individual source allocations. Nutrient targets, TMDLs, allocations, and load reductions were based on a comparison of nutrient chemistry data from listed streams with geographically stratified nutrient reference data.

The modeled estimate of nutrient loading from livestock confinements includes a number of broad assumptions regarding animal numbers, the rate of animal waste generation, the nutrient concentrations in the runoff, and the frequency of clean-out and land application. The description of uncertainty in nutrient TMDLs was expanded to incorporate that associated with estimated animal numbers and their distribution within the planning area.

A field-based inventory that includes survey information from each facility and operational specifications from each owner was not feasible with the personnel, funding and time limitations inherent in the TMDL program. The reality of these limitations is acknowledged in published guidance for nutrient TMDL development that allows for allocations to broad source categories (USEPA 1999).

The small per animal contributions from both swine and sheep to nutrient loading, in turn, translate to small contributions from these animal classes at the planning area scale. Eliminating all swine from the calculations reduces TN loading from livestock by 0.03 percent and reduces TP loading by 0.06 percent. Similarly, eliminating all sheep from the calculations reduces livestock TN and TP loading by 0.4 and 0.2 percent respectively. At the planning area scale, these are not significant contributions to loading from livestock. Again, the uncertainty in livestock numbers and distribution is specifically itemized in **Section 5.7** of the document.

The nutrient load allocations for listed tributaries in the Redwater TPA are to natural background sources and composite agricultural sources. This allocation scheme recognizes the uncertainty in the absolute values from the model for nutrient loading from livestock and cropland sources. The loading analysis broadly concludes that livestock and crop production are nutrient sources that likely affect surface water quality. Excluding either of these sources would not constitute a rational allocation scheme in a predominantly agricultural planning area.

The uncertainty in the loading estimate can be reduced by a comprehensive inventory of the livestock source category throughout the planning area, similar to that suggested in the above comment. The process of adaptive management provides for future loading and allocation adjustments based on a targeted assessment of a subset of livestock confinements and an extrapolation of conditions to similar facilities.

Comment #25:
Page 24; The model calculates the annual nutrient loading for each subbasin based on runoff volume and runoff pollutant concentration 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 loading from sheet and rill erosion is calculated from the Universal Soil Loss Equation (USLE) and an area-based sediment delivery ratio. Nutrient loads are determined using event mean concentrations developed from the water quality database for the planning area. How can this be determined for such a large area It is very hard to determine slope and runoff on a very small area. And you are taking a whole sub basin watershed of 2.1 million acres.

DEQ Response to Comment #25:
The USLE and runoff curve number equation are applied generally to large subbasins because individual, field-based assessments cannot be applied within the time, funding and staffing constraints inherent in the TMDL program. This type of modeling approach is common for TMDL evaluations throughout the United States and is appropriate for an area like the Redwater.

Comment #26:
How many shallow wells in the watershed that are considered shallow. Was the volume of groundwater actually measured to determine the discharge to a stream? I don't see anywhere in the document the number of springs in the planning area addressed. There are 85 appropriated springs on file in 1971. Sampling that was done in 2003-2004 on Prairie Elk had springs flowinf

into the stream from along the creek banks. They also had algae growing from the source of water. Photos were taken of those springs.

DEQ Response to Comment #26:
There are about 111 wells with water quality data that are less than 150 feet in total depth. In the STEPL modeling exercise, the volume of groundwater discharging to streams is a calculated fraction of precipitation. No loading analysis described in the document included a measured value for groundwater discharge to streams. The flow calibration related to the modeling exercise used gaged flows for several streams (including Prairie Elk Creek) that would have included flows contributed by springs and other groundwater sources. While useful for a field scale loading assessment, measurement of discharges from individual springs would have little advantage in quantifying the groundwater contribution to stream flow at the subbasin scale.

Comment #27:
Page 25 You list BMPs that you have selected that DEQ assumes will help reduce nutrients. Have you talked to any landowners to see if these are already put into place? I know for a fact that landowners already have prescribed grazing in place. Another issue is that I see no reference to continuous cropping or chem.-fallow. There are very few landowners that use crop fallow rotation.

DEQ Response to Comment #27:
The planning area landowners were not surveyed to determine the type and extent of BMP use. The BMP selection in the model was based on field and aerial evidence of current common practices. The differences in nutrient contributions from continuous cropping versus crop-fallow rotations for grain production are not distinguished in the STEPL model framework. The USLE soil parameters are selected to broadly characterize cropland cover conditions and these parameters are the principal drivers of sediment yield that is the major contributor to nutrient loading. The USLE C-factor used in the model for cropland reflects a crop residue level of 750 pounds per acre.

Comment #28:
Page 28 It states; Based on engineering specifications for the new ponds and liners and an assumed effluent TN concentration of 10.6 mg/L, the daily seepage volume from the new system is approximately 40 gallons per day, delivering a small fraction (0.004) of a pound of nitrogen per day to the river. Assuming that the permeability test for the liner material is the actual permeability of the primary cell, detectable TN loading to the river from effluent pond seepage has practically been eliminated by the system upgrade. The only remaining seepage load is associated with sewage sludge disposal at the pond site". Approximately 3,100 tons of sewage sludge that accumulated in the old ponds between 1954 and 2009 has been deposited in the portion of the former two-celled system that is outside of the newly built, three-celled system. The sludge was "bulked up with on-site soils and covered with 3-5 feet of on-site soils as a final cover" (Interstate Engineering 2009). Appendix E contains a third computation page to estimate residual nitrogen loading to the Redwater River from groundwater affected by precipitation infiltration through the buried sludge. This process was permitted by DEQ. Why is that not in this document?

DEQ Response to Comment #28:
Although DEQ reviewed the new lagoon design and was aware of the sludge disposal approach, a formal written permit from DEQ for disposal of the sludge was not a requirement. EPA also was aware of the disposal approach and determined that a formal permit via 503 sludge disposal regulations was not required. Land application based on agronomic rates would have been a preferred alternative for protecting water quality.

Comment #29:
Page 32 Figure 5-8; I would like to see the amount of acres each one of these land uses covers.

DEQ Response to Comment #29:
See response to Comment #21 above.

Comment #30:
Page 33 You state" The results reflect the dominant land area extents of rangeland and cropland in the planning area. The contributions from livestock confinements within the model are driven by the high nutrient concentrations in runoff from these areas rather than the facility acreage." How did you determine that confinements are driven by high nutrient? Did you actually check all of these livestock confinements to see if they were a huge source for nutrients? Then you state "Application of a simple loading model over 2.1 million acres of the Redwater TPA introduces significant uncertainty in the loading estimates. Much of this uncertainty is associated with the assumed uniformity of precipitation patterns, soil conditions, water quality conditions and land management practices over such a large area. Despite its simplicity, STEPL is considered an adequate load allocation tool for the Redwater because it addresses all of the major land use categories in this predominantly agricultural planning area. However, the lack of information on the current extent and location of BMPs on the landscape and the broad application of BMPs through the model make its output for relative source loading more useful than its absolute nutrient loading estimates. Therefore, load allocations are based on the relative source contributions predicted by the model rather than its absolute load values. This has a potential for huge error. Have you not adequately looked into the geology, soils that are huge factor in the landscape that could result from a natural background.

DEQ Response to Comment #30:
The estimates of loading from livestock confinements are driven by the nutrient concentrations in runoff from such facilities. The link between runoff concentrations and loading are built into the model equations. The STEPL model uses literature-based load reduction efficiencies to quantify the reductions associated with BMP implementation.

Because, near-stream livestock confinements are a nationally recognized source of nutrient pollution, they were included in the nutrient source assessment. The modeled estimate of loading from livestock confinements was not used to calculate loading to listed streams. Loading was calculated based on the water quality record and modeled determinations of relative source contributions. Uncertainty in loading estimates is unavoidable. The sources of uncertainty are acknowledged in **Section 5.7** of the document.

Comment #31:
Page 40; You state "The 10 samples collected from 2003 through 2008 (Table 5-5) with TP target exceedences had either no corresponding flow measurements or were collected under non-flowing conditions." Were these samples used?

DEQ Response to Comment #31:
Yes, the growing season water quality data in **Table 5-5** were used to calculate the mean nutrient parameter concentrations that, in turn, were used to estimate loading.

Comment #32:
Page 41,Table 5-24; With all the data that has been collected and all the uncertainly, the percent of reduction that is needed to meet the TMDL my not be accurate or even possible.

DEQ Response to Comment #32:
Questionable accuracy in required loading reductions is addressed through adaptive management, which can include additional water quality sampling and analysis to improve the understanding of source contributions and effects of BMPs. This process consists of implementing the suggested BMPs, evaluating the resultant water quality response relative to the TMDL, and reevaluating both the TMDL and BMP effectiveness if maximum daily loads are being exceeded. Adjustments to initial load reductions or BMP applications are a logical follow-up if targeted growing season monitoring shows that targets are not being met by BMP implementation, or if monitoring results refine our understanding of current and future water quality. DEQ's five-year review process is being developed to facilitate TMDL implementation and adaptive management.

Comment #33:
Page 43 Table 5-25 In order for Nelson Creek to meet the TMDL it needs 2.0 cfs for flow. This is very unrealistic. Have you check the gauging station on Nelson Creek that has been operating for 3 years. It is the Van Norman Gauging Station.

DEQ Response to Comment #33:
The value of two cfs in the table is used as an example flow condition. A stream flow of two cfs is not needed to meet the TMDL. Pollutant loading changes with flow. At any flow rate, TMDLs are met by meeting in-stream nutrient concentrations equal to or less than the nutrient parameter targets.

Comment #34:
Why would you use the gage station from Timber Creek to estimate Horse Creek and Pasture Creek flows. Why not the Redwater or the Vida gage station? Timber Creek is in the Big Dry Creek and start from the Big Dry Creek-Redwater River Divide Basin (Water Survey Resource Report 1971) and Pasture Creek is in the Lower Redwater River Basin (Water Survey Resource Report 1971)Wouldn't it be more accurate to use one in the Redwater Basin? Two different watersheds or basins.

DEQ Response to Comment #34:
The Redwater River is a fourth order perennial stream. Timber Creek, like Horse and Pasture creeks, is an intermittent stream draining an upland watershed in the planning area.

Comment #35:
As it states on page 72 Figure 5-18 shows the load duration curve of the TN TMDL for Pasture Creek, based on Equation 5-1. The mean growing season TN concentration is 1,835 µg/l. Pasture Creek is a sedimentary upland watershed lacking the river breaks topography of Nelson Creek. The flow duration curve shows a short base flow period followed by rapid evaporative dewatering. All current TN loads in the figure are based on samples collected under low flow conditions. When sampling was done in June there were two sample sites. In August there was no water at the one site upstream and an isolated pool at the sample site near the mouth of the Pasture Creek. In fact the site at the mouth of Pasture Creek was a different site for sampling then you previous sampling that took place in June due to no water at the original site. DEQ and the Consultant moved down stream to an isolated pool of water to collect a sample. The training that the District received from DEQ and consultants was that you GPS a site so that you can go back to the same site to keep your sampling consistent to compare to other samples collected at that site. In Table 1.3, Pasture Creek samples; is it listed in the field notes that this is a differenct site from the sample taken in June? Were you measuring groundwater or stangnant surface water? Is this data credible? Technically it should have been noted that it was dry. Other comment is that 2.0 cfs seems unrealistic for Pasture Creek.

DEQ Response to Comment #35
The spatial difference between the sample sites on Pasture Creek in June and August of 2008 for site M48PSTRC01 was about 2,500 feet; the August site collected downstream of the June location. The location adjustment made by the field crew under non-flowing conditions in August were in keeping with the objective of the sampling and analysis plan to characterize impairment determinations and, when possible, bracket potential sources. No significant nutrient sources occur between the June and August locations. Pasture Creek, typical of intermittent prairie streams, becomes a series of isolated pools under dry conditions. In its more gravelly lower reaches, sub-surface flow is likely occurring in the channel alluvium between pools. The sampling of the isolated pool in August simply served to characterize the seasonal water quality and represented no undue bias toward sampling stagnant water in an intermittent stream.

The flow volume of two cfs used in the allocation table for Pasture Creek (**Table 5-25**) is for example purposes only. Any flow that might occur in Pasture Creek during the growing season could be used for TMDL example purposes. The specific daily allocations for nonpoint sources adjust with changes in flow because the nutrient targets are expressed as concentrations.

Comment #36:
Page 45-46 it states "Figure 5-18 shows the duration curve of the TN TMDL for Prairie Elk Creek, based on Equation 5-1. Based on existing data, the mean growing season TN concentration is 1,833 µg/L. The clustering of measured TN loads around the 32nd percentile flow (about 2.0 cfs) puts downward pressure on the growing season mean. This is offset by several extremely high loads measured during common summer storm events.

Figure 5-19 shows the load duration curve for the TP TMDL based on Equation 5-2 and measured growing season TP loads based on existing data with corresponding flow measurements. As with TN, measured data are clustered along the dry conditions portion of the curve. All loads measured under high flow conditions are greater than the TMDL. The mean growing season TP concentration is 549 µg/L."

Isn't this consider to be standard since when these creek are stagnant and there has been drought and no runoff I would think common sense would say high flow during storm events would exceed the TMDL because the creeks haven't been flushed out for sometime.

DEQ Response to Comment #36:
The large number of results at flows between 0.5 and 1.0 cfs is due, in large part, to the larger number of samples collected between mid-July and mid-September when low flow conditions prevail. The comment assumes that target exceedences result from either evaporative concentration or the flushing of evaporative concentrations during flushing flows. Plausible alternative explanations for target exceedences are that runoff from uplands actually contains TN and TP concentrations that exceed the targets, or that a combination of evaporation, flush loading and runoff target exceedences cause excess loading. Given the large stream lengths in the planning area, elevated concentrations in high flows may be strongly linked to controllable nutrient loading occurring at lower flows or periodic high flow loads that have settled in channel pools.

The reference datasets, that are the basis for ecoregional nutrient targets, are based on sample results over a range of flow conditions. Approximately 50 percent of samples from reference prairie streams were collected from isolated channel pools under non-flowing conditions. Despite this notable proportion of reference stream results from non-flowing channel pools, the mean TN concentration in Prairie Elk Creek exceeds the 1,120 µg/L target by over 60 percent; the mean TP concentration in Prairie Elk Creek exceeds the 150 µg/L TP target by several hundred percent. Under these circumstances, it is reasonable to assume that some upland loading reductions are possible.

Comment #37:
Page 47; You have less flow for Prairie Elk Creek than Pasture and Nelson Creek. Pasture Creek is more of ephemeral stream then Prairie Elk. Prairie Elk at the bottom end usually flow year round.

DEQ Response to Comment #37:
The load duration curves for Prairie Elk Creek (**Section 5.6.8**), show *greater* flows than those for either Nelson Creek (**Section 5.6.6**), or Pasture Creek (**Section 5.6.7**).

Comment #38:
Page 54-55 You state " At a flow rate of 0.1 cfs, the mean daily TN load from Horse Creek is 2.05 lbs/day (Table 5-24). This load, added to 3.09 lbs/day calculated for MCNREDW-03 at 0.335 cfs, should result in a loading rate of 5.14 lbs/day (2.05+3.09) in the Redwater River flowing at 0.435 cfs (0.1+0.335) downstream of Horse Creek. The combined TN load of 5.14 lbs/day is only 63 percent of the 8.16 lbs/day calculated from the 3,472 µg/L mean TN

concentration at MCNREDW-04 multiplied by the combined flow of 0.435 cfs. Therefore, 37 percent of the TN loading at MCNREDW-04 remains unaccounted for after Horse Creek loading is added to loading from the Redwater River above Horse Creek.

Pages 56-57; states "The nutrient loading analysis in Sections 5.6.9.1-3 documents increasing downstream concentrations of both TN and TP from the upper to the lower end of the listed river segment. The magnitude of potential agricultural loading adjacent to the eight-mile length of the listed segment is assumed small compared to that from the 550 square miles of watershed area upstream of the segment. Loading from agricultural sources in the upper watershed is accounted for in the water quality monitoring records of sites MCNEDW-01, MCNEDW-02 and 06177500. It is reasonable to assume that the 40 percent increase in TN loading and the more than doubling of the TP loading along the 1.4 mile reach between station 06177500 and site MCNREDW-03 are mainly from seepage from past operations of the Circle WWTP pond system."

Have you taken any consideration of the household septic systems that are not on city sewer or out of the city limits along Horse Creek as a source? Or the storm drains that drain to Horse Creek. There are also household septic systems upstream from sample site MCNREDW-03 in the 8 miles of Redwater above the lagoon. Has any consideration been taken as far as fertilizer that residents put on their lawns that could enter the storm drain during runoff. Did you know that there is a bigger source of nutrients from fertilizer applied to golf courses then applied to agricultural lands?

DEQ Response to Comment #38:
The wording in **Section 5.6.9.4** describing the discrepancy identified above has been changed to attribute the unexplained nutrient increases within the listed reach of the Redwater River to unspecified human-caused loading. The corresponding column heading in the allocation table (**Table 5-28**) has been changed to read "Combined Domestic and Agricultural LA". If the source of the unexplained increase was exclusively single family dwellings, the three pound difference in daily TN loading would require about 90 homes discharging a waste stream about twice the strength of the Circle WWTP effluent. It is unlikely that storm water nutrient loading to either the listed Redwater River reach or lower Horse Creek is reflected in the growing season data records for these two streams since storms discharges were not encountered during growing season sampling events. Lawn fertilizers are a recognized source of nutrient loading to groundwater but probably represent a minor contribution in a setting containing a 20-acre wastewater pond with excessive leakage for 55 years and a domestic sewage collection system with acknowledged deteriorating segments. The unexplained source is more likely a combination of individual septics, deteriorating segments of the municipal collection system, local livestock sources, and past seepage from the Circle WWTP pond system. The language regarding unknown sources reflects the contribution from a combination of sources.

Comment #39:
Page 59-61 where and when were these samples taken and was there flow ?There is nothing on the tables that indicate time of year flow etc.

DEQ Response to Comment #39:
The tables on pages **Sections 5.6.10** and **5.6.11** are loading and allocation tables for Sand and Timber creeks. They present loading conditions under example flow conditions with the mean TN and TP concentrations from the datasets for these streams and the target TN and TP concentrations. The entries in the tables do not represent individual sampling events.

Comment #40:
Page 62; States" Approximately 87 percent of the Timber Creek watershed is native rangeland where livestock grazing is the predominant land use. Annual, near-stream livestock grazing, during extended periods of high temperatures and minimal surface flows, is a conceivable source of elevated phosphorus loading to pooled channels of intermittent streams. Grazing patterns that reduce hot weather livestock access to intermittent channels may help prevent sporadic TP loading that exceeds the allocation. Although target exceedences are uncommon, focused reductions are needed to consistently meet the TMDL." Have you taken in to consideration the rest area as a source of nutrients?

DEQ Response to Comment #40:
See response to Comment #18 above.

Comment #41:
Under Section 5.6 There was a sample taken on Horse Creek and Redwater during a major storm event that flooded the flat on Horse Creek. I did not see that sample referenced. The District did comment about this sampling that did take place in June earlier in the process. The sample was taken June 5, 2005. Then the district was told the growing season is mid June to September. Throughout the document it states June -September for the growing season. How is it that the document can change to fit the criteria to apply only to samples that were taken in mid June?

DEQ Response to Comment #41
The Horse Creek and Redwater River samples collected during high flow in 2005 were collected on June 7th at sites MCNREDW-04, MCNREDW-1-8, MCNREDW-2A and MCNHORC-05. They are contained in **Appendix B**, **Table 1.3** of the document.

The growing season assumed in the document is mid-June through September. The references to the "June-September" growing season length in **Sections 5.6.3**, **5.6.9.4**, and **5.8** have been edited to read "mid-June" through September. The "June through September" growing season length was specified by Suplee (2010). The DEQ continues to refine the algae growing season length applicable to prairie streams. The mid-June through September timeframe in applied in the Redwater River TMDL document.

Comment #42:
Other comments You state that DEQ has developed recommendations for numeric standards and anticipates a formal rule making process for adoption of numeric standards in the near future. The process includes a statutory requirement to accept public comment on proposed standards. Depending on the outcome of standards adoption, the targets presented in Table 5-3 may be

revised. The revisions may, in turn, require adjustments to the TMDLs and allocations in Section 5.6.

This is very troublesome. Just like the assessments that were done by DEQ in the early phase of the Clean Water Act or the TMDL process; Some of the assessments have errors and a lot of professional judgment calls and the stream was listed impaired. Some creeks had only one sample taken with a reading that exceed the clean water standards without any scientific facts to see what actually could be the problem. It seems like the standard practice is to set a number right or wrong then we will look at it later to see if it's right. Then we are set with a numbers that never seems to get changed due to lack of funds and personnel. What if the number that is set is too high or too low? Nelson Creek is a good example with one bad sample. If the process was done properly the first time then we would have credible data.

DEQ Response to Comment #42

The current protocol for nutrient impairment listings is contained in the reference by Suplee and Sada de Suplee (2010) entitled *Guidance Document: Assessment Methodology for Determining Wadeable Stream Impairment due to Excess Nutrients (Nitrogen and Phosphorus). Draft. Montana Department of Environmental Quality, Water Quality Planning Bureau*. Standards development is, by necessity, an evolving process influenced by changes in analytical methods and our understanding of the effects of in-stream nutrient concentrations on growth of aquatic organisms. Significant investigations have occurred over the past decade to better refine water quality criteria for nutrients in Montana's wadeable streams. Adjustments to recommend criteria can be interpreted as logical outcomes of an investigative process that improves our understanding of nutrients aquatic systems, rather than as a randomly changing selection of values. Aside from the peculiar timing of the NO_{2+3}-N impairment on East Redwater Creek and the development of ecoregion specific NO_{2+3}-N criteria, there have been no nutrient impairment determinations in the Redwater planning area that have been based on a single sample result. The Nelson Creek data record (**Table 5-7**) contains several target exceedences for each of the three nutrient parameters.

Comment #43:

As with any empirical model applied at the scale of the Redwater TPA, a number of assumptions are required to simplify the range of existing conditions that affect nutrient loading. The following are among the most notable simplifying assumptions that introduce uncertainty in the modeled loading estimates:

I was in a workshop several years back when DEQ had an employee talking about modeling to help determining the affects of runoff etc. I remember that they were looking at a stretch of the Tongue River and the Yellowstone. The model wasn't working the way it should because one area they had 2 inches of rainfall while just 1-2 miles away they had very little rain if any and wasn't give an accurate picture. Just like any modeling it was never intended to be precise. What data you enter into any modeling tool can make a huge difference. If this is to be done right and with the best data available you need to ground truth every reach of each creek in the TMDL planning area. There are so many variables that come into play. The McCone CD took on task in 1998 to assess the whole length of the Redwater (168 miles) with several partners including

DEQ, NRCS, FW&P and landowners. The whole Redwater was listed and after taking the time and effort to ground truth the entire reaches, parts that were listed impaired were not impaired.

DEQ Response to Comment #43
All empirical models have limitations similar to those listed in the uncertainty discussion in **Sections 5.7** and **6.8**. While the results of field scale assessments may more accurately describe current stream conditions, they have limited utility for an assessment program that is large in scale, has legal time constraints, limited funding, and requires numeric estimates of loading from significant, discrete sources. Because of these logistical constraints, nearly all TMDLs are based on modeled or extrapolated conditions. Numeric modeling is a means of applying a broad understanding of the relationships between climate, hydrology, land characteristics and pollutant loading to a localized set of environmental conditions. Due to the scale of TMDL planning areas, modeling exercises are a realistic approach to loading analysis. The improved accuracy of a well-designed field scale assessment, applied through the process of adaptive management, can be used to fine tuning the results of a broader analytical approach. We encourage data collection and analysis in combination with an evaluation of where BMPs are and are not being implemented to help provide a more detailed view of water quality and potential activities impacting water quality.

Comment #44:
Page 90 Table 5-31;1 don't believe the STEPL model was intended to set target departures. Some of the reduction percentages are very high. What if the percentages cannot be achieved due to more of a natural component?

DEQ Response to Comment #44
The STEPL model was not used to set target departures. The comparison in **Table 5-31** is of percent reductions determined from the data record versus those suggested by the application of BMPs through the model. Adjustment in the load reduction percentages may be appropriate where all reasonable land, soil and water conservation practices have been applied for a sufficient duration without significant reductions in human caused loading.

Comment #45:
Appendix D-37 The District questions the number of rain days and the average rain event. According to the STEPL model the data was collected from the Glasgow Air Base Station. The District contacted the NOAA/NWS weather station in Glasgow. They found it hard to believe that that folks running the model are not using the National Climate Data Center normals. This is the official database can't imagine why they would use anything else. This is just another example of how data can be flawed by using a model with default data set in the model.

DEQ Response to Comment #45
The average value of a meteorological element over 30 years is defined by the National Oceanic and Atmospheric Association as a climatological normal. The normal climate parameters include temporal temperature, precipitation and heating and cooling degree-day averages. They do not include parameters specifying number of rain days or values for average number of rain events (a rainfall that results in runoff). Meteorological data from weather stations within the planning area, rather than model default values, were used to specify mean annual rainfall for modeled

subbasins. Number of rain days and values for average number of rain events were generated from the Glasgow database because such parameters cannot be generated for all existing weather stations. Glasgow was the closest station with a daily data record capable of generating values for these parameters. In other words, the data used was the data available.

Comment #46:
Page 109 second paragraph need to change 21 month fallow period to 19-21 months.

DEQ Response to Comment #46
This comment was addressed in response to stakeholder review. The length the fallow period is described as ranging from 19 to 21 months.

Comment #47:
Table 6-11 Under the table is list other assumptions and states Most tilled cropland is managed in a crop-fallow rotation. Even if this is the case the producers have to leave a certain amount of residue on the land to be in compliance with their conservation plan. Have considered any of this data in your TMDL data?

It seems that DEQ is assuming that everything has a recharge area or that the cropping practices are the main problem. That is not always true in the watershed. There are some area landowners that though they had a saline seep and found out there was no recharge area. It was just a saline area. The McCone County Resource Survey Report data states several times where there is poorly drained floodplains and saline and alkali soils that are in the TMDL planning area.

Prairie Elk Creek watershed is alluvial soil in the upper drainage is generally light textured and free of saline salts. However, there are numerous areas of high saline soil in portions of the area. The lower part of Prairie Elk is in the Bearpaw shale soils formed from the shale parent material are high in exchangeable sodium, and also saline salts.

In the Big Dry Creek Basin Nelson Creek and Timber Creek drain into the Big Dry Creek Arm of the Fort Peck Reservoir. The geologic formations are stratified sandstones and shale-capped buttes and ridges on the upper divides. The erosion of the predominantly shale formations has deposited highly saline, sodium alluvium into the stream valleys. The soils formed from this alluvium are heavy textured,highly saline and unfit for any consideration of irrigation. (McCone County Water Resource Survey 1971) It seems that maybe there could be more of a natural component of high TDS and salinity in the planning area.

DEQ Response to Comment #47
The estimate of the area contributing to agricultural contributions to salinity is based on broad land cover classification categories that may include other than the crop-fallow rotation. This source of error, and that associated with the landscape scale, versus field scale, approach to estimating loading is acknowledged in the discussion of uncertainty in **Section 6.8.2**. Inherently broad approaches to load estimation are commonly used where temporal and financial limitations restrict the level of analytical complexity.

The low flow TDS target of 3,332 mg/L is intended to represent loading from a landscape dominated by native rangeland cover underlain by salt laden stratigraphy. At low flow conditions, loading with TDS concentrations at or below the target are considered as naturally occurring levels. At these concentrations, naturally occurring sources contribute tons of dissolved solids to surface waters each day. Therefore, the salinity loading analysis identifies a significant natural salt load in each of the salinity listed segments.

Comment #48:
In Appendix B; Why are there no field meter readings listed for the samples that were collected in 2003, 2004 and 2005. They are listed for the samples collected in June and August of 2008 by DEQ. The samples collected in 2003,04 and 05 followed the proper protocol for DEQ. In fact DEQ trained the District and helped with some of the sampling. The District bought high quality equipment through 319 grants to assure that the data collected was credible and spent several days and hours to collect data to help with the TMDL process. All of the data was entered into the WEBSIM STORET data base for DEQ as part of the grant requirements.

DEQ Response to Comment #48
Appendix B, **Table 1.3** has been edited to include the field meter readings.

Comment #49:
DEQ reference's Suplee's Wadeable Stream and Rivers 2008. Under the nutrient criteria It states that a 12 sample minimum is recommended. Some of the reference streams in this report do not have 12 samples and DEQ does not have 12 samples on the creeks in the planning area. This section also talks more about nutrient criteria wastewater treatment. How does this apply to prairie streams?

Most of the reference streams listed in Suplee's report originate from the mountains and then flow to prairie streams. The creeks that are in the planning area do not originate from the mountains. Also the reference streams are all in a glaciated region. How can this data be reference materials for creeks in the Redwater TMDL planning area?

DEQ Response to Comment #49
Although the 12 sample minimum is recommended, both the binomial test and the t-test statistical tools used by DEQ to determine impairment can be used with fewer samples to draw impairment conclusions based on number and magnitude of exceedences.

The effects of point source discharges from wastewater treatment facilities are not unique to mountain and foothill streams. An example is the suite of wastewater issues related to the Circle wastewater treatment plant in the Redwater River planning area.

Approximately 50 percent of the planning area is within the glaciated region. The uncertainty in extrapolating conditions from the reference prairie streams to the unglaciated portions of the planning area is compensated by use of a lower (75^{th}) percentile of the reference dataset. The streams in the two broad ecoregions have many similarities such as similar climate, common intermittent flows, low stream gradients, fine textured substrate materials, and support of warm water fisheries and associated aquatic life.

Comment #50:
Page 88 Section 5.7 With all the assumptions and uncertainties in the accuracy of field data, source assessments methods, loading calculations and the uncertainty in the model loading estimates in the TMDL document.; Do you know if the reduction percentage of TP and TN are possible. If BMP's suggested will work or maybe are already in place. DEQ talks about adaptive management. Who is going to pay for this continued monitoring and collecting accurate data? During the public meeting it was addressed that DEQ just needs to get the TMDL plan done. As professional government entity every effort should be made to produce a high quality document.

Past history shows that once something is put into place and TMDL standards are set based on professional judgment or windshield assessments, you are stuck with these TMDL's. It is too costly to start over. Funds and personnel are usually a factor. This is a huge waste of tax payer's money. There has already been thousands of dollars spent on the Redwater planning area since 1998. The District has always taken a proactive approach since the TMDL process started. The District takes great pride in putting sound conservation practices on the ground and protecting our natural resources. We have stressed numerous times the need to produce high quality and accurate information yet we continue to go down the road of assumptions and uncertainty.

DEQ Response to Comment #50
Refer to the response to Comment #44 above regarding the level of uncertainty and the use of assumptions in developing loads and allocations. **Table 5-31** contains a comparison of the nutrient reductions suggested by the data record with those derived by applying BMPs in the STEPL model framework. While noted differences exist for the listed segment of the Redwater River and Horse Creek, there is reasonably good agreement between the two modes of quantifying reductions. Reduction percentages in the range of from 30 to 50 percent are not inherently unreasonable for agricultural operations.

Comment #51:
The data in the study is not scientifically sound. The number of livestock confinement operations is incorrect. Using averages to apply limits to a large area is not fair to specific areas. The growing season is too narrow; should be April 10th to October 15th. The methods and science is too weak. The number of samples are two limited to make comparisons. Targets based on sites north of the Missouri do not reflect local soils. Dry season samples and old data are used as baseline.

DEQ Response to Comment #51
The water quality data were collected according to sampling and analysis protocols in place at the time. When issues with laboratory interference came to light, methods were adjusted and additional field work was completed. The correct number of livestock confinement operations is currently and will probably remain a moving target. The limited GIS-based inventory has correctly concluded that these facilities, whatever the exact number, are a justifiable component of a broad agricultural nutrient load allocation. The growing season dates are geared to bracketing the sunlight and temperature conditions that produce aquatic plant growth that could be a threat to beneficial uses. They do not necessarily correspond to crop growing seasons that may be longer. As in the case of loading from the municipal sewage source, where early season

loading patterns could result in later damage to aquatic life and fishery uses, the loading allocation was protectively applied a month prior to the growing season.

The diffuse nature of nonpoint sources of pollutants along with climatic variability, the variety of land management practices, the effects of crop type, soil variables, ground cover conditions and flow path characteristics creates a great degree of uncertainty in estimating loading and measuring the effects of applied BMPs. Strategies for reducing uncertainty include measuring, modeling or estimating BMP effectiveness. Lacking detailed measurements of BMP effectiveness in the planning area, modeling and literature-based estimates of effectiveness were used to estimate possible loading reductions.

See the response to Comment #49 regarding the applicability of data collected north of the Missouri River. See the response to Comment #36 above regarding sampling from channel pools under low flow conditions.

Comment #52:
We think that DEQ should do more testing and use test that were done with this years samples and not 2008. As for the lagoon in circle it hasn't even been tested since the new one was put in we feel like you are just trying to get this done without a good study or testing so you meet your deadline and you could care less how it is going to effect the people that live here and ranch and farm.

DEQ Response to Comment #52
The samples collected during the 2008 field work were helpful in both validating impairment listings and sorting out the source contributions within the listed reach of the Redwater River. However, future monitoring of the Circle pond system performance will be needed to verify the assumptions in the analysis about loading from the ponds, sludge disposal area and uncontrolled sewage sources in the Circle area. The degree to which the loading conclusions in the document affect local residents and agricultural producers depends on how they voluntarily wish to proceed to both carry out additional monitoring and apply land management practices that reduce nutrient and dissolved solids loading.