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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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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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 4^{th}-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:

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

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.

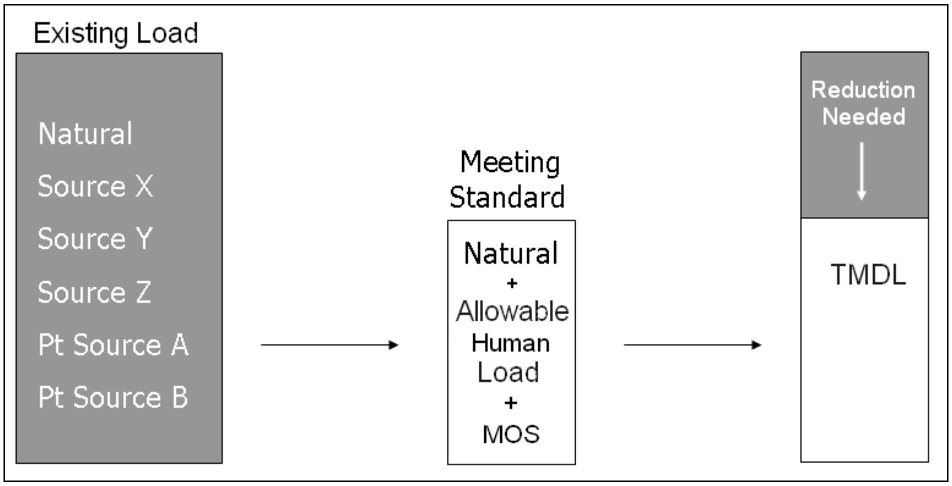

Figure 4-1. Schematic example of TMDL development

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.

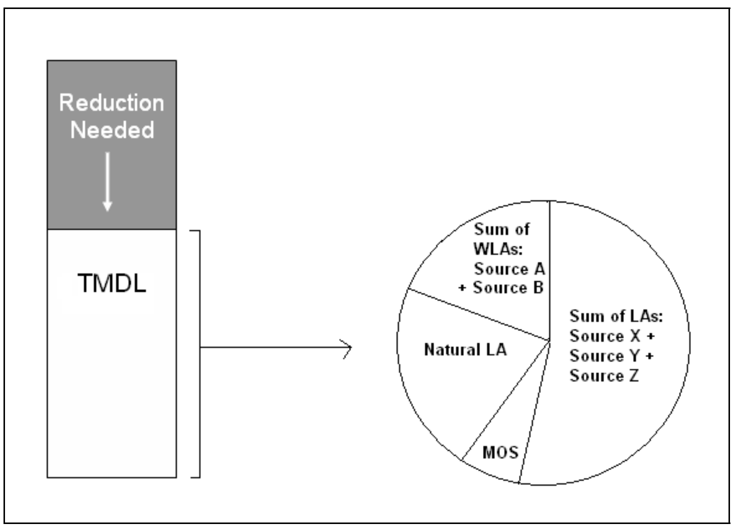

Figure 4-2. Schematic diagram of TMDL and allocations

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.

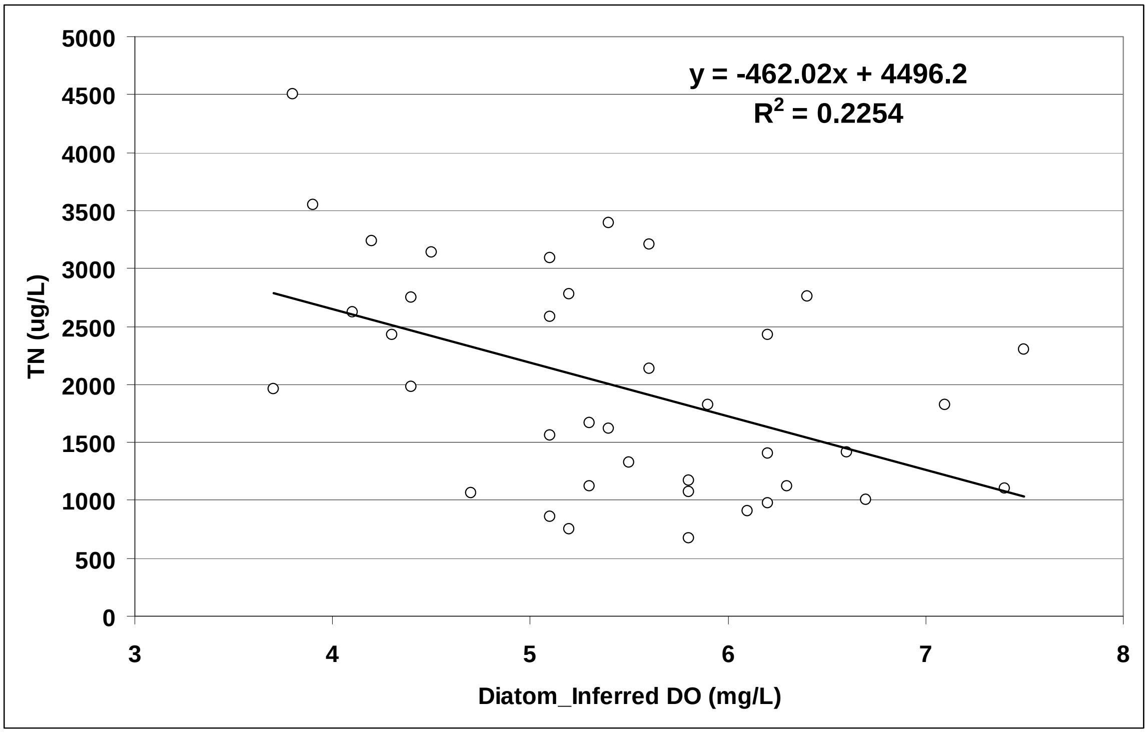

Figure 5-1. Scatter plot of inferred DO-TN relationship for Redwater streams

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**.

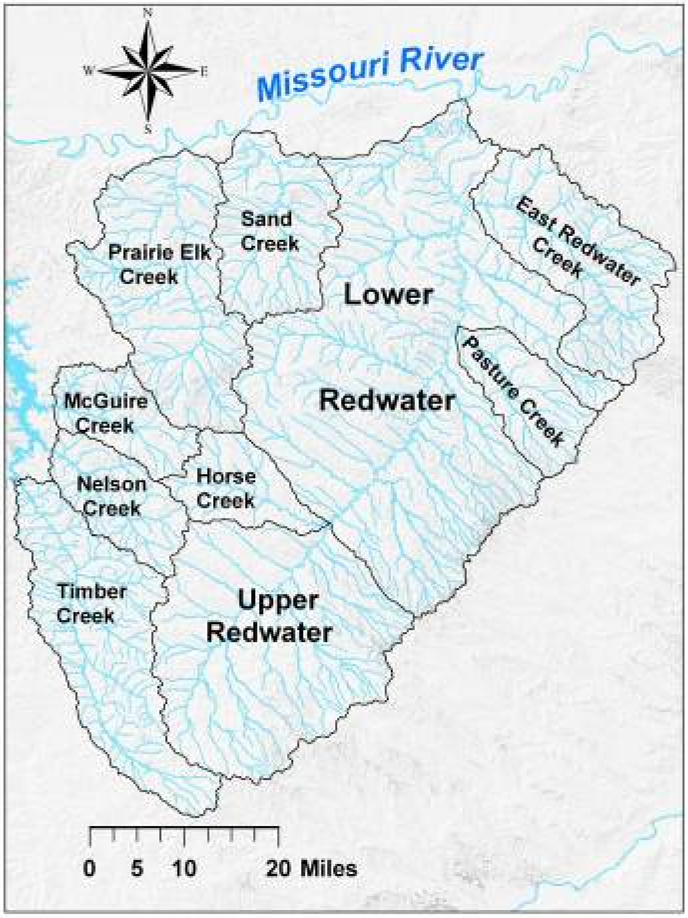

Figure 5-3. Map of modeled subbasins in the Redwater TPA.

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.

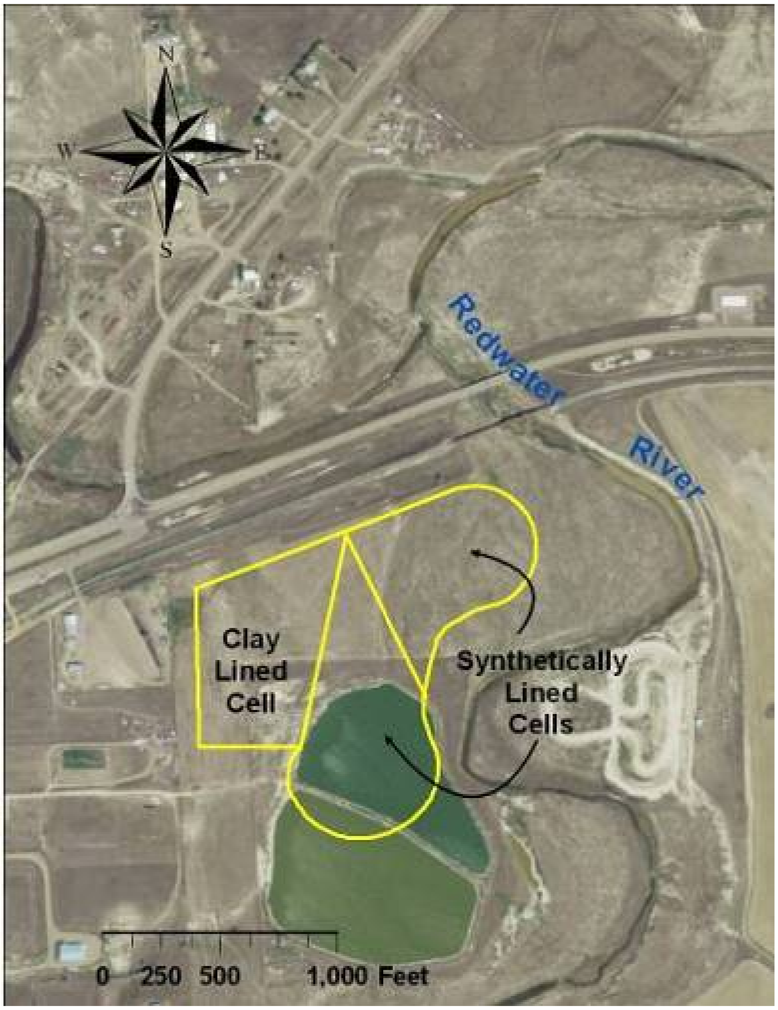

Figure 5-4. Footprint of the newly-constructed Circle wastewater treatment pond system on a pre-construction aerial photograph.

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.

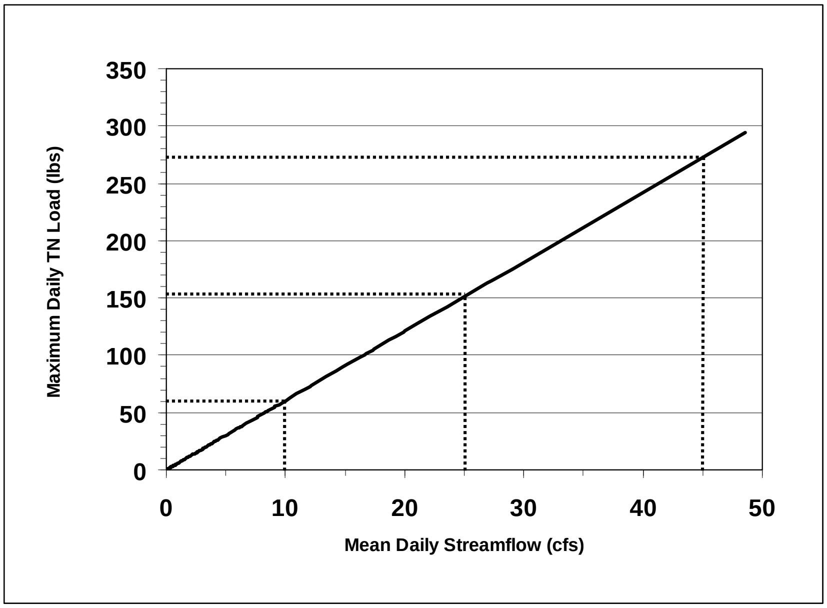

Figure 5-5. Graph of the TN TMDLs for mean daily flows from zero to 48 cfs.

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.

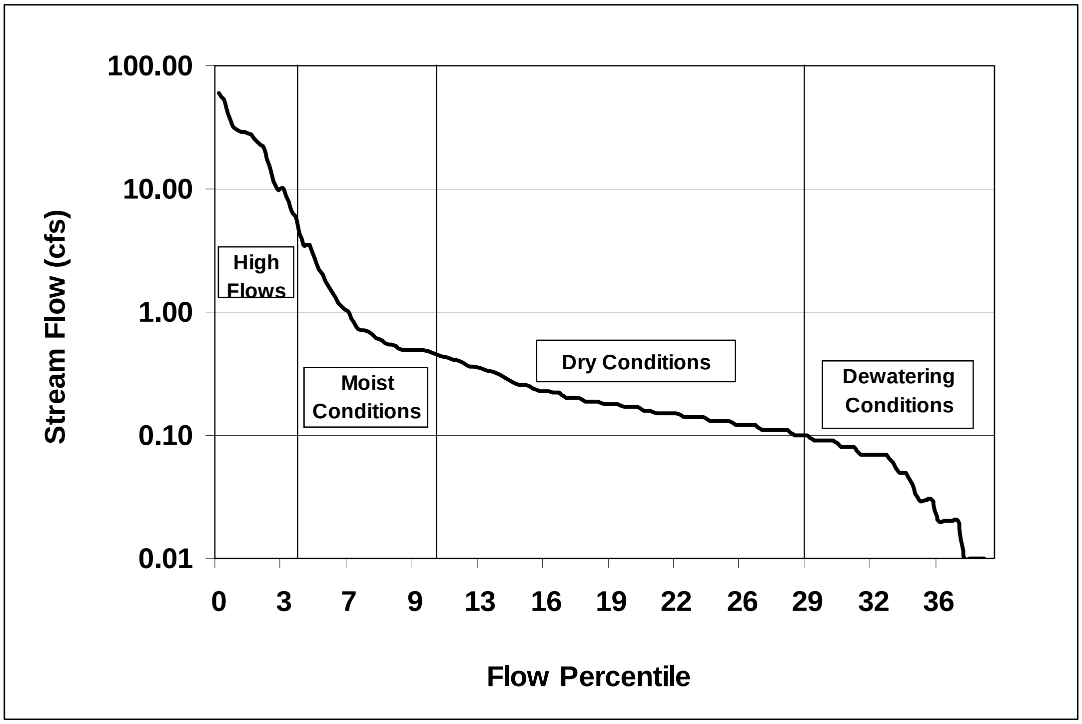

Figure 5-6. Flow duration curve for Nelson Creek at USGS Station 06131200, partitioned by annual hydrologic condition (after Cleland 2003)

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.

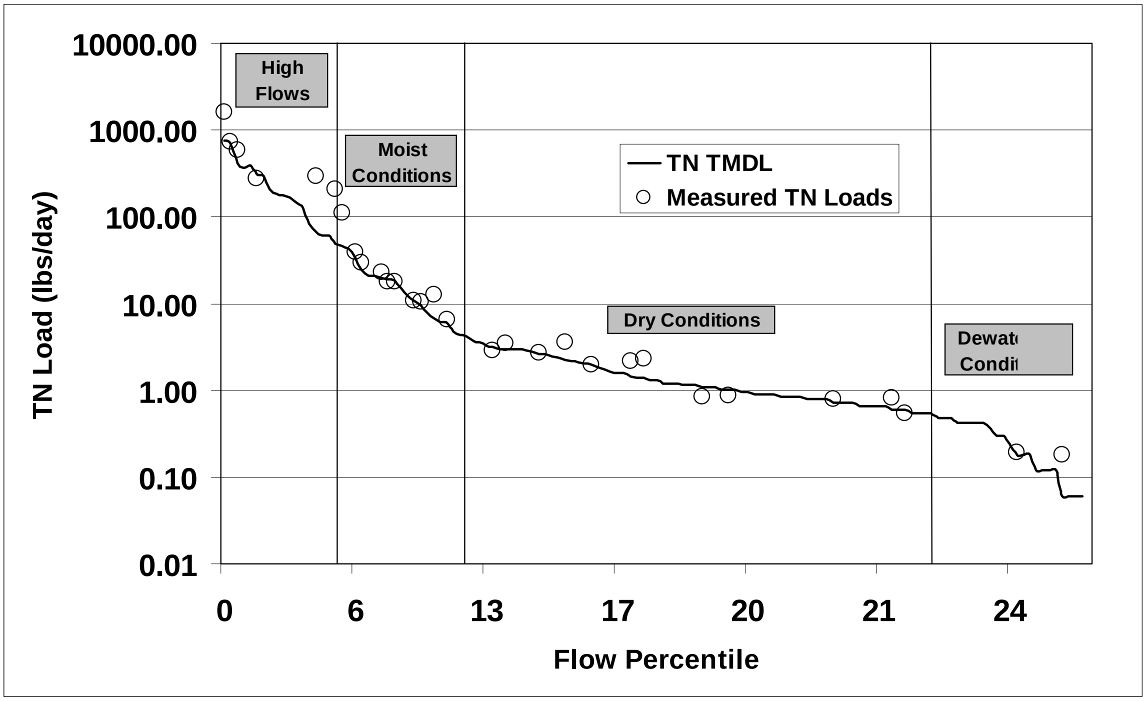

Figure 5-7. Load duration curve for Nelson Creek illustrating the TMDL for TN and measured daily TN loads during the growing season.

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.

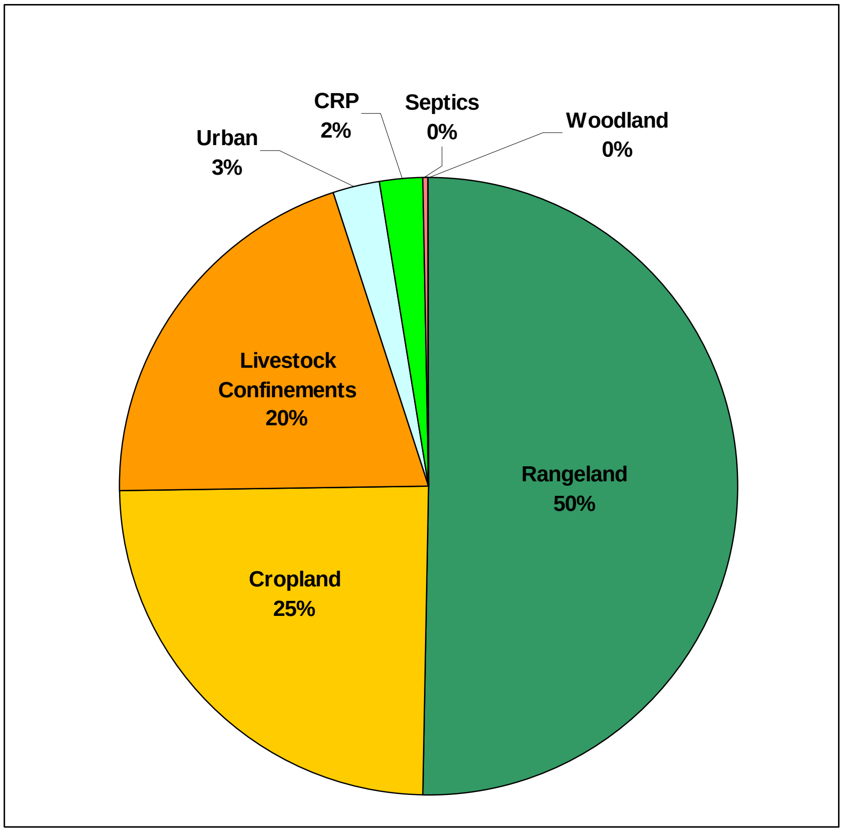

Figure 5-8. Annual TN loading percentages by source category

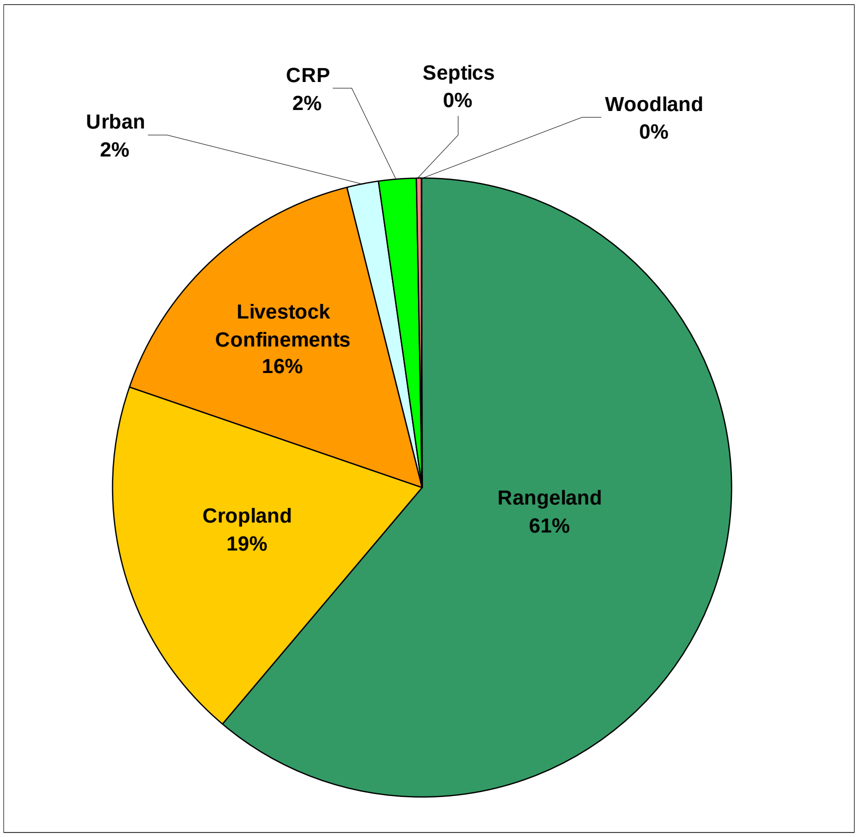

Figure 5-9. Annual TP loading percentages by source category

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**.

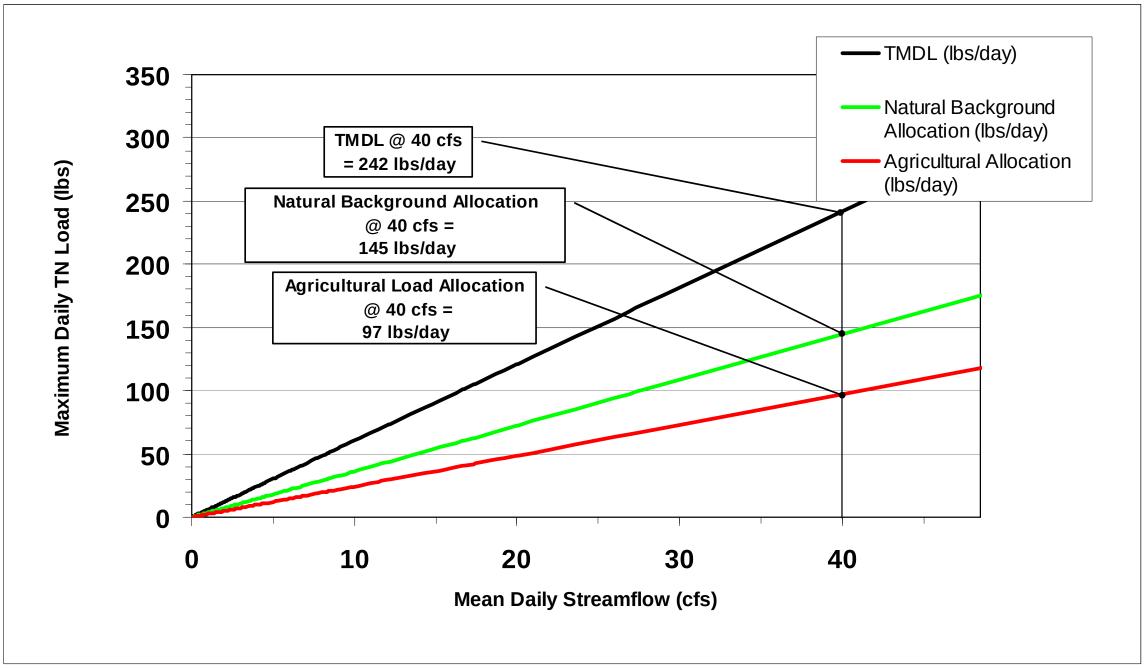

Figure 5-10. Total nitrogen TMDL and allocations to natural background and agricultural sources at a mean daily discharge of 40cfs.

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.

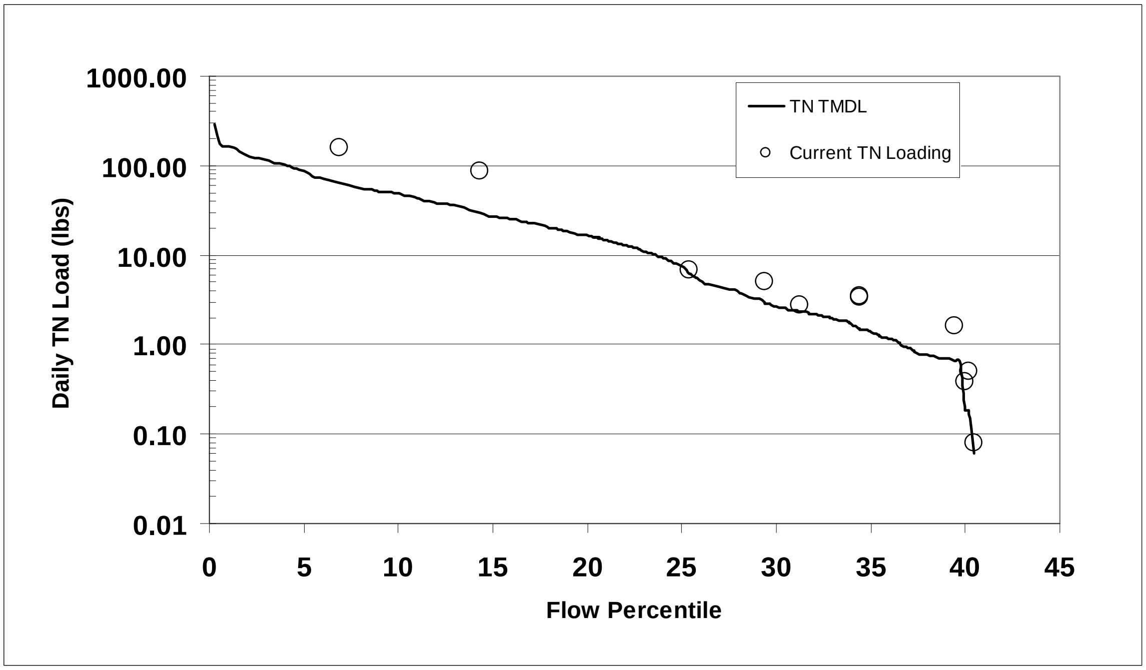

Figure 5-11. Load duration curve for the TN TMDL and current TN loading in East Redwater Creek

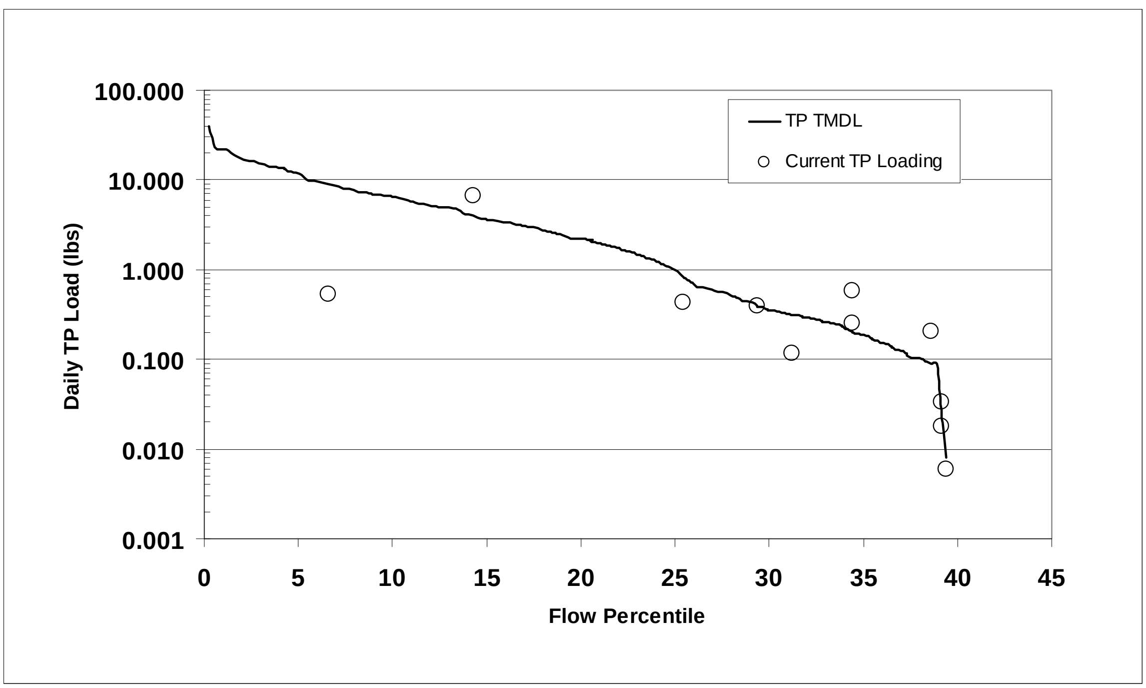

Figure 5-12. Load duration curve for the TP TMDL and current TP loading in East Redwater Creek

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.

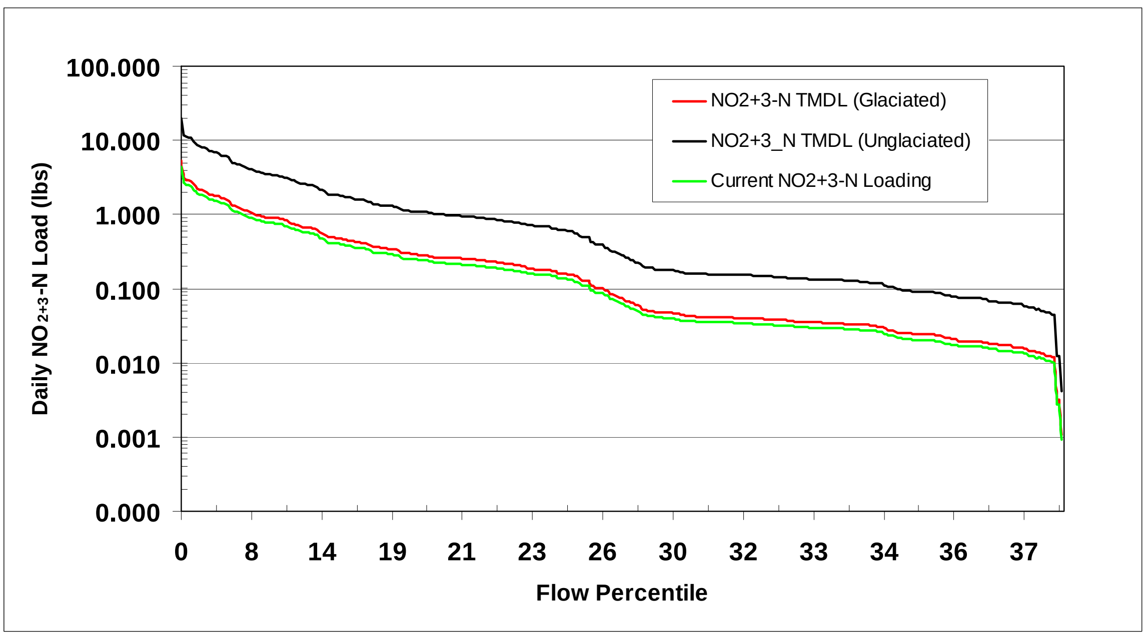

Figure 5-13. Load duration curves for the $NO_{3}+_{2}$-N TMDLs (glaciated and unglaciated ecoregions) and current $NO_{3}+_{2}$-N loading in East Redwater Creek

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.

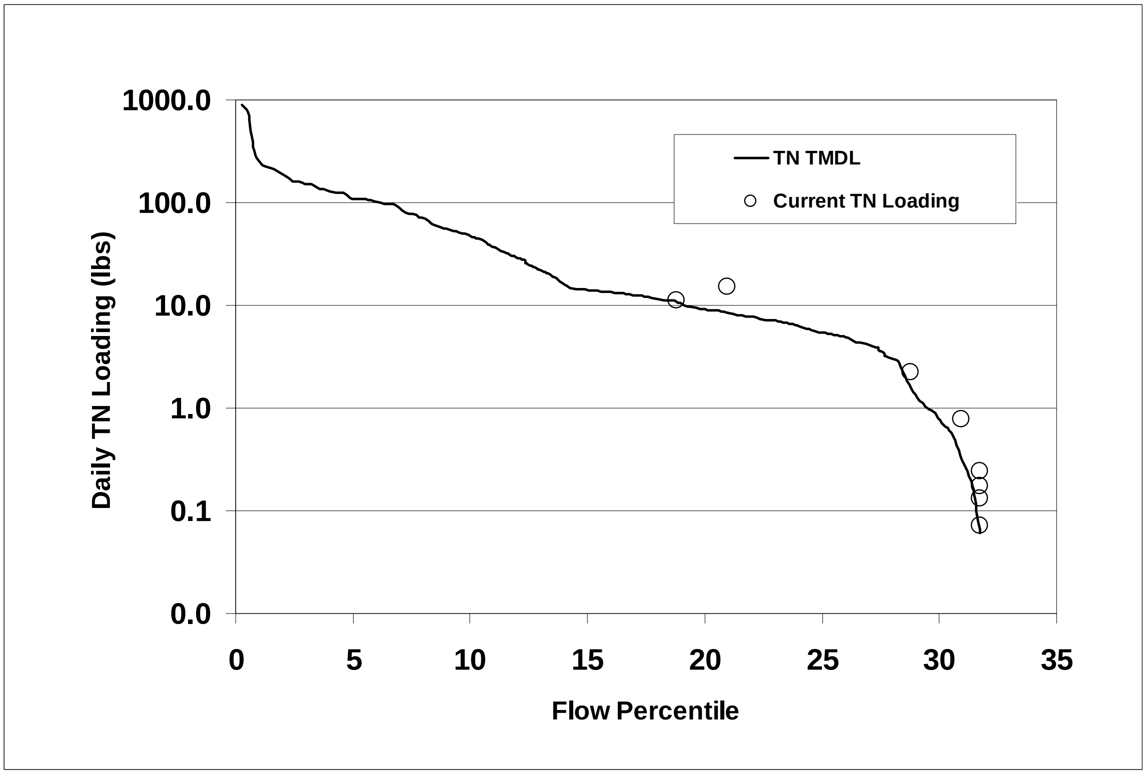

Figure 5-14. Load duration curve for the TN TMDL and current TN loading in Horse Creek

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.

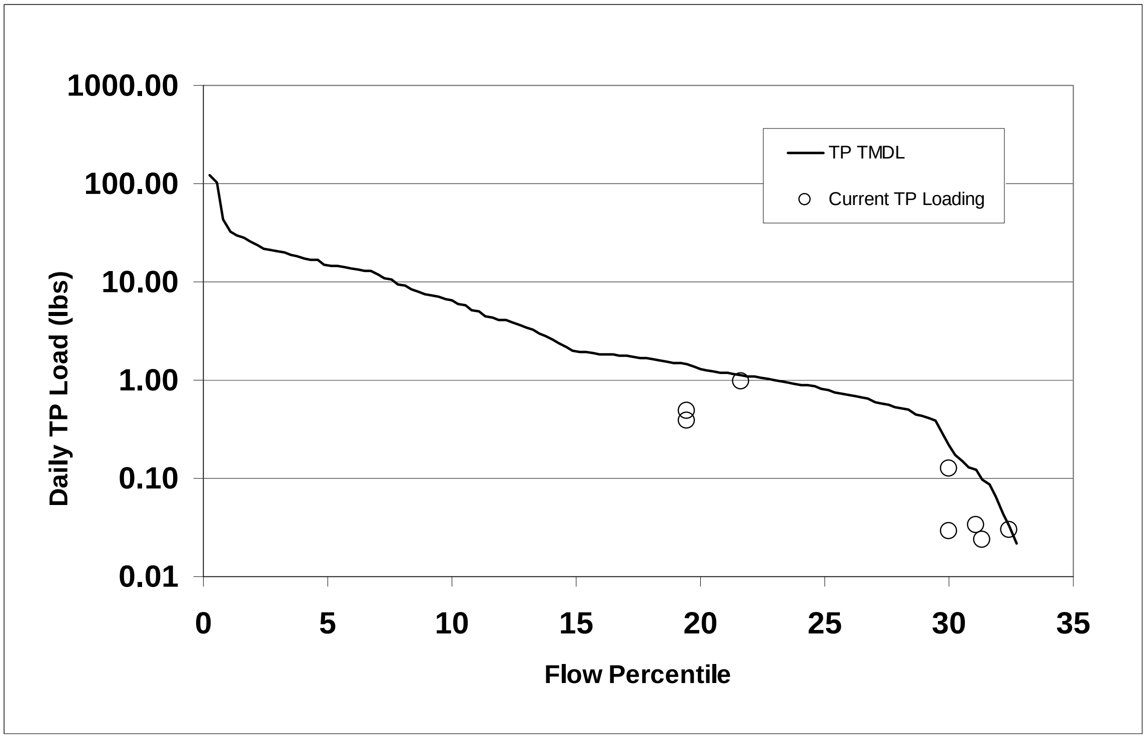

Figure 5-15. Load duration curve for the TP TMDL and current TP loading in Horse Creek

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.

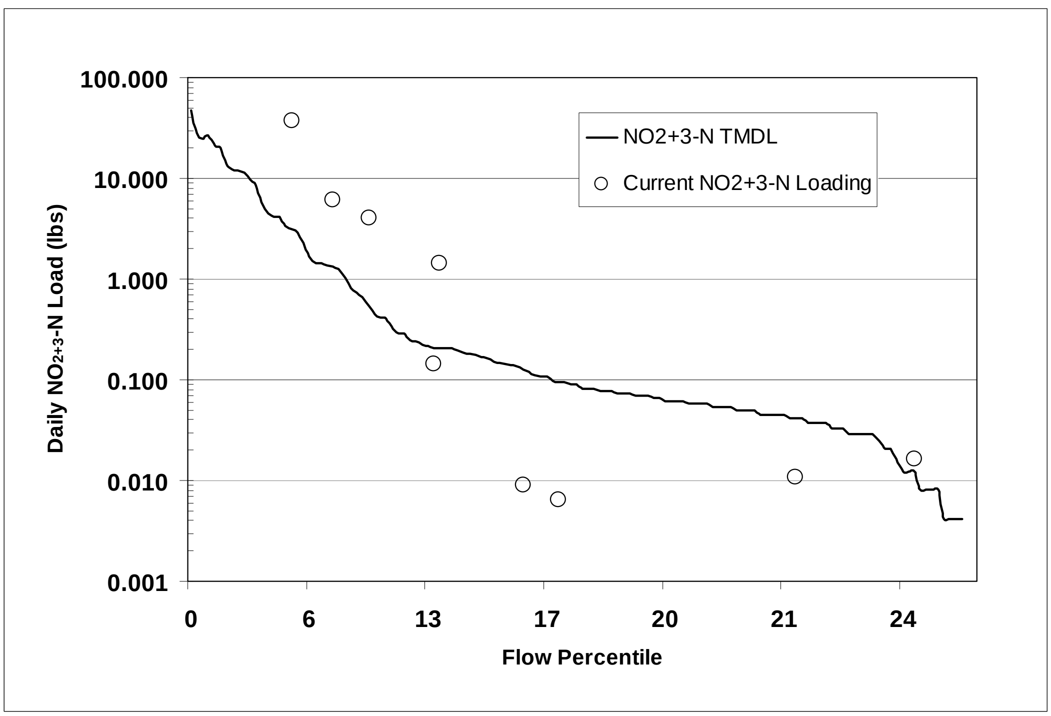

Figure 5-16. Load duration curve for the NO_3+_2-N TMDL and current NO_3+_2-N loading in Nelson Creek

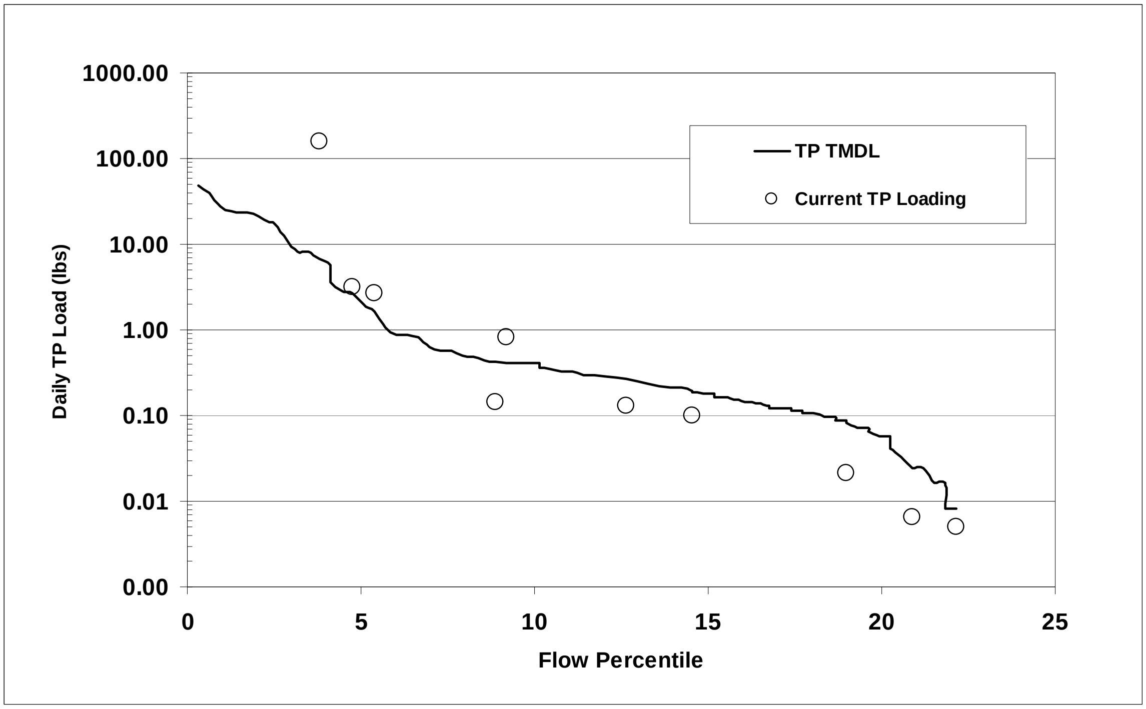

Figure 5-17. Load duration curve for the TP TMDL and current TP loading in Nelson Creek

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

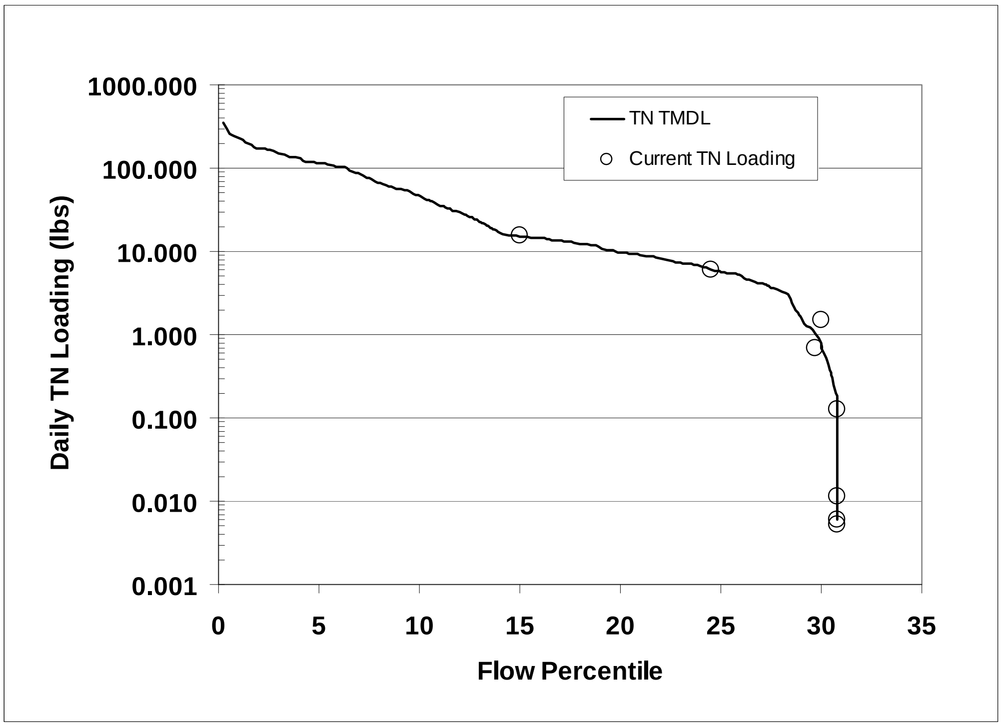

Figure 5-18. Load duration curve for the TN TMDL and current TN loading in Pasture Creek

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.

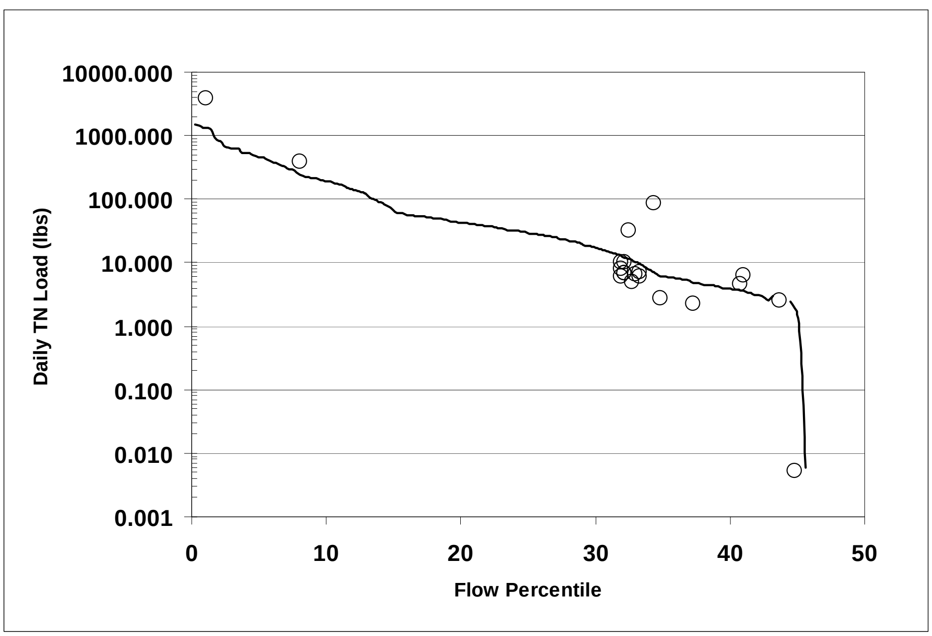

Figure 5-19. Load duration curve for the TN TMDL and current TN loading in Prairie Elk Creek

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.

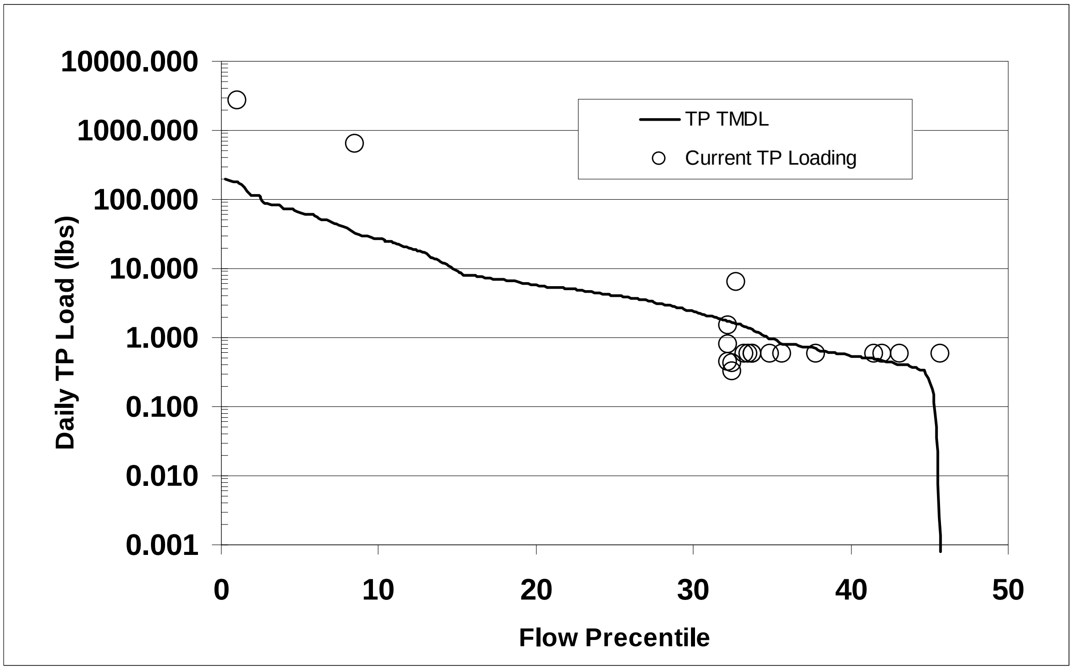

Figure 5-20. Load duration curve for the TP TMDL and current TP loading in Prairie Elk Creek

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.

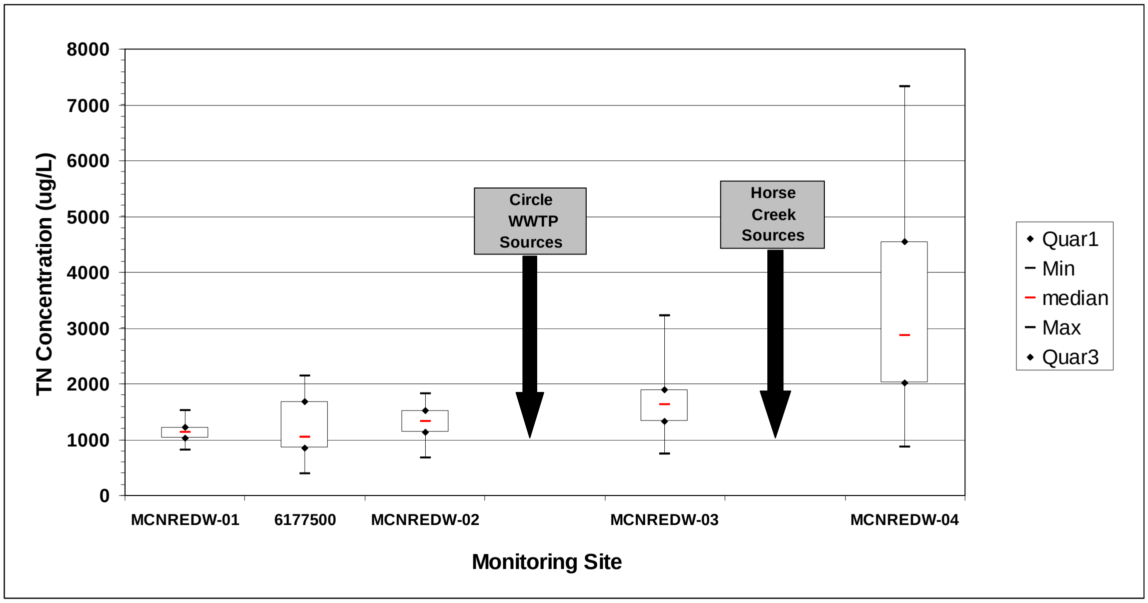

Figure 5-21. Box Plot Graph of TN Concentrations for Redwater River Monitoring Sites Showing Relative Source Locations.

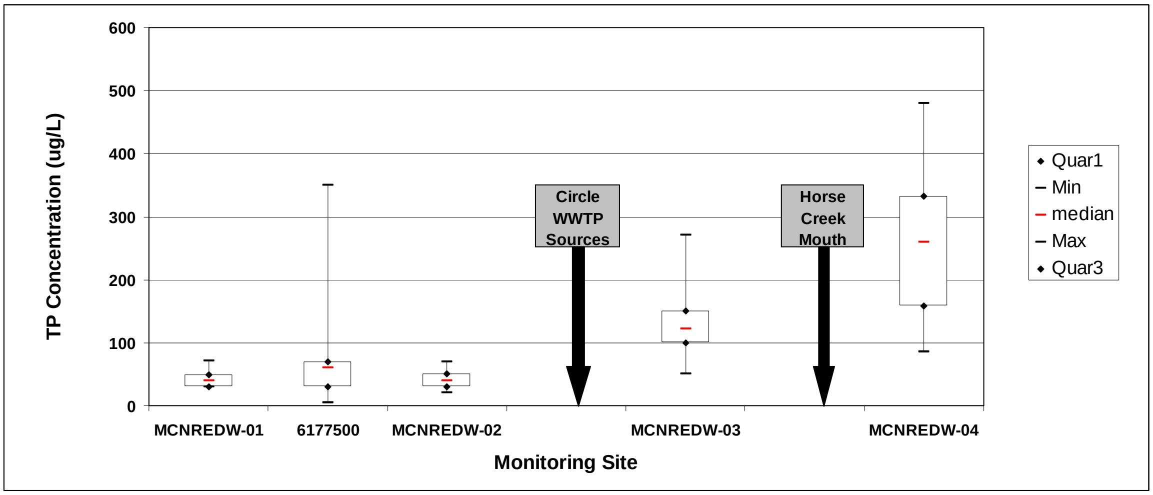

Figure 5-22. Box Plot Graph of TP Concentrations for Redwater River Monitoring Sites Showing Relative Source Locations.

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.

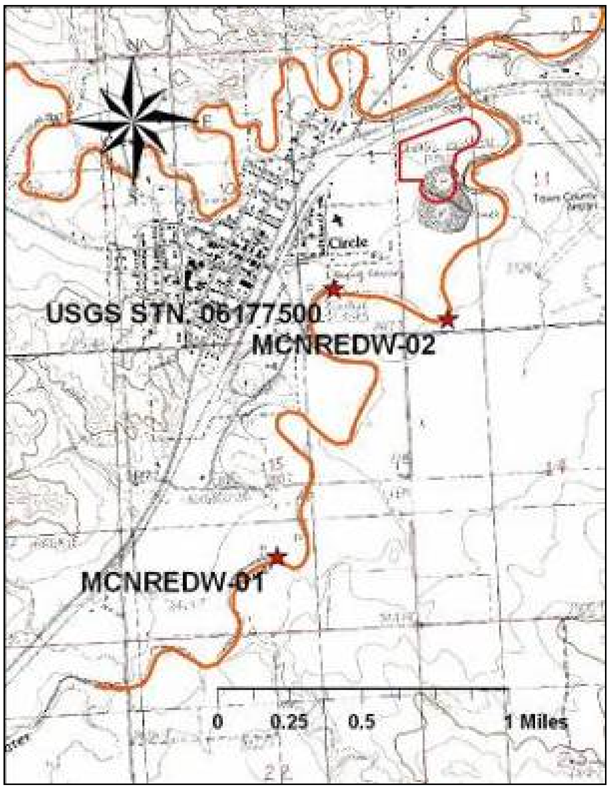

Figure 5-23. Monitoring Stations Used to Characterize Upstream Nutrient Loading to the Redwater River.

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.

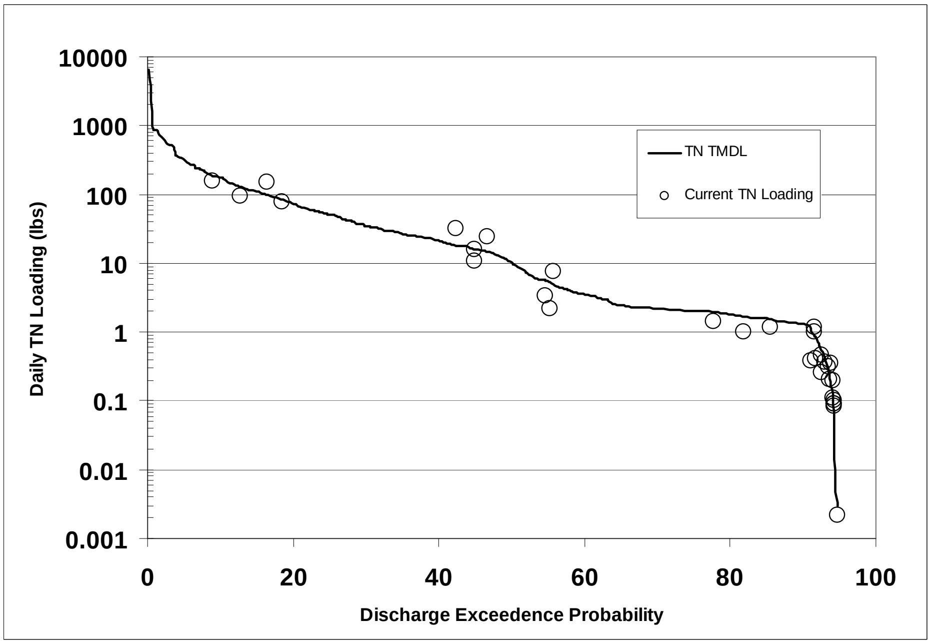

Figure 5-24. Load duration curve for the TN TMDL and current TN Loading to the Redwater River at sites MCNREDW-01, MCNREDW-02, and USGS Station 06177500

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.

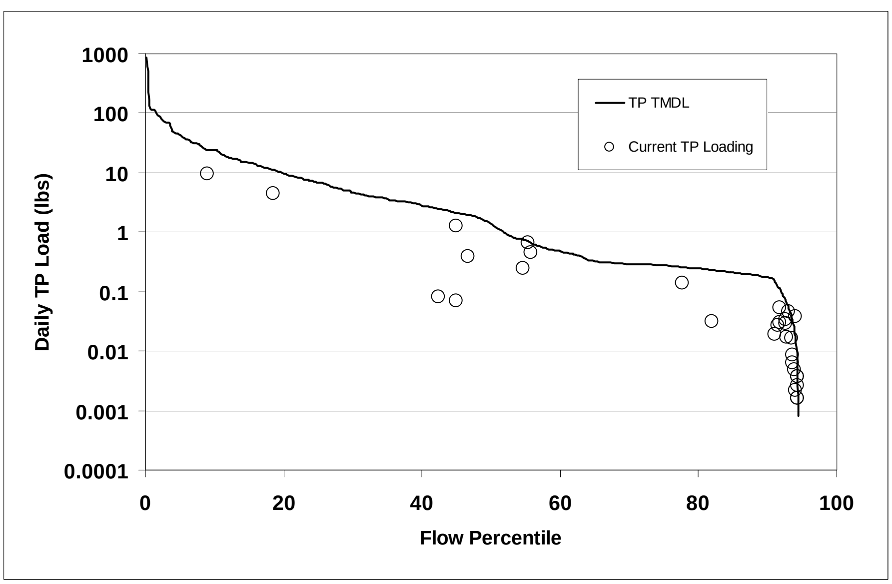

Figure 5-25. Load duration curve for the TP TMDL and current TP loading to the Redwater River at sites MCNREDW-01, MCNREDW-02, and 06177500

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.

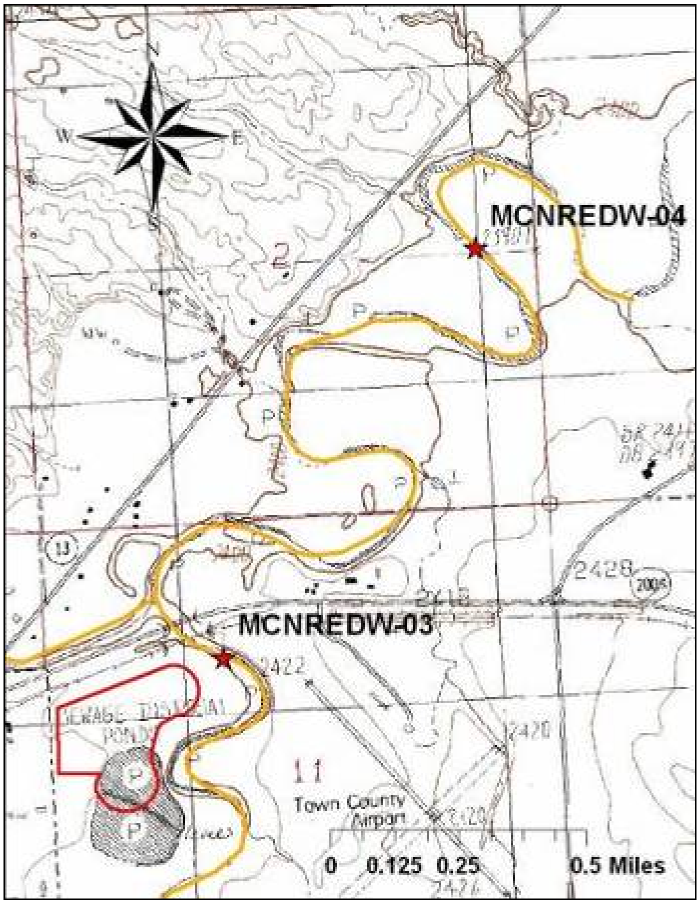

Figure 5-26. Location Map of Redwater River Monitoring Sites below the Circle WWTP and Below the Mouth of Horse Creek.

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.

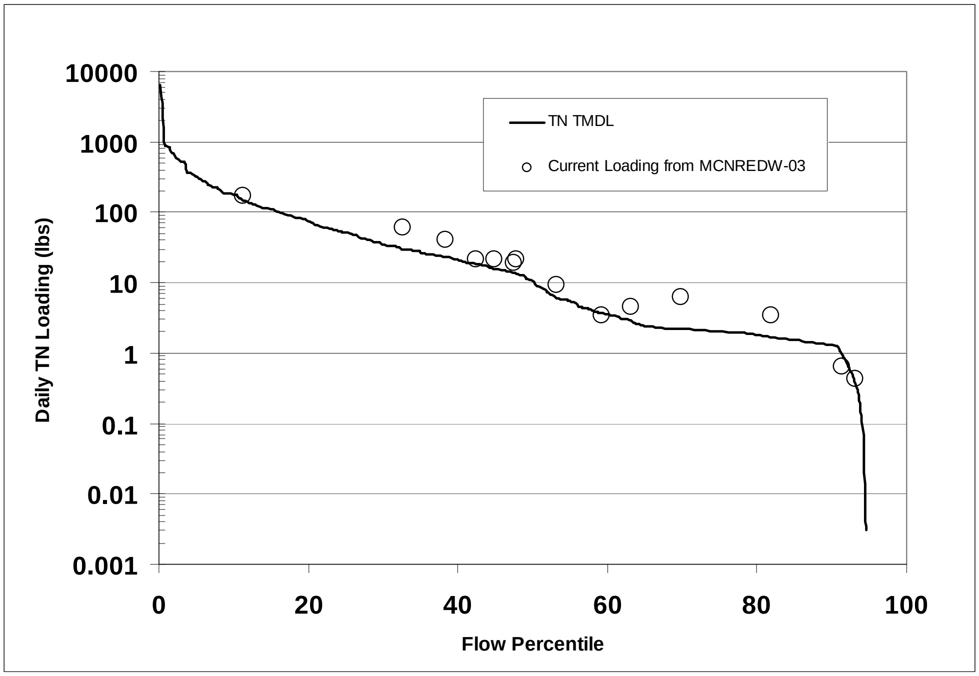

Figure 5-27. Load duration curve for the TN TMDL and current TN loading to the Redwater River at site MCNREDW-03.

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.

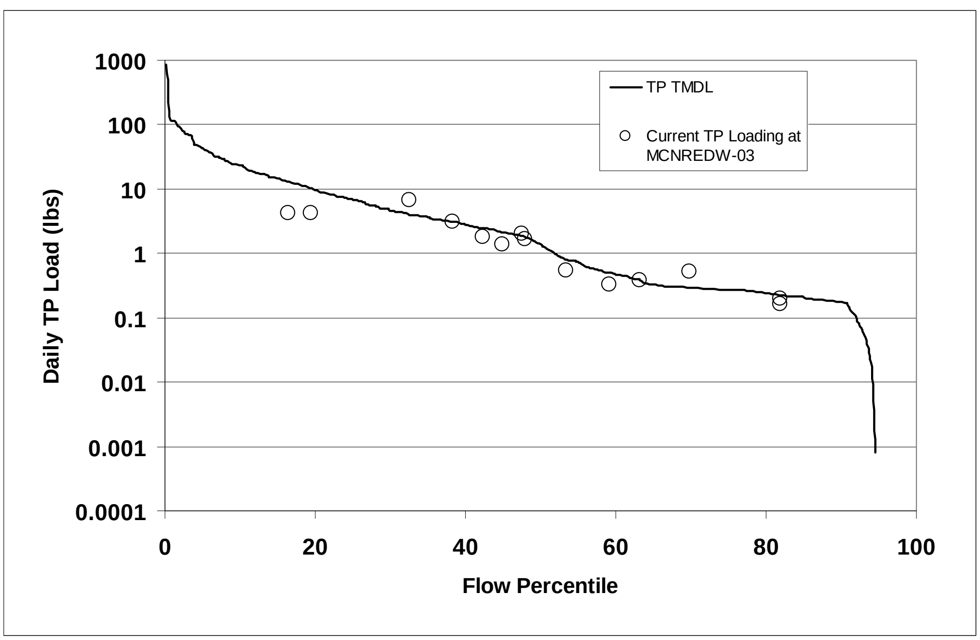

Figure 5-28. Load duration curve for the TP TMDL and current TP loading to the Redwater River at site MCNREDW-03.

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.

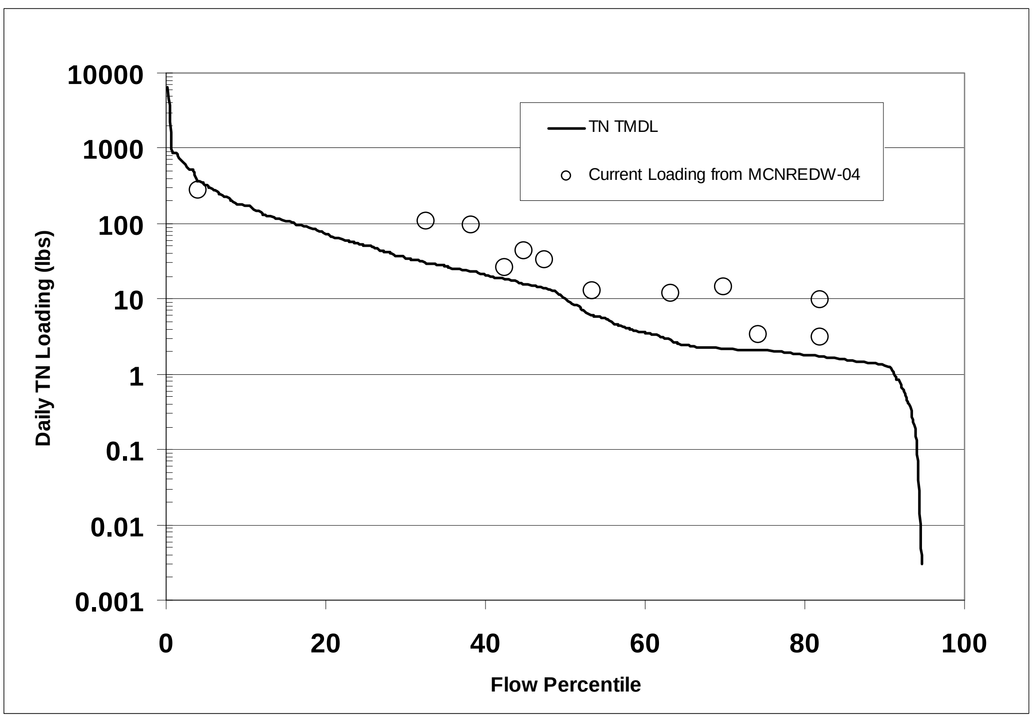

Figure 5-29. Load duration curve for the TN TMDL and current TN loading to the Redwater River at site MCNREDW-04.

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.

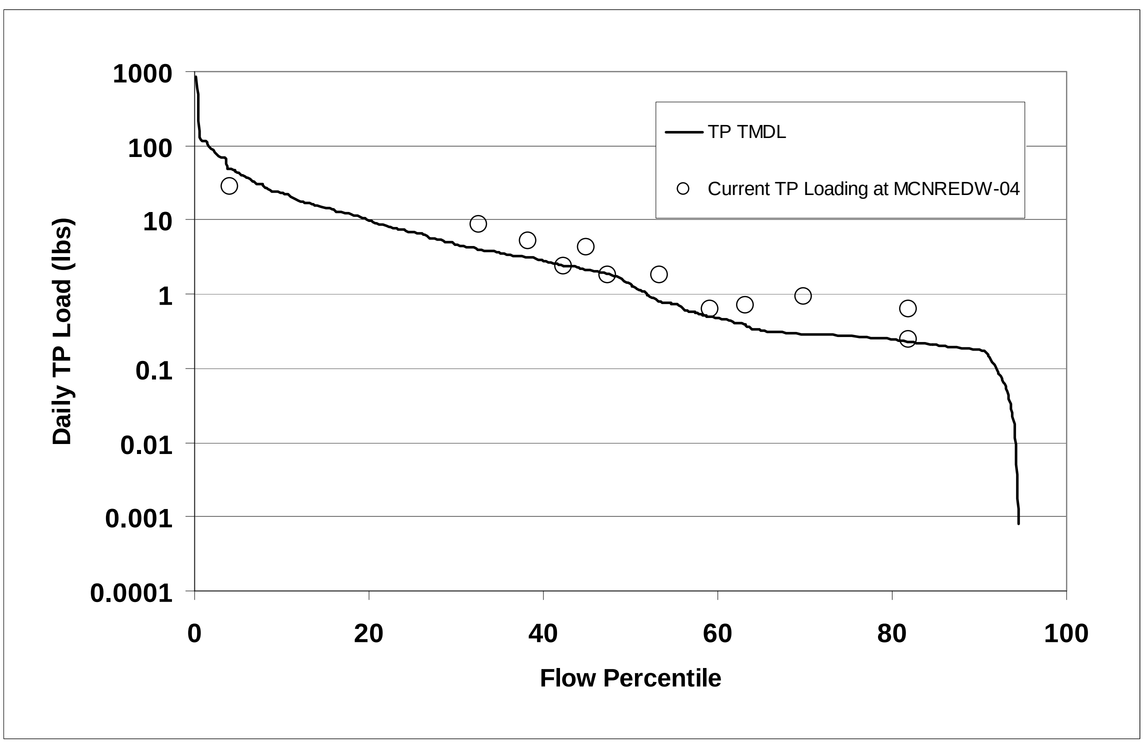

Figure 5-30. Load duration curve for the TP TMDL and current TP loading to the Redwater River at site MCNREDW-04.

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.

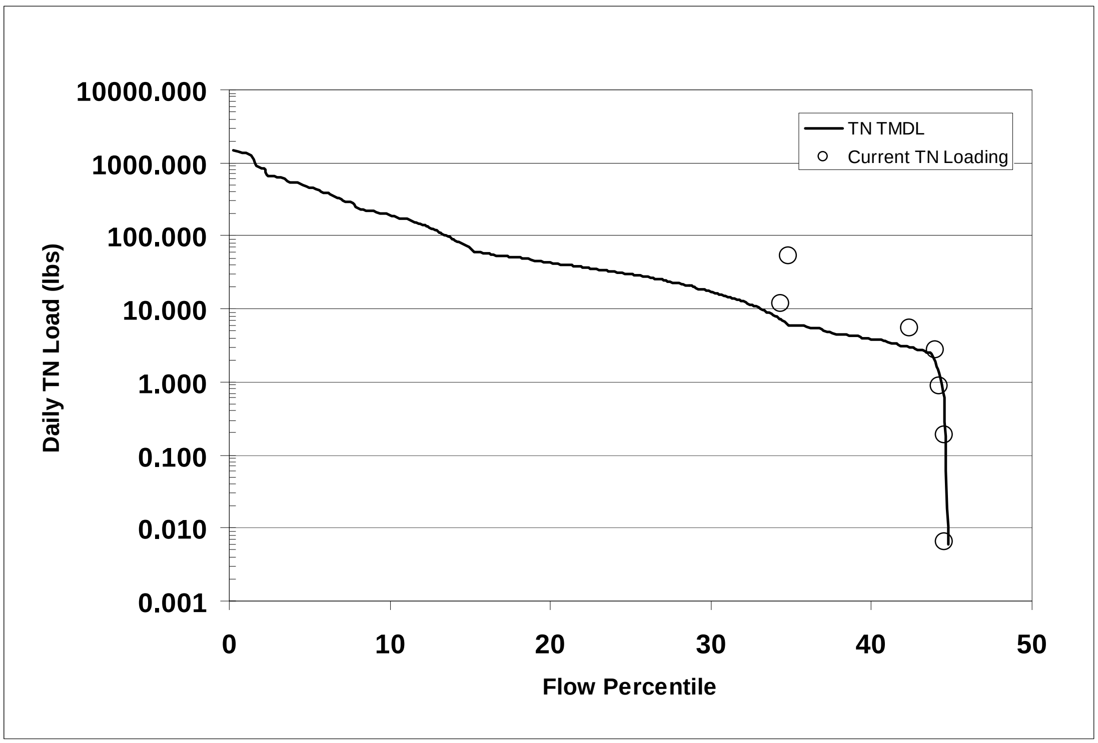

Figure 5-31. Load duration curve for the TN TMDL and growing season TN loading in Sand Creek

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

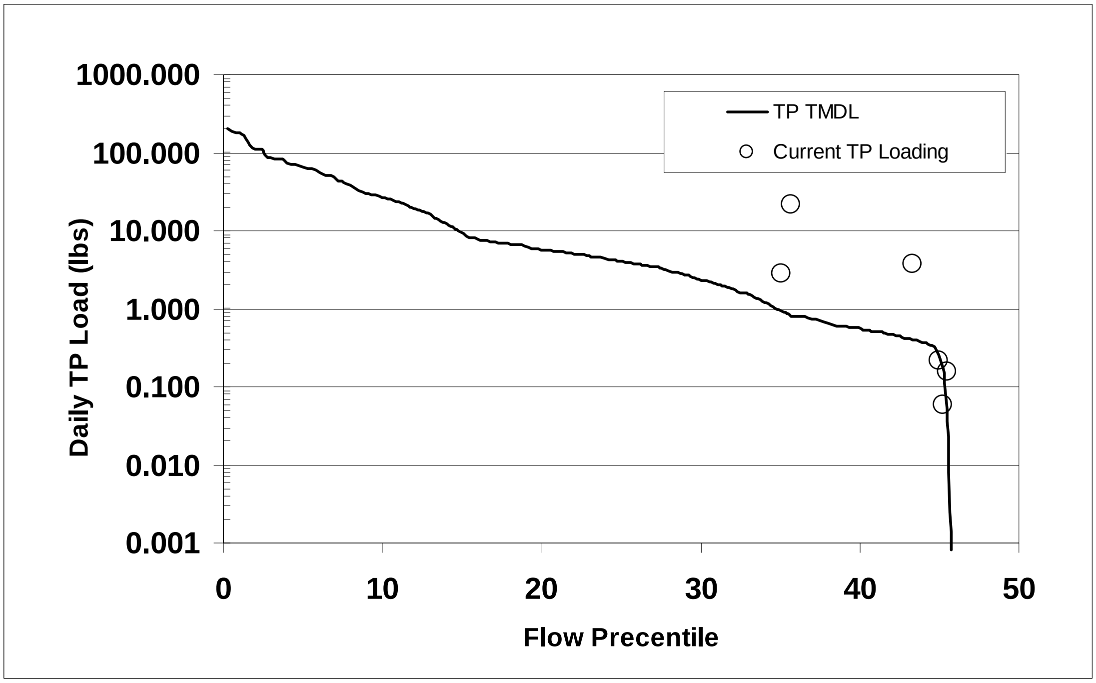

Figure 5-32. Load duration curve for the TP TMDL and current growing season TP loading to Sand Creek.

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.

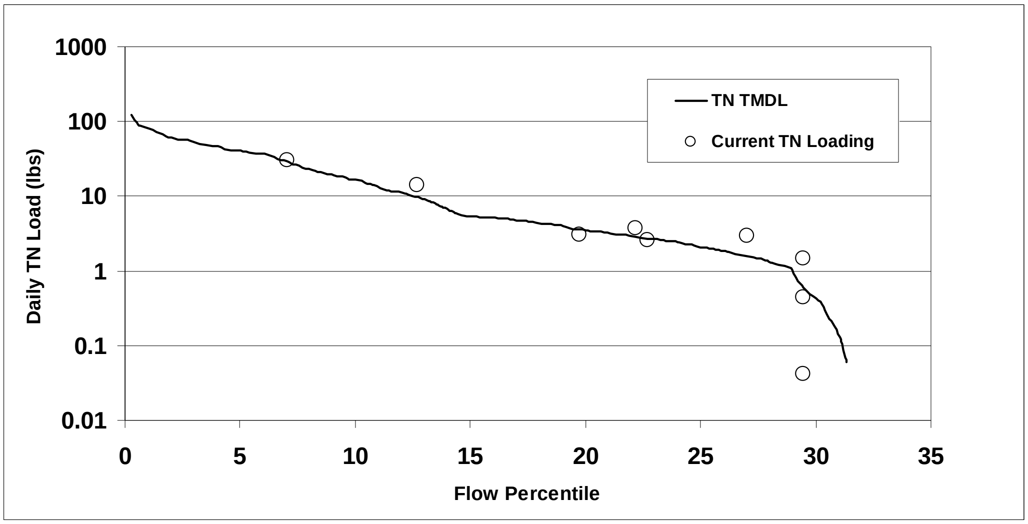

Figure 5-33. Load duration curve of the TN TMDL and current TN loading in Timber Creek

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.

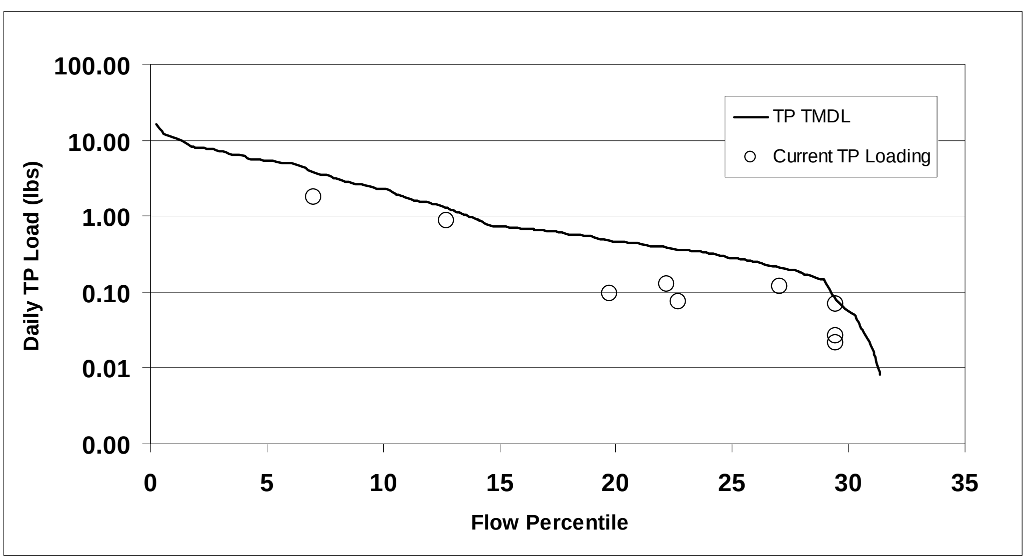

Figure 5-34. Load duration curve for the TP TMDL and current TP loading in Timber Creek

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).

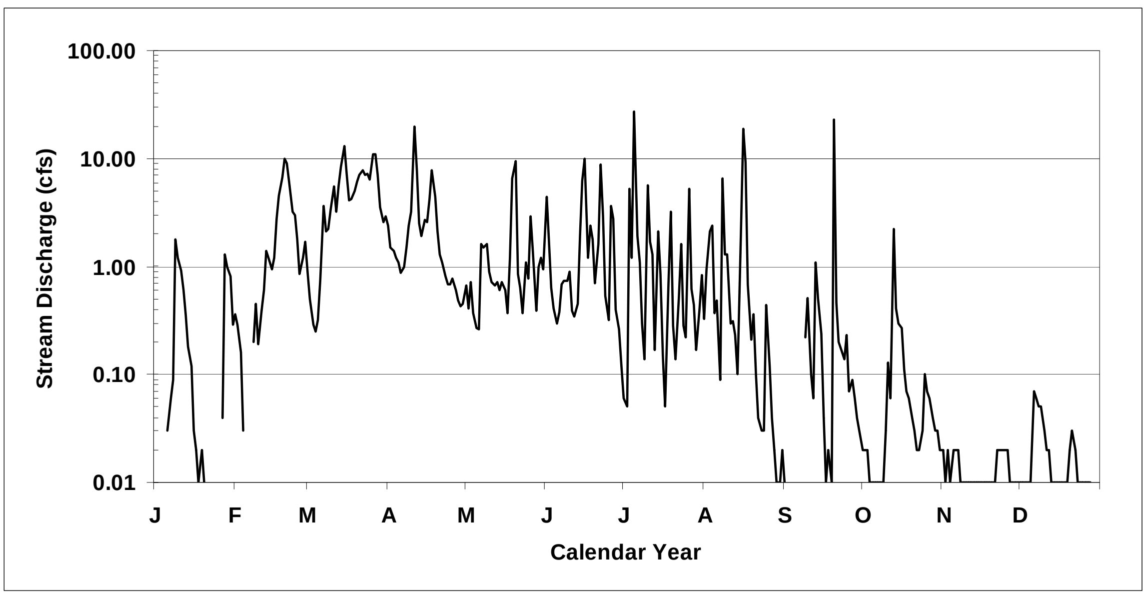

Figure 5-35. Hydrograph of Lower Nelson Creek at USGS Station 06131200

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.

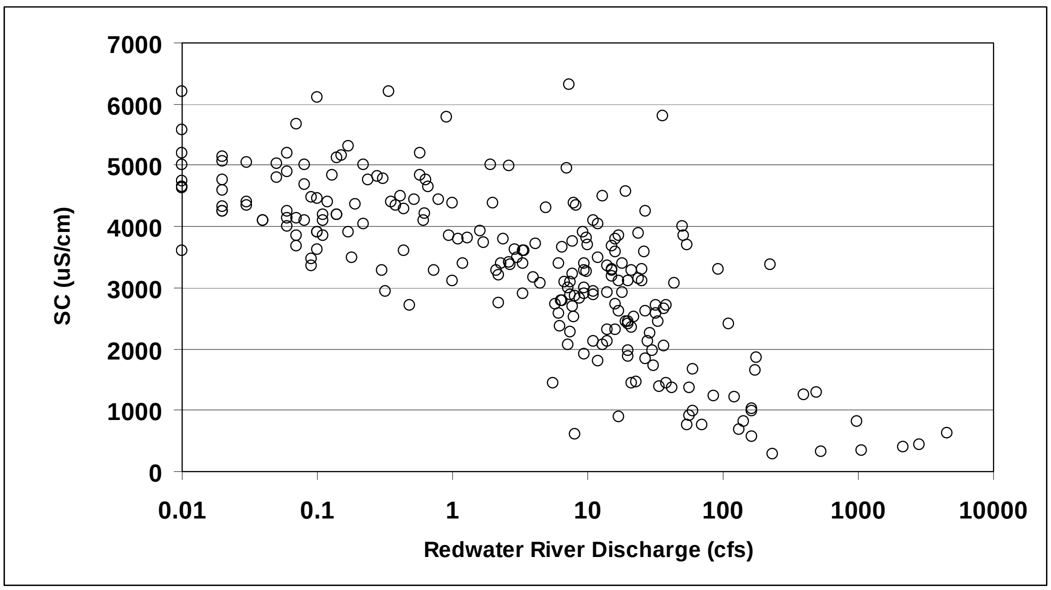

Figure 6-1. Graph of specific conductance and measured flow of the Redwater River at Circle

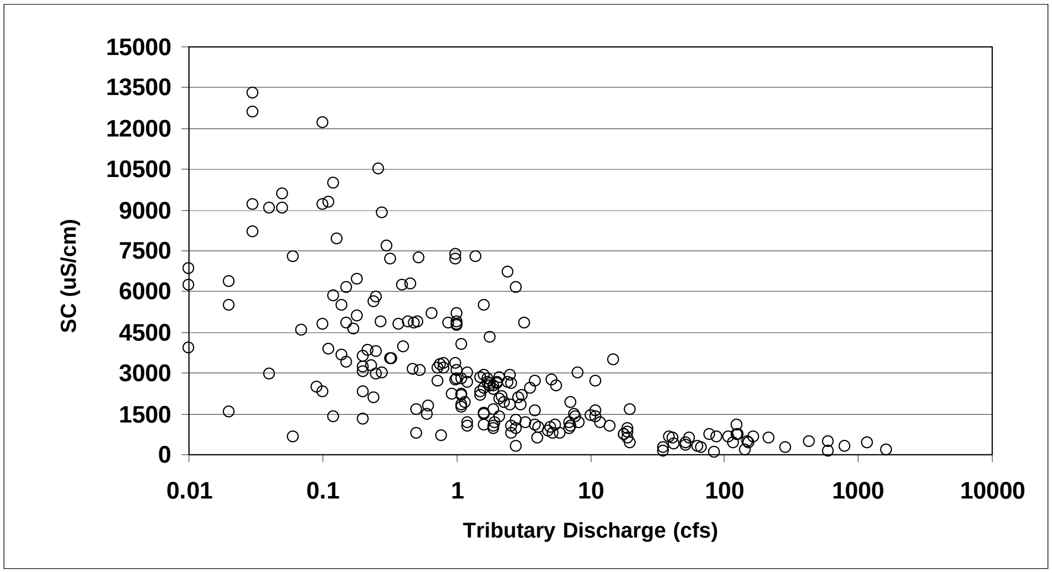

Figure 6-2. Graph of specific conductance and tributary stream flow.

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.

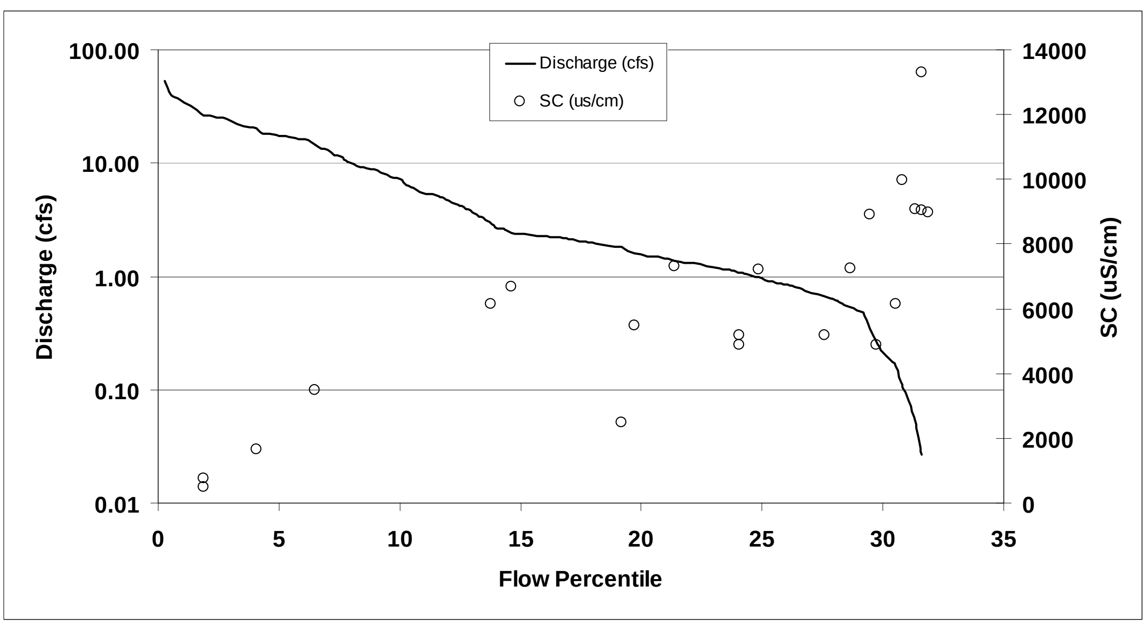

Figure 6-3. Flow duration curve for Horse Creek with measured SC values.

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.

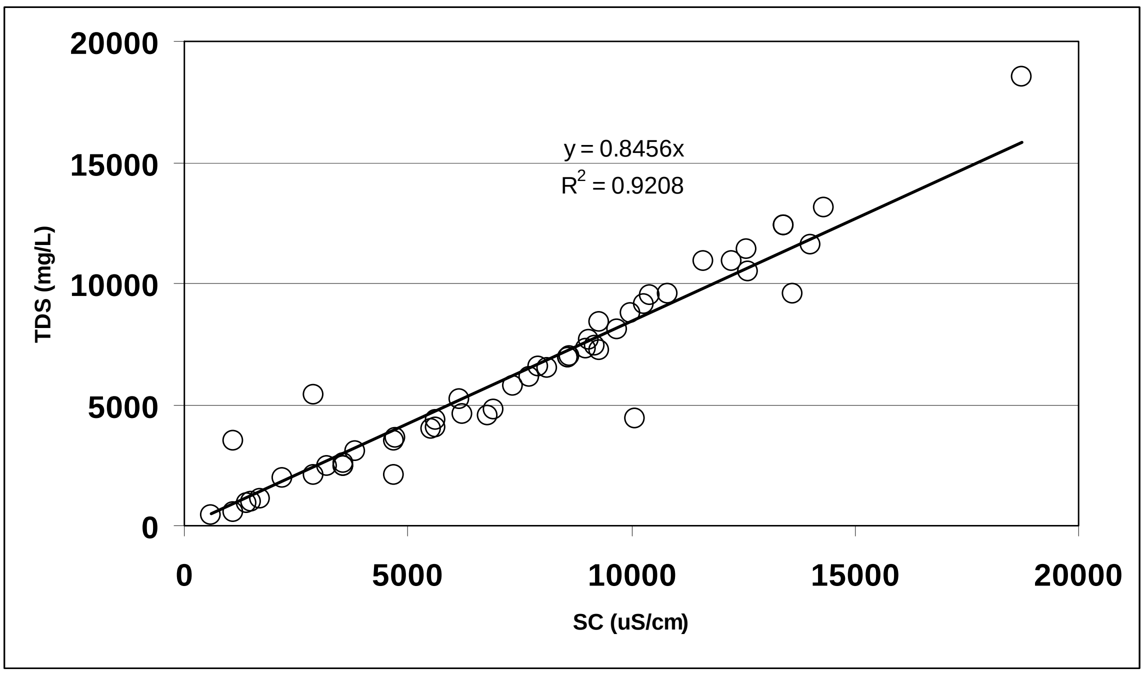

Figure 6-4. Graph of the linear relationship between TDS and SC for wadeable streams in the Redwater TPA.

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.

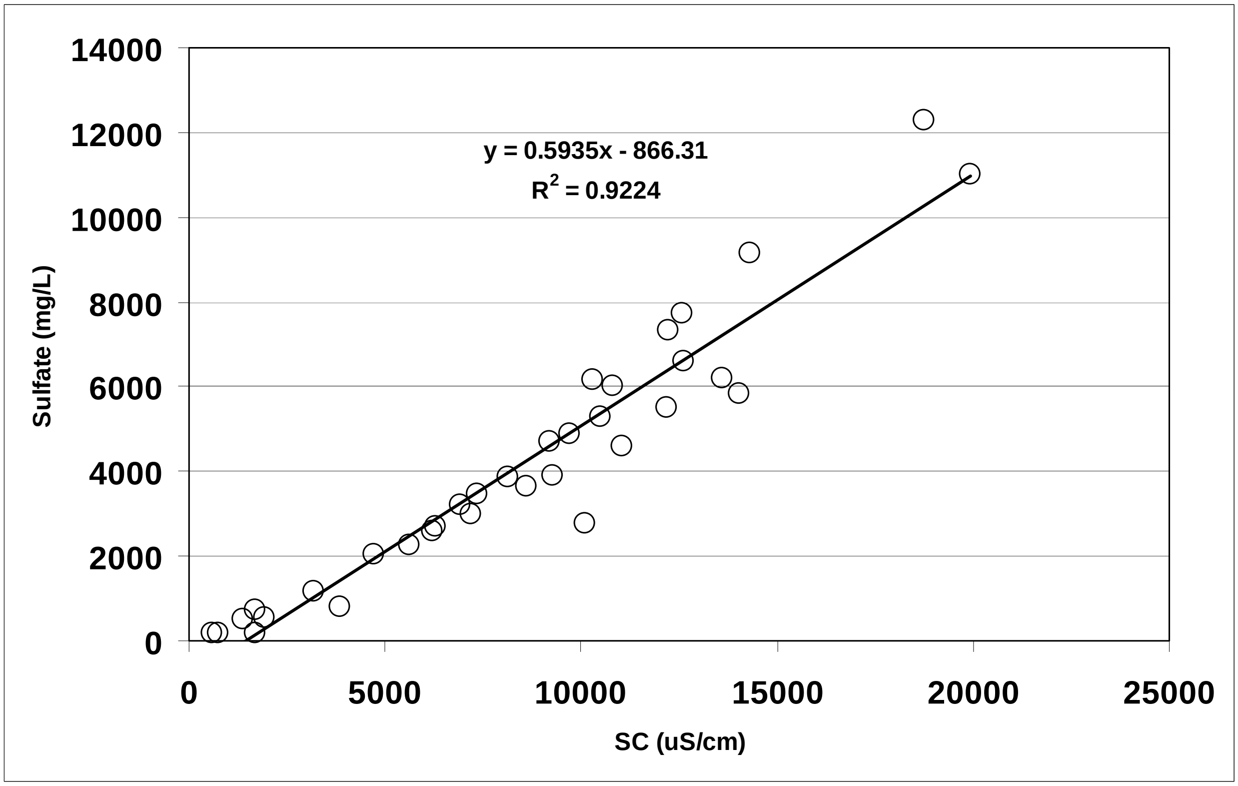

Figure 6-5. Graph of the linear relationship between TDS and sulfate for Redwater TPA tributaries.

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.

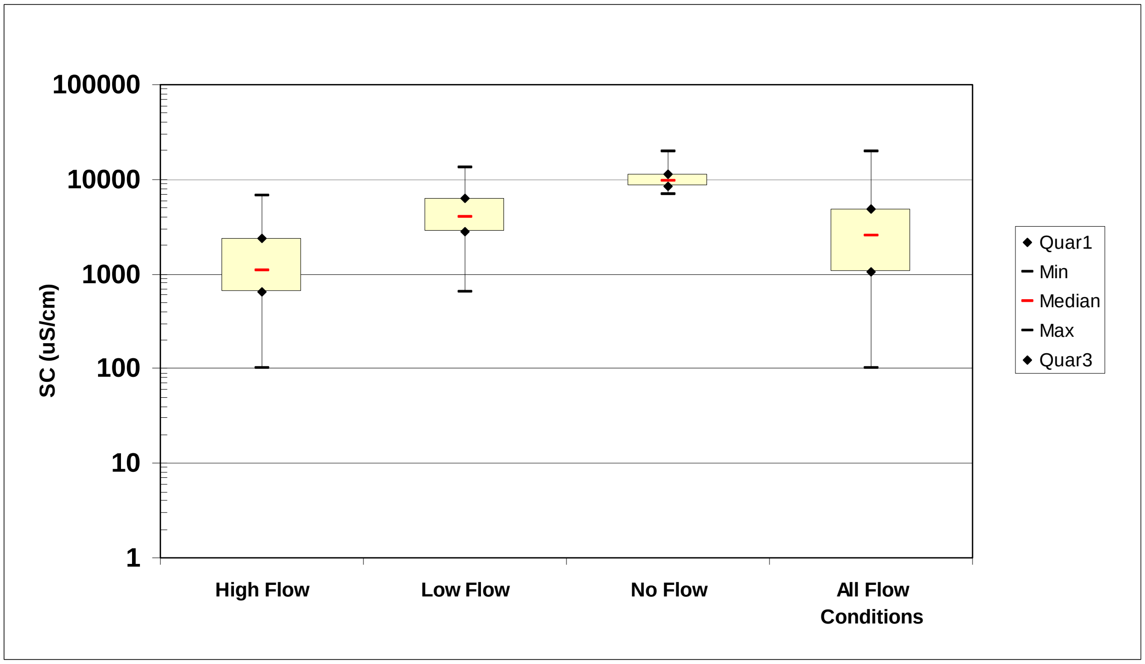

Figure 6-6. Box plot graph of specific conductance of tributary streams in the Redwater TPA stratified by flow condition.

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.

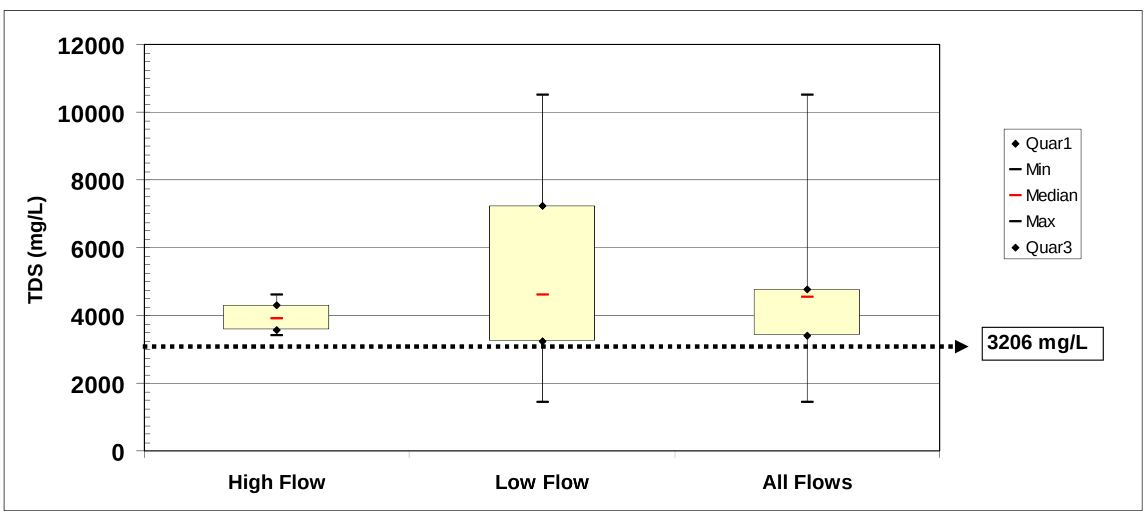

Figure 6-7. Target departures for TDS data collected on East Redwater Creek.

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.

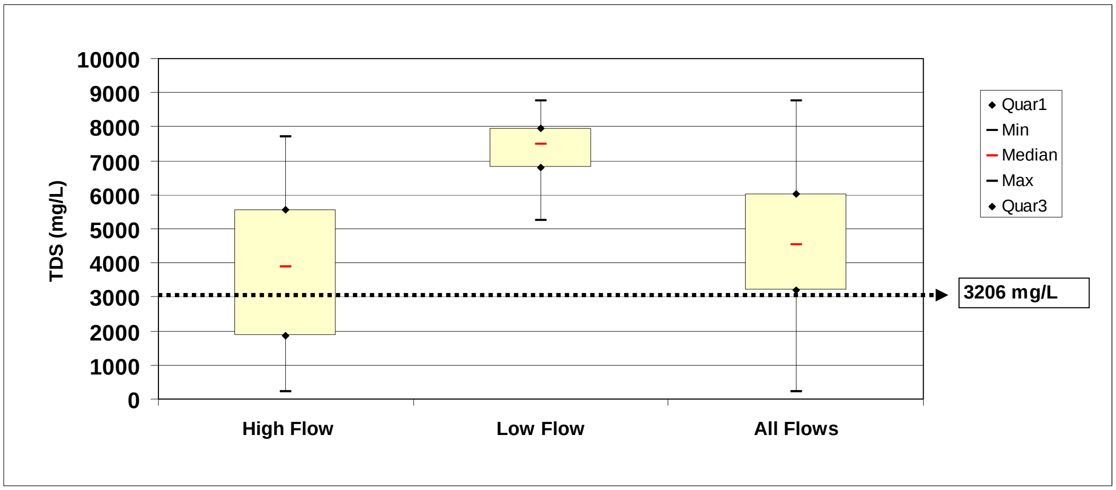

Figure 6-8. Target departures for Horse Creek TDS data distributions for high and low flow conditions

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.

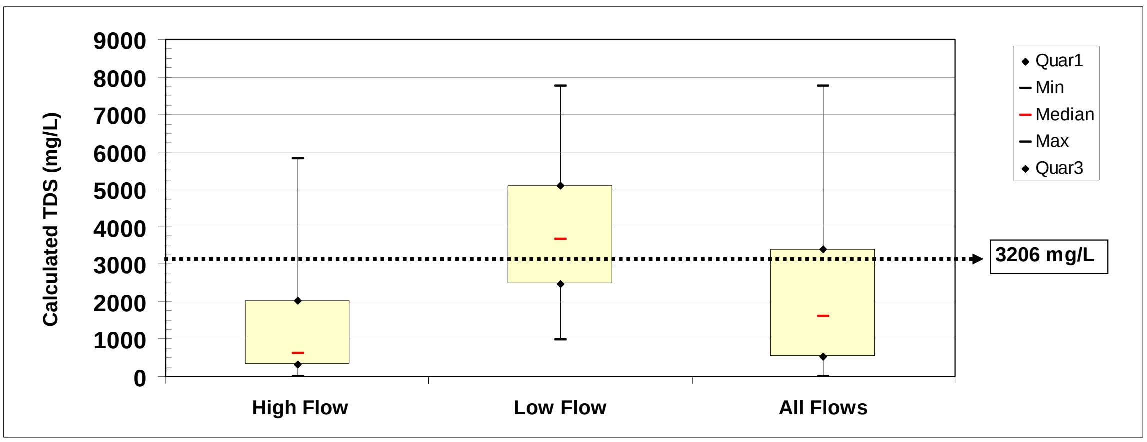

Figure 6-9. Target departures for calculated TDS data distributions for high and low flow conditions in Nelson Creek

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.

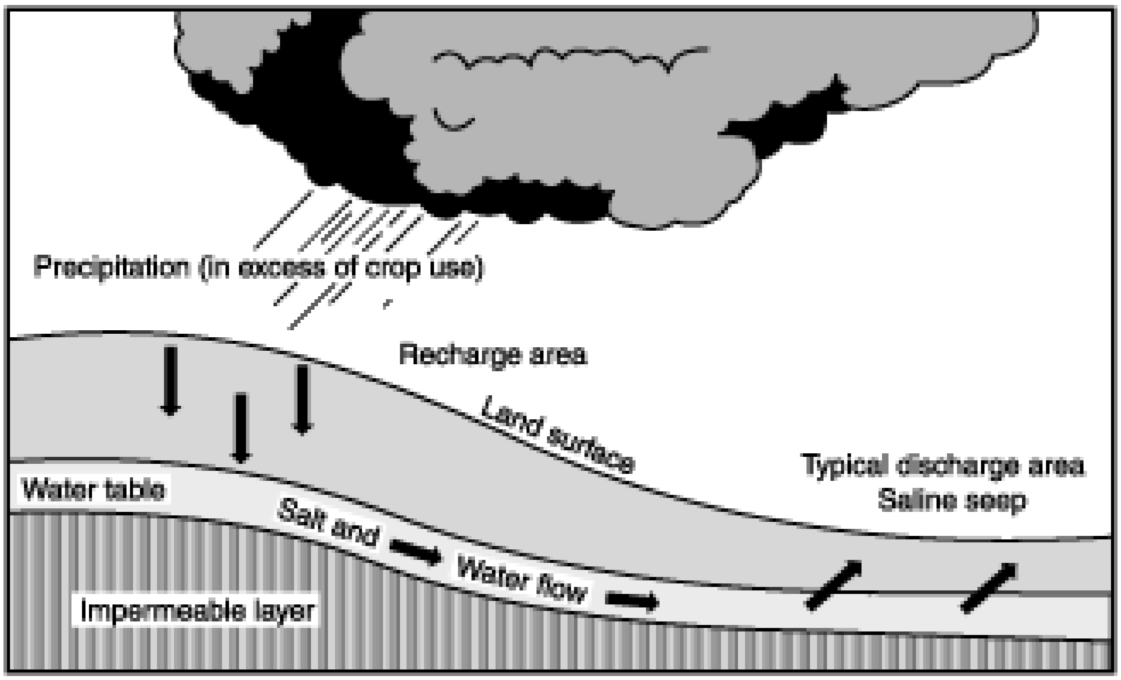

Figure 6-10 Conceptual model of dissolved solids loading from excess precipitation recharge of shallow aquifers beneath croplands.

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.

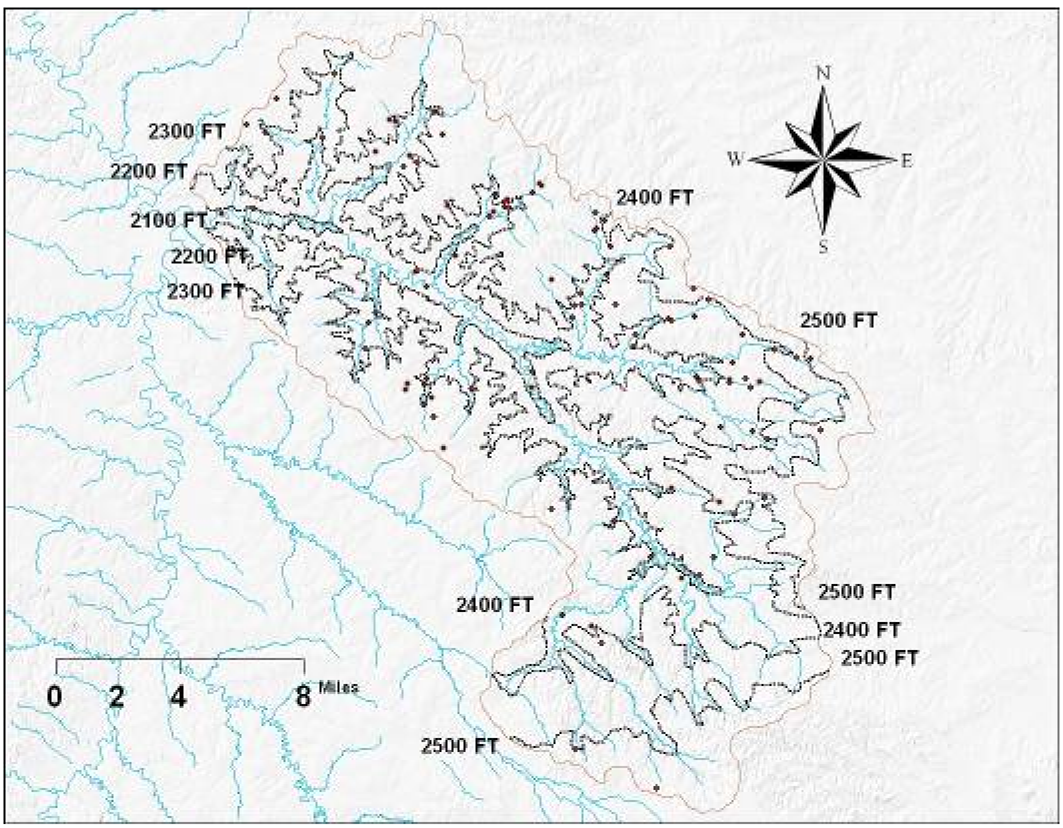

Figure 6-11. Approximate water table contour map of East Redwater Creek with locations of GWIC well construction data

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.

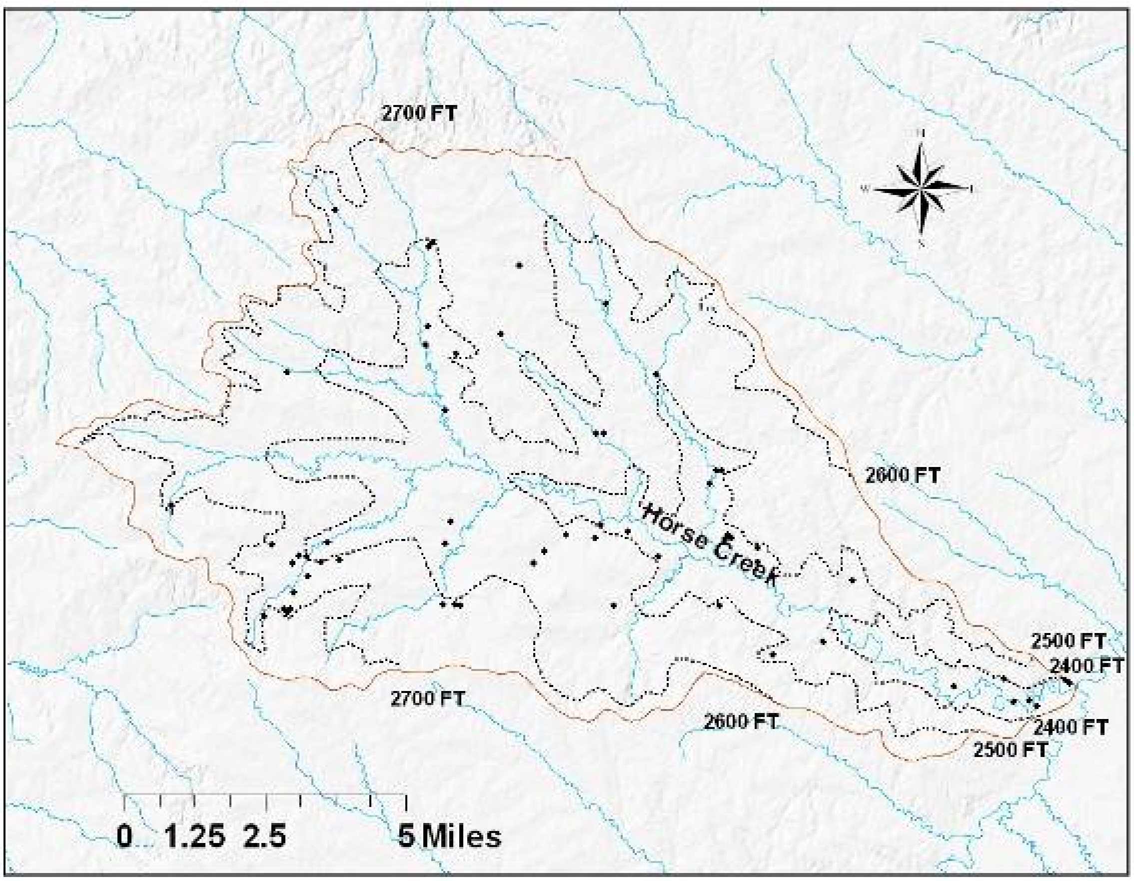

Figure 6-12. Approximate water table contour map of Horse Creek with locations of GWIC well construction data

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**.

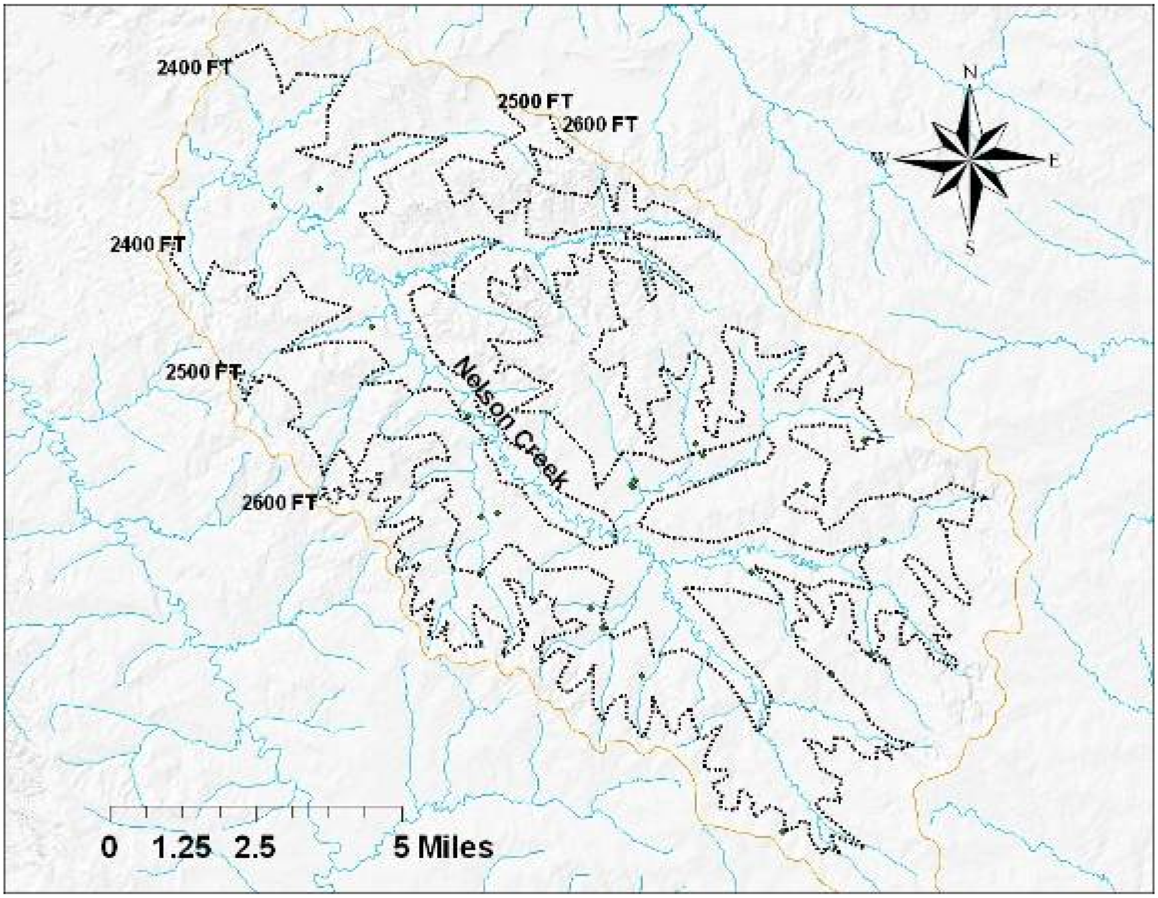

Figure 6-13. Approximate water table contour map of Nelson Creek with locations of GWIC well construction data

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.

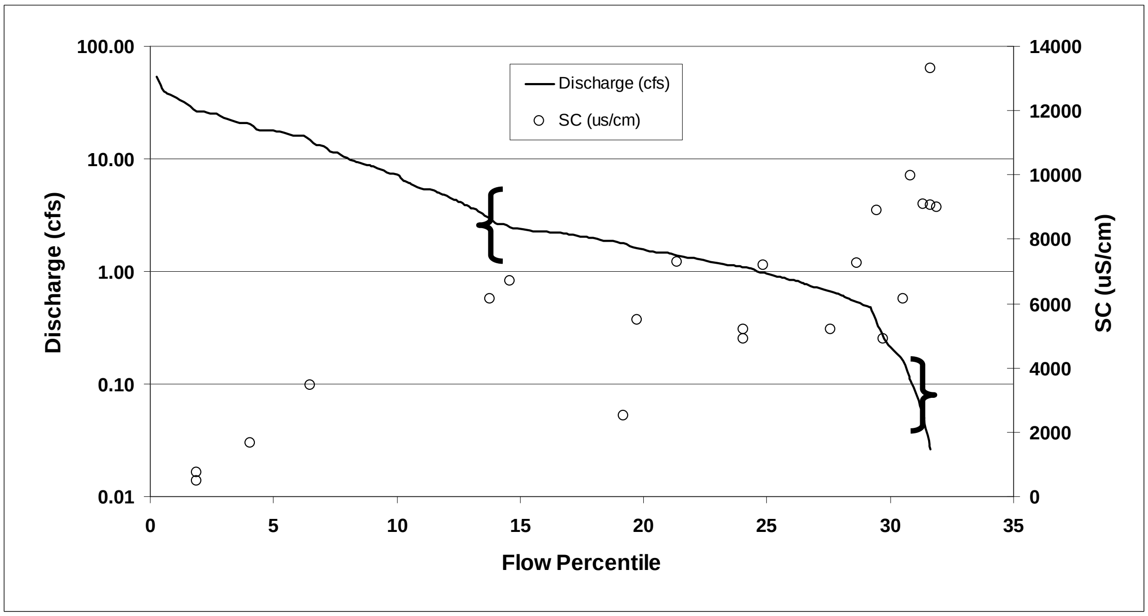

Figure 6-14. Graphed relationship between flow and measured SC in Horse Creek bracketing the flow conditions when targets would apply

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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