Water Quality and Watershed Assessment Results for the Upper and Middle Sheyenne River-“Pierce Model” Watershed in Pierce, Benson, Wells, McHenry, and Sheridan Counties 2009-2010

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2009-2010

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1.0 INTRODUCTION

The Upper Sheyenne River sub-basin (09020202) and the Middle Sheyenne River sub-basin (09020203) collectively encompass approximately 3,913 square miles, or nearly 2.5 million acres located within twelve counties (Barnes, Benson, Eddy, Foster, Griggs, McHenry, Nelson, Pierce, Sheridan, Steele, Stutsman, and Wells Counties). This was the focus of the Upper and Middle Sheyenne River Water Quality and Watershed Assessment Project (Figure 1).

The primary goals of the Upper and Middle Sheyenne River Water Quality and Watershed Assessment Project are to assess the current water quality condition and beneficial use (e.g., aquatic life and recreation) support status of the Sheyenne River above Lake Ashtabula (Upper and Middle Sheyenne River sub-basins) and their tributaries. The project is also intended to identify possible sources or causes of any documented impairment(s) to beneficial uses. This project was funded through the North Dakota Department of Health's (NDDoH) Section 319 Nonpoint Source Pollution Management Program and Section 604(b) Watershed Planning Grant Program in partnership with the Upper Sheyenne Joint Water Resource Board, Wells County Soil Conservation District, Griggs County Soil Conservation District, State Water Commission, and Garrison Diversion Conservancy District. Data for this project was collected from May of 2009 through October of 2010.

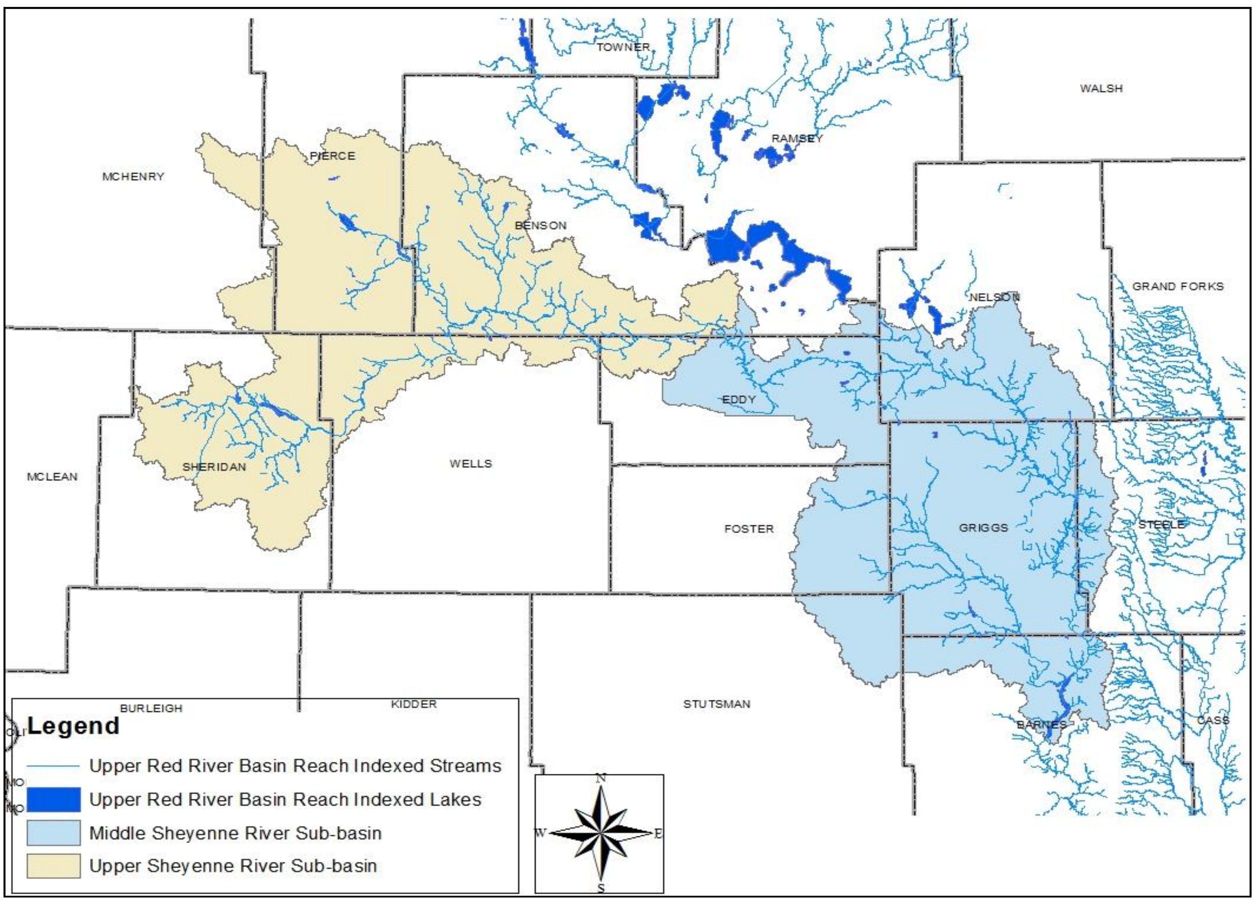

Figure 1. Upper and Middle Sheyenne River Sub-Basins.

1.1 Water Quality Assessment Report Strategy

The primary tool used to model the transport of nutrients and sediment throughout the watersheds for this assessment is the Annualized Agriculture Non Point Source (AnnAGNPS) Model. Due to the large size of the Upper and Middle Sheyenne River sub-basins above Lake Ashtabula (3,913 square miles or 2,504,106 acres in total) and the limitations of the AnnAGNPS Model, seven separate watershed models had to be developed for the project (Figure 2, Table 1).

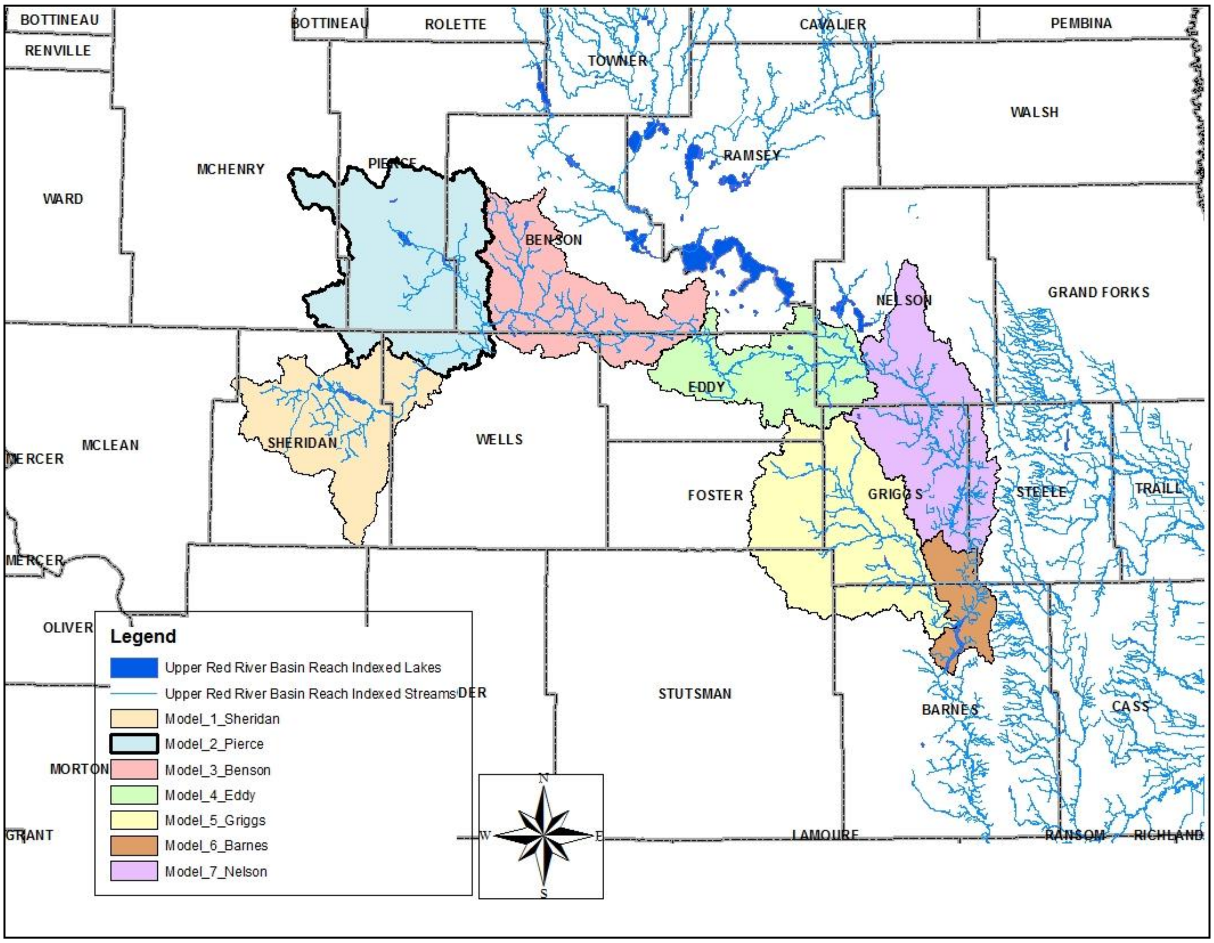

Figure 2. Upper and Middle Sheyenne River Watershed AnnAGNPS Models (Highlighting the Model 2 - Pierce).

Each of the watershed models were developed based on two criteria: 1) to maintain similar watershed sizes; and 2) by placing a watershed so that a majority of the area lay with one county (Table 1).

Table 1. Description of the Seven Watershed AnnAGNPS Models.

Watershed Model	Description
Model 1 - Sheridan	Area above Harvey encompassing Sheridan and Wells Counties
Model 2 - Pierce	**Area between Harvey and the junction with the North Fork Sheyenne River encompassing Pierce, Wells, Sheridan, and McHenry Counties**
Model 3 - Benson	Area between the junction with the North Fork Sheyenne River and 1 mile upstream of Eddy County Hwy 1 encompassing Benson, Wells, and Eddy Counties
Model 4 - Eddy	Area between 1 mile upstream of Eddy County Hwy 1 and south of Pekin encompassing Eddy, Ramsey, Griggs, and Nelson Counties
Model 5 - Griggs	Baldhill Creek watershed encompassing Griggs, Barnes, Stutsman, Foster, and Eddy Counties
Model 6 - Barnes	Area between upstream of the Griggs and Barnes County and Baldhill Dam (excluding Baldhill Creek) encompassing Barnes, Griggs, and Steele Counties
Model 7 - Nelson	Area south of Pekin and to upstream of the Griggs and Barnes' County lines encompassing Nelson, Griggs, and Steele Counties

In order to provide stakeholders in the Upper and Middle Sheyenne River watersheds with necessary information for making conservation management decisions, the water quality report strategy will consist of seven separate water quality reports depicting water quality and watershed assessment data for that particular modeled watershed. This approach will permit stakeholders to focus on water quality and watershed data in their specific study area. The water quality report will provide information to assist stakeholders with developing water quality and watershed restoration targets and implementation strategies to improve water quality. This report is focused on Model 2, referred to as the "Pierce Model". It encompasses a large portion of Pierce County along with smaller portions of Benson, Wells, Sheridan, and McHenry Counties.

1.2 Environmental Setting

1.2.1 Land Use

The "Pierce Model" watershed encompasses 529,982 acres in Pierce, Benson, Wells, Sheridan, and McHenry Counties, North Dakota (Table 2). According to National Agricultural Statistics Service (NASS) 2007 land cover data, the dominant land use in the watershed is agriculture with 49 percent used for grassland/pasture, 42 percent cropland, and the remaining 9 percent a combination of water, wetlands, fallow/idle cropland, or developed/open space (Figure 3). The dominant crops grown in the watershed are spring wheat, soybeans, corn, sunflowers, barley, canola, dry beans, and winter wheat.

Table 2. Watershed Size for the Seven AnnAGNPS Watershed Models.

Watershed Model	Area (mi^2)	Area (acres)
Model 1 - Sheridan	543.6	347,914
Model 2 - Pierce	**828.1**	**529,982**
Model 3 - Benson	535.7	342,826
Model 4 - Eddy	438.0	280,303
Model 5 - Griggs	762.7	488,125
Model 6 - Barnes	159.5	102,069
Model 7 - Nelson	645.0	412,887
Total	3,912.6	2,504,106

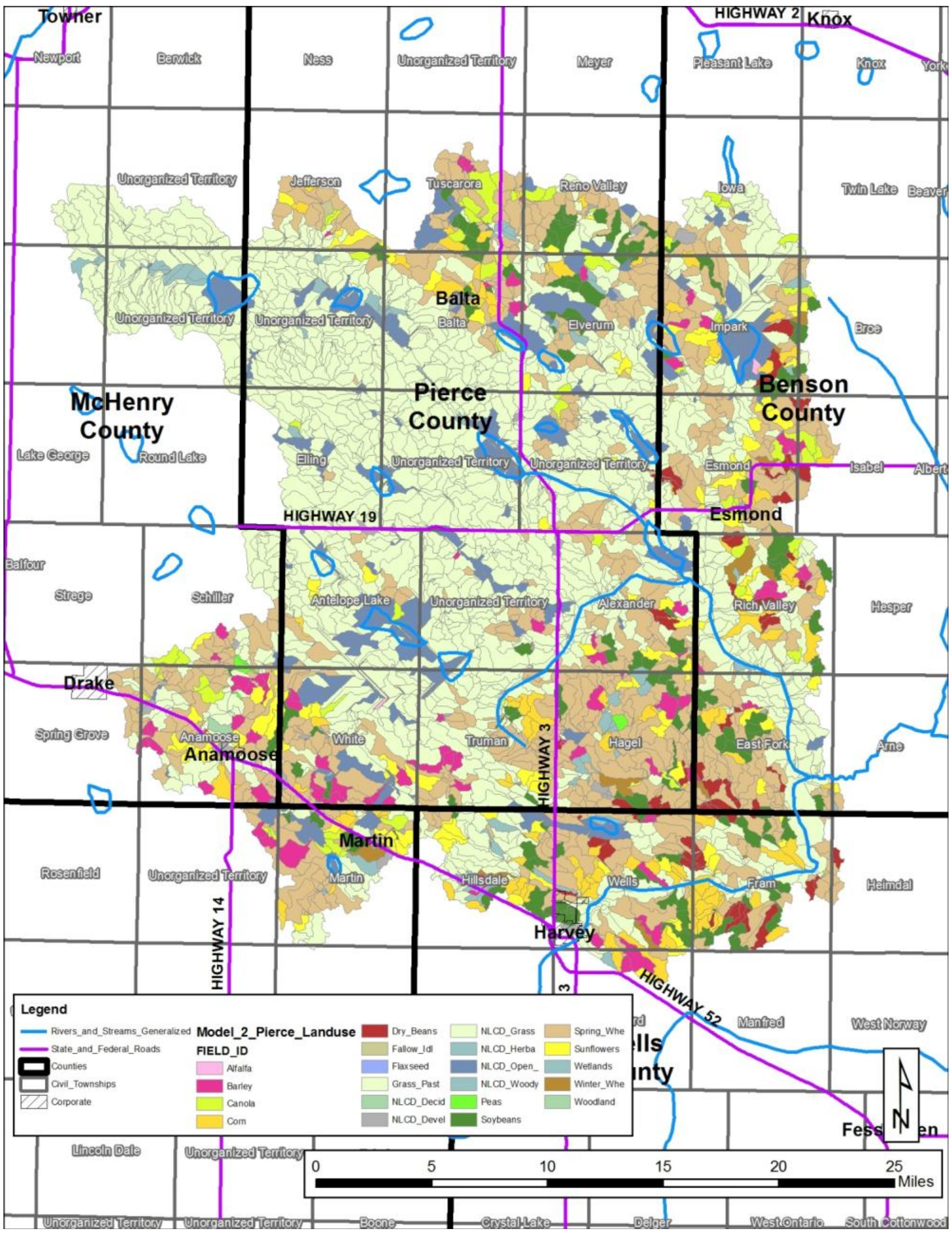

Figure 3. National Agricultural Statistical Survey Land Use Map, 2007 (Pierce Model).

1.2.2 Ecoregions

The Pierce Model watershed lies within three level IV ecoregions. These are the Glacial Lake Deltas (46d), End Moraine Complex (46f), and Drift Plains Ecoregion (46i) (Figure 4).

The Glacial Lake Deltas ecoregion (46d) was created by rivers entering glacial lakes basins. Sand and fine gravel formed delta fans at the river inlets, during glacial withdrawal lake floors were exposed and wind worked the sand in some areas into dunes. These dunes have a thin vegetative cover and a high risk for wind erosion. Grazing and irrigated agriculture are the dominant land use.

The End Moraine Complex ecoregion (46f) is composed of blocks of material scraped off and thrust up by the continental glacier at the south end of the Devils Lake basin. The western part of the ecoregion exhibits similar stagnate moraines similar to the Missouri Coteau while the southern moraines contain slightly higher elevations resulting in wooded lake boundaries and morainal ridges. Land use within the End Moraine Complex ecoregion consists of mixed range and cropland depending on slope and presence of rocky soil.

The Drift Plains ecoregion (46i) was created from the retreating Wisconsinan glaciers which left a subtle rolling topography, thick glacial till and a large number of temporary and seasonal wetlands. The Drift Plains contain productive soils and level topography which largely favors cultivation practices. Historic grasslands of transitional and mixed grass prairie have been replaced with fields of spring wheat, barley, sunflowers and alfalfa (USGS, 2006).

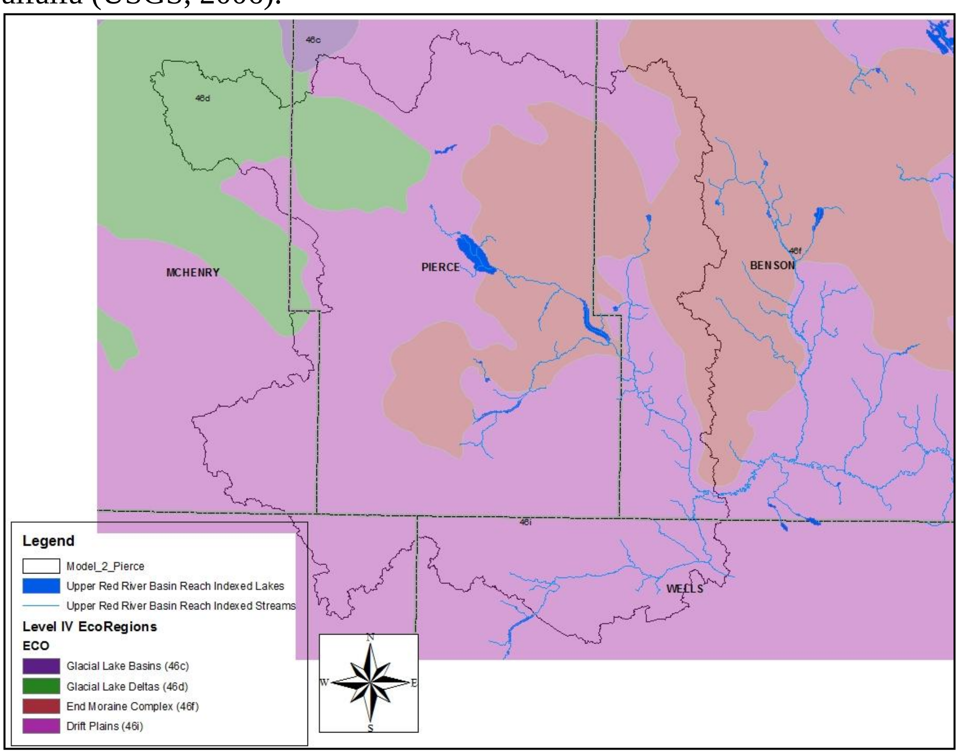

Figure 4. Level IV Ecoregions in the Pierce Model Watershed.

1.2.3 Weather Data

Precipitation data for the Upper and Middle Sheyenne River Watershed Project was obtained from the North Dakota Agricultural Weather Network (NDAWN) station located near Harvey, ND in the southeast corner of the watershed. Figure 5 shows monthly precipitation data averaged for the years of 1995 to 2008 compared to the precipitation totals for each month during 2009 and 2010. Snowfall data had not been converted into precipitation for the months of January through March and November through December for the years 1995 to 2010, and so those months do not appear in Figure 5.

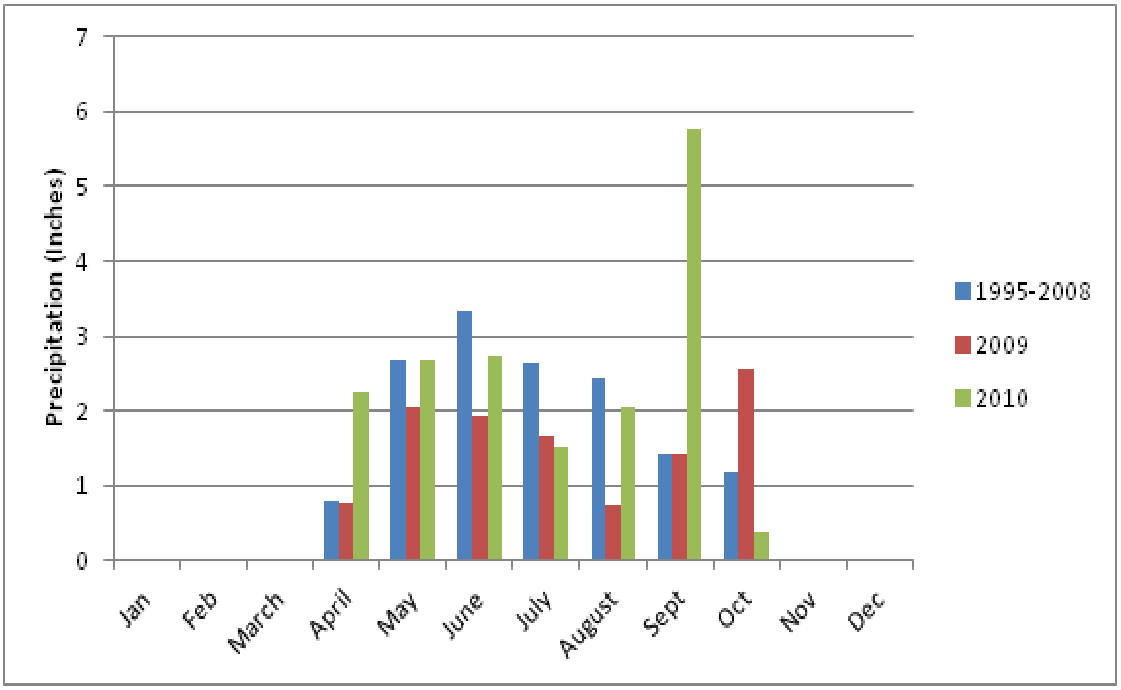

Figure 5. Monthly Precipitation for NDAWN Weather Station Located Near Harvey, ND.

1.3 Water Quality Standards and Guidelines

State law (NDCC 61-28) establishes policies to protect, maintain, and improve the quality of waters of the state, while the overall goal of the federal Clean Water Act (CWA) is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (NDDoH, 2010).

The national water quality standards regulation requires that states specify appropriate water uses to be achieved and protected. Appropriate uses are identified by taking into consideration the use and value of the water body for public water supply, for protection of fish, shellfish, and wildlife, and for recreational, agricultural, industrial, and navigational purposes. The protected beneficial uses of North Dakota's surface waters are defined in the *Standards of Quality for Waters of the State* (NDDoH, 2011), as provided in NDAC 33-16-02.1, along with narrative and numeric criteria to protect those uses.

1.3.1 Beneficial Use and Class Description

The primary beneficial uses identified in the State's water quality standards are aquatic life and recreation. Protection for aquatic life means that surface waters should be suitable for the propagation and support of fish and other aquatic biota, including aquatic macroinvertebrates, and that these waters will not adversely affect wildlife in the area. Protection of all surface waters, except wetlands, for recreation means waters should be suitable for direct body contact activities such as bathing and swimming and for secondary contact activities such as boating, fishing, and wading. Other beneficial uses identified in the State's water quality standards are municipal and domestic water (e.g. water suitable for drinking after appropriate treatment), agriculture (e.g., stock watering and irrigation), and industrial (e.g., washing and cooling). These uses apply to all classified rivers, streams, lakes, and reservoirs.

The State's water quality standards provide for four stream classes (I, IA, II, and III) and five lake classes (1-5). All classified lakes, reservoirs, rivers and streams in the state are protected for aquatic life, recreation, agricultural and industrial uses. In addition, Class I, IA, and II rivers and streams, and all classified lakes and reservoirs, are designated for use as municipal and domestic drinking water supplies, unless specifically stated otherwise.

The entire Sheyenne River is classified as Class IA. Rivers that fall into the Class IA category have the same water quality standards as Class I streams, except where natural conditions exceed Class I criteria for municipal and domestic use. In these cases the availability of softening or other treatment methods may be considered in determining whether ambient water quality meets the drinking water requirements of the NDDoH. The Sheyenne River from its headwaters to one-tenth mile downstream from Baldhill Dam is not classified for municipal or domestic use (NDDoH, 2011). Class IA rivers also have the exceptions from Class I rivers listed in Table 3 below.

Table 3. North Dakota Water Quality Standards Exceptions for Class IA Streams.

Substance or Characteristic	Maximum Limit
Chlorides (total)	175 mg/L (30-day arithmetic average)[1]
Sodium	60% of total cations as mEq/L[2]

[1] Milligrams per Liter or parts per million
[2] Milliequivalents per Liter

The Pierce Model portion of the Upper Sheyenne River is assigned aquatic life, recreation, agriculture, and industrial beneficial uses by the *Standards of Water Quality for State of North Dakota* (NDDoH, 2011). However, the focus of this assessment will be on the aquatic life and recreational beneficial uses as the water quality standards applied will be protective of all other beneficial uses.

1.3.2 Narrative Water Quality Standards

For this report, the water quality standards, guidelines, and goals relevant to the Upper and Middle Sheyenne River and its beneficial uses involve both numeric and narrative standards. The NDDoH has set narrative water quality standards which apply to all surface waters in the state as listed below:

- All waters of the state shall be free from substances attributable to municipal, industrial, or other discharges or agricultural practices in concentrations or combinations which are toxic or harmful to humans, animals, plants, or resident aquatic biota.

- No discharge of pollutants, which alone or in combination with other substances shall:
  1) Cause a public health hazard or injury to environmental resources;
  2) Impair existing or reasonable beneficial uses of the receiving waters; or
  3) Directly or indirectly cause concentrations of pollutants to exceed applicable standards of the receiving waters.

In addition to the narrative standards, the NDDoH has set a biological goal for all surface waters in the state. The goal states that "the biological condition of surface waters shall be similar to that of sites or waterbodies determined by the department to be regional reference sites." Direct measures of biological community health (i.e., indices of biotic integrity), various chemical data (e.g., dissolved oxygen or metals concentrations) or best professional judgment can be used to determine if the waterbody is achieving certain narrative and numerical standards, and the narrative biological goal to fully support aquatic life uses (NDDoH, 2011).

1.3.3 Numeric Water Quality Standards

Water quality standards also identify specific numeric criteria for chemical, biological and physical parameters. The specific numeric standard assigned to each parameter ensures protection of the beneficial uses for that classification. For the purposes of this assessment report, relevant numeric standards are for E. coli bacteria and dissolved oxygen, with a site specific standard for total sulfate.

The numeric criteria for E. coli bacteria is defined as not to exceed 126 organisms per 100 mL as a geometric mean of representative samples collected during any 30-day consecutive period, nor shall more than ten percent of samples collected during any 30-day consecutive period individually exceed 409 organisms per 100 mL. For assessment purposes, the 30-day consecutive period shall follow the calendar month. This standard shall apply only during the recreation season of May 1 to September 30. The waterbody is classified as fully supporting beneficial uses if both criteria are met, fully supporting but threatened if only the first criteria is met, and not supporting if neither of the criteria are met by the waterbody (NDDoH, 2010). Month-specific beneficial use attainment for the Upper and Middle Sheyenne River is determined and explained in Section 3.5.1.

Also, in addition to the Class IA exceptions for water quality standards listed in Table 3 above, the Sheyenne River from the headwaters to one-tenth mile downstream of Baldhill Dam has a site specific total sulfate standard of 750 mg/L.

Currently, North Dakota is in the process of developing nutrient criteria for the State's waters. Excessive nutrients typically manifest themselves as elevated amounts of algae in lakes and reservoirs and as epiphytic algae or rooted macrophytes in streams and rivers. The NDDoH is currently performing a pilot project to establish numeric criteria for lentic (lake) systems, but does not yet have guidance on lotic (river) systems.

Since the NDDoH has not yet defined numeric nutrient criteria for rivers and streams, reference nitrogen and phosphorus values developed as part of the draft report entitled *An Ecological Assessment of Perennial, Wadeable Streams in the Red River Basin – North Dakota* (NDDoH, 2012) will be used in this assessment report. These values which were developed for the Northern Glaciated Plains (46) ecoregion are 0.581 mg/L and 0.115 mg/L for nitrogen and phosphorus, respectively.

1.3.4 Impaired Waters Listings

Currently, this portion of the Sheyenne River is not listed for any water quality standards impairments in the *2012 Section 303(d) List of Waters needing Total Maximum Daily Loads* (NDDoH, 2012).

2.0 WATER QUALITY SAMPLING METHODS

2.1 Sampling Sites

Monitoring stations were selected in the Upper and Middle Sheyenne River sub-basins to determine the current condition of water quality, potential effects of pollutant loadings, stressors and/or pollutant sources or any use impairments. Descriptions and locations of sites and parameters sampled for the Pierce Model are provided in Table 4 and Figure 6.

Table 4. Description of Sampling Sites and Parameters for the Pierce Model.

Storet ID	Site Description	Parameters	Collection Year
385503	Sheyenne River-1.25 miles east, 0.5 miles north of Harvey, ND	Water Chemistry[1] Fecal Coliform and E. coli bacteria Stage (Automate Stage Recorder) Discharge[2] (USGS gauging station 05055000) Suspended Sediment[3]	2009-2010
385504	North Fork of Sheyenne River-1.75 miles east, 3 miles North, of Wellsburg, ND	Water Chemistry[1] Fecal Coliform and E. coli bacteria Stage (Automate Stage Recorder) Discharge[2] (USGS gauging station 05055070) Suspended Sediment[3]	2009-2010

[1]Water chemistry includes major cations/anions, trace elements, nutrients (total nitrogen, total Kjeldahl nitrogen, nitrite-nitrate, ammonia, and total phosphorus), and total suspended solids.
[2]Collocated with USGS stream gauge station.
[3]Collected and analyzed by the USGS North Dakota Water Resource Office.

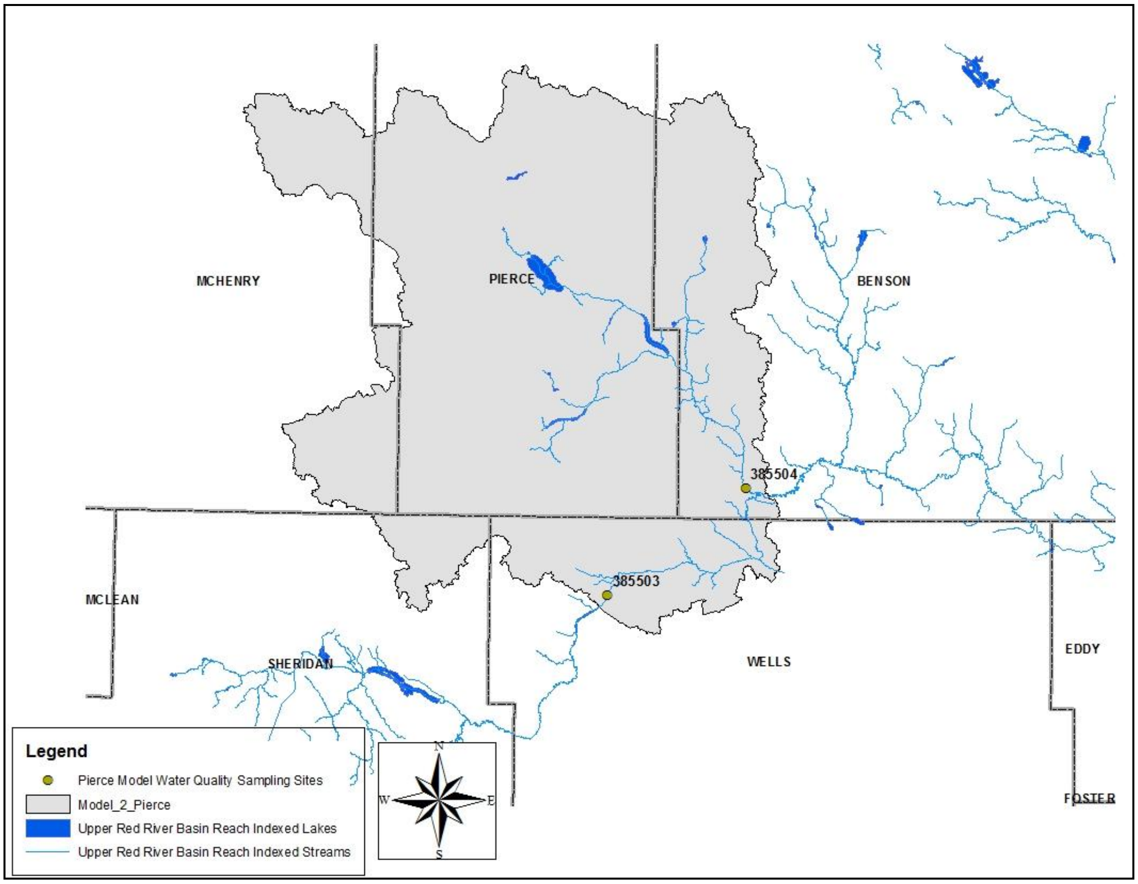

Figure 6. Stream Sampling Sites for the Upper and Middle Sheyenne Water Quality and Watershed Assessment (Pierce Model).

2.2 Sampling Design

The primary goal of the Upper and Middle Sheyenne River Water Quality and Watershed Assessment Project was to assess the water quality condition and beneficial uses support status of the Upper and Middle Sheyenne River and tributaries and to identify possible sources/causes of any documented impairment to beneficial uses.

A quality assurance project plan (QAPP) was developed focusing on sample locations, frequency schedules, and methods to support the primary goal of the Upper and Middle Sheyenne River Water Quality and Watershed Assessment Project.

For a complete description the reader is referred to the Quality Assurance Project Plan for the Upper and Middle Sheyenne River Water Quality and Watershed Assessment Project (NDDoH, 2009).

2.3 Sampling Methods

Project sampling methods for the Upper and Middle Sheyenne River Water Quality and Watershed Assessment Project QAPP included water chemistry, stage, bacteria (E.coli), and macroinvertebrates.

The reader is referred to the Standard Operating Procedures for Field Samplers found at the end of the Quality Assurance Project Plan for the Upper and Middle Sheyenne River Water Quality and Watershed Assessment Project (NDDoH, 2009) for a complete description of the sampling methods used for this project.

3.0 STREAM ASSESSMENT DATA

While the Sheyenne River was sampled and analyzed for a variety of water quality constituents, only those parameters of concern are discussed in detail in this report. For a summary of all parameters sampled see Appendix A.

3.1 Hydrology

Hydrology describes the way water flows through a watershed. The water discharge measurement (volume of water) is an important complement to the concentration data collected during water quality analysis, as it allows the determination of what quantity (load) of a pollutant flows through the system over a given time. A concentration value of ten milligrams per liter (mg/L) has a very different effect on the river depending on whether there are three or three thousand liters of water that flow through a system in a day.

According to the National Oceanic and Atmospheric Administration (NOAA) National Weather Service Glossary, discharge is measured in cubic feet per second (cfs). One cubic foot per second is equal to the discharge through a rectangular cross section, one foot wide by one foot deep, flowing at an average velocity of one foot per second or approximately 7.48 gallons per second.

Discharge measurements were taken at two sites on the Sheyenne River (385503 and 385504). Stream stage was measured by Wells County Soil Conservation District using automated stage recorders and a standard manual staff gauge. The automated stage recorders measured stage every hour. There were 13 discharge measurements taken by the United States Geological Survey (USGS) on sites 05055000 and 05055070. It should be noted that site 05055070 is not directly on the North Fork of the Sheyenne where the water quality samples were taken, but slightly downstream of the confluence with the main stem of the Sheyenne River. These discharge measurements were used to develop a hydraulic discharge rating curve. Stream stage data (manual and automated stage recorder) and the discharge rating curve were combined to create a mean daily discharge for sites 385503 and 385504.

For site 385503, discharge data was collected April 15th – December 1st, 2009, and April 14 – November 15th , 2010. For site 385504, discharge data was collected May 29th – December 1st, 2009 except for the period of September 9th – October 13th when the state recorder malfunctioned, and April 20th – November 15th, 2010. Mean discharge values are shown in Table 5.

Table 5. Mean Discharge Values for Sites 385503 and 385504.

Site	Mean Discharge – 2009	Mean Discharge - 2010
385503 (collocated with USGS site 05055000)	96.41cfs	52.09 cfs
385504 (collocated with USGS site 05055070)	67.44 cfs[1]	78.16 cfs

[1] Data for the period of September 9th – October 13th is missing due to malfunction in stage recorder.

Discharge for the watershed is then used to create the flow duration curve. Flow duration curve analysis looks at the cumulative frequency of historic daily flow data over a specific period of time. The flow duration curve relates flow (expressed as mean daily discharge) to the percent of time those mean daily flow values were met or exceeded. The use of "percent of time exceeded" (i.e., duration) provides a uniform scale ranging from 0 to 100 percent, thus accounting for the full range of stream flows. Low flows are exceeded most of the time, while high flows or flood flows are exceeded infrequently (USEPA, 2007). As mentioned earlier, this is a complement to the concentration data (measured in mg/L) and will help to depict how often large amounts of water are flowing through the watershed.

A basic flow duration curve runs from high to low (0 to 100 percent) along the x-axis with the corresponding flow value on the y-axis (Figures 7 and 8). By using this approach, flow duration intensities are expressed as a percentage, with zero corresponding to the highest flows in the record (i.e., flood conditions) and 100 to the lowest flows in the record (i.e., drought). Therefore, as depicted in Figure 7 for USGS site 05055000, a flow duration interval of 50 percent, associated with the stream flow of 37.1 cubic feet per second (cfs), implies that 50 percent of all observed mean daily discharge values equal or exceeded 37.1 cfs. For USGS site 05055070 (Figure 8), the flow had a considerably smaller range between minimum and maximum flows and very few flow values less than 10.0 cfs. For this figure, the flow associated with the flow duration interval of 50 percent is 77.7 cfs

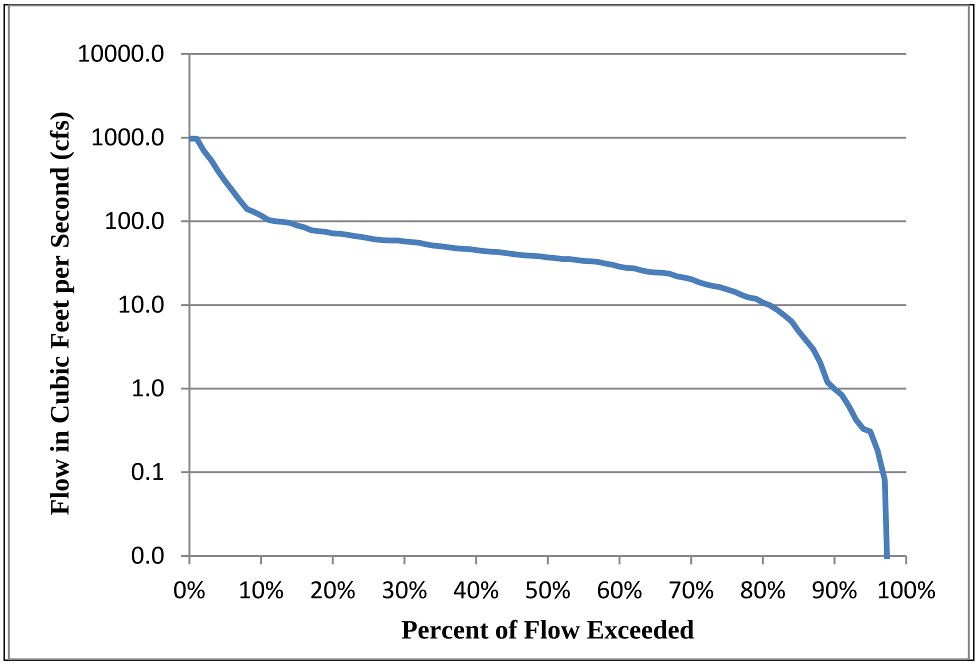

Figure 7. Flow Duration Curve for USGS Gauging Station 05055000.

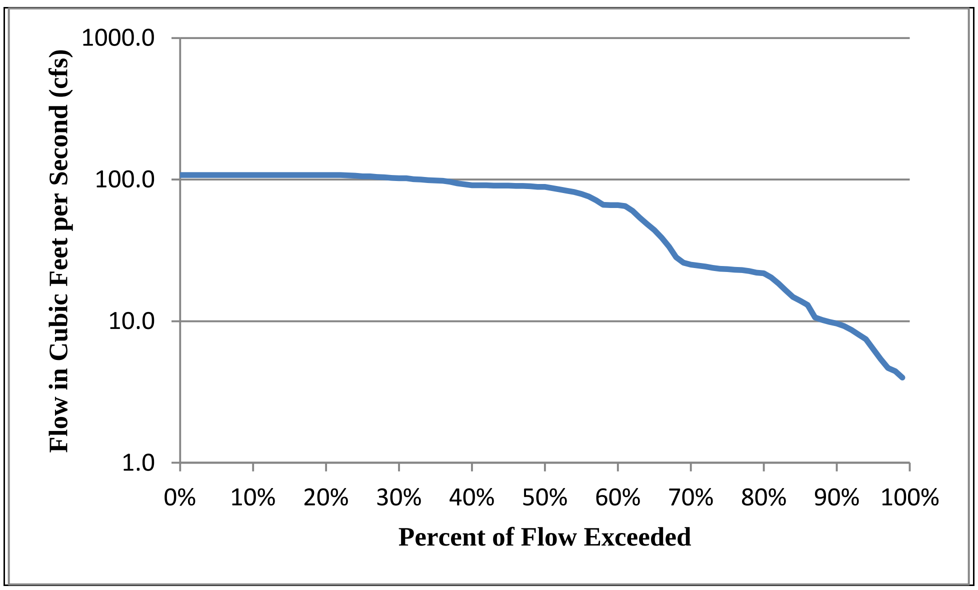

Figure 8. Flow Duration Curve for USGS Gauging Station 05055070.

Variable stream flows at high and low intervals are important factors in determining NPS pollution loads. To better correlate the relationship between the pollutants of concern and the hydrology of the Sheyenne River, load duration curves were developed for total nitrogen (TN) and total phosphorus (TP). Curves were constructed by multiplying concentrations for each parameter by the mean daily flow and a conversion factor specific to each parameter. The curve represents a reference value for TN and TP based on ecoregion criteria discussed in the draft report entitled *An Ecological Assessment of Perennial, Wadeable Streams in the Red River Basin – North Dakota* (NDDoH 2012). The points on the graphs represent the samples taken. The State does not have a water quality standard or reference value for total suspended solids (TSS), so a summary of that data is provided in Appendix A.

3.2 Nutrients

To best understand how nitrogen and phosphorus work together in a waterbody, a description of the concept of limiting nutrients is appropriate. Many studies suggest that a ratio of total nitrogen (TN) to total phosphorus (TP) between 10 and 17 is the optimum value for the growth of algae (i.e. proportions of both nitrogen and phosphorus are sufficient for growth). For example, if there was an average TN value of 30 mg/L and an average TP value of 3 mg/L, that would equal a TN:TP of 10. A nutrient in short supply, one that causes this ratio to be above or below this range of values, is called the limiting nutrient. It is generally thought that a TN:TP ratio less than 10 is nitrogen limited and a TN:TP ratio of greater than 17 is phosphorus limited. In most North Dakota waters, nitrogen is the limiting nutrient. This means that once the nitrogen drops to a very low amount, no matter how much phosphorus is still present, rapid uptake by plants will not occur. Calculating this relatively simple ratio can sometimes provide a useful clue as to the relative importance of nitrogen or phosphorus as it affects the abundance of algae in a waterbody.

3.2.1 Total Nitrogen

Nitrogen is an essential nutrient for plants and animals. However, an excess amount of nitrogen in a waterway promotes the excessive growth of algae. When the algae die and decompose, dissolved oxygen in the water, which is essential to the health of aquatic life, is consumed and can reach critically low levels resulting in mortality to fishes and other aquatic organisms. Increased levels of both nitrogen and phosphorus in the water can also lead to blue-green algae blooms which can be toxic to domestic animals, wildlife, and humans if ingested. The die-off of rooted vegetation due to lack of dissolved oxygen can lead to an increase in water temperature to a decrease in suitable habitat for aquatic organisms. Both of these factors can lead to stress-caused mortality of aquatic life. In addition to the local effects on the river or stream itself, excessive transport of nutrients can cause eutrophication (excessive algae growth and the subsequent decrease of dissolved oxygen) of downstream lakes and impoundments.

High levels of nitrates (a component of total nitrogen) in the water used as a livestock water supply can also harm livestock. Exceedingly high levels of nitrates in drinking water for humans, those above 10 mg/L, are considered a threat to human health. Generally, concentrations of nitrates in surface waterbodies do not reach this level because nitrates are readily taken up by plants.

Increased costs to treat drinking water supplies are also associated with high nutrient levels. The costs include filtering of algae toxins as well as the increased cost of treating disinfection by-products formed during the drinking water treatment. High nutrient levels in drinking water sources also affect water quality in other ways such as taste and odor problems, clogging of intake structures, diminished filtration effectiveness and pH fluctuations that can lead to corrosion in the distribution pipes. It is estimated that for a small community water system serving 500 or fewer people, the capital cost for installing ion exchange treatment to remove excess nitrate from source water would be more than $285,000 with increased operating costs of $17,600 per year. Sources of nitrogen include wastewater treatment plants, runoff from fertilized lawns and croplands, failing septic systems, and runoff from animal manure and feeding/storage areas (USEPA, 2009). Nitrogen is also converted from one form to another through biological processes.

There are three forms of inorganic nitrogen that are commonly measured in water bodies: ammonia, nitrates and nitrites. Ammonia and nitrates are the reactive forms for plant uptake. Total nitrogen (TN) is the sum of organic nitrogen, ammonia, and nitrate-nitrite. It can be derived by analyzing for total Kjeldahl nitrogen (TKN) (organic nitrogen), ammonia, and nitrate-nitrite.

3.2.2 Total Nitrogen Load Duration Curve Analysis

According to the draft report *An Ecological Assessment of Perennial, Wadeable Streams in the Red River Basin* (Larsen, 2012), Ecoregion 46, the Northern Glaciated Plains, had a total nitrogen reference value of 0.581 mg/L. This value was derived from nutrient data collected at a set of "least disturbed" reference sites located in the Northern Glaciated Plains ecoregion of North Dakota. This value is not a water quality standard, as nutrient criteria or standards have not yet been developed, but is provided as a point of reference or goal when evaluating the data collected within the watershed.

Observed in-stream total nitrogen data obtained from monitoring site 385503 and 385504 in 2009 and 2010 were converted to a total nitrogen load by multiplying the observed total nitrogen concentration for each sampling event by the mean daily flow and a conversion factor. These loads are plotted against the percent exceeded of the flow on the day of sample collection (Figures 9 and 10). Daily load estimates points above the criteria line of 0.581 mg/L depict observed concentrations that exceeded the reference concentration value for that flow, and would have also exceeded the nitrogen load of a least impaired/impacted reference stream for that given flow.

Ideally, values that are close to the line indicate a nitrogen load for the stream that is close to the least impacted condition for this ecoregion, and therefore is more healthy. The further away from the criteria line, the larger the negative impact to the stream becomes. As mentioned in the section above, the criteria line is provided for assessment purposes only as statewide nutrient criteria have not been developed for North Dakota at this time.

In Figure 9, the load duration curve for site 385503 indicates that the total nitrogen load is highly related to flow as the symmetry of the samples follow the flow curve quite closely. This indicates that sources of nitrogen are most likely from overland flow related to nonpoint source pollution runoff. If there were significant point sources of in-stream nutrients, like wastewater treatment plant discharge, one would expect to see large increases in loads during low flow events (i.e. 80% - 100% duration intervals on the graph). The load duration curve for site 385504 show values less symmetrical to the flow curve, as well as higher above it. These values deserve even more critical attention owing to the fact that the water quality samples were taken directly on the North Fork of the Sheyenne River, while the collocated discharge site was located slightly downstream of the confluence on the main branch of the Sheyenne, and therefore carries more water than where the water quality samples were taken.

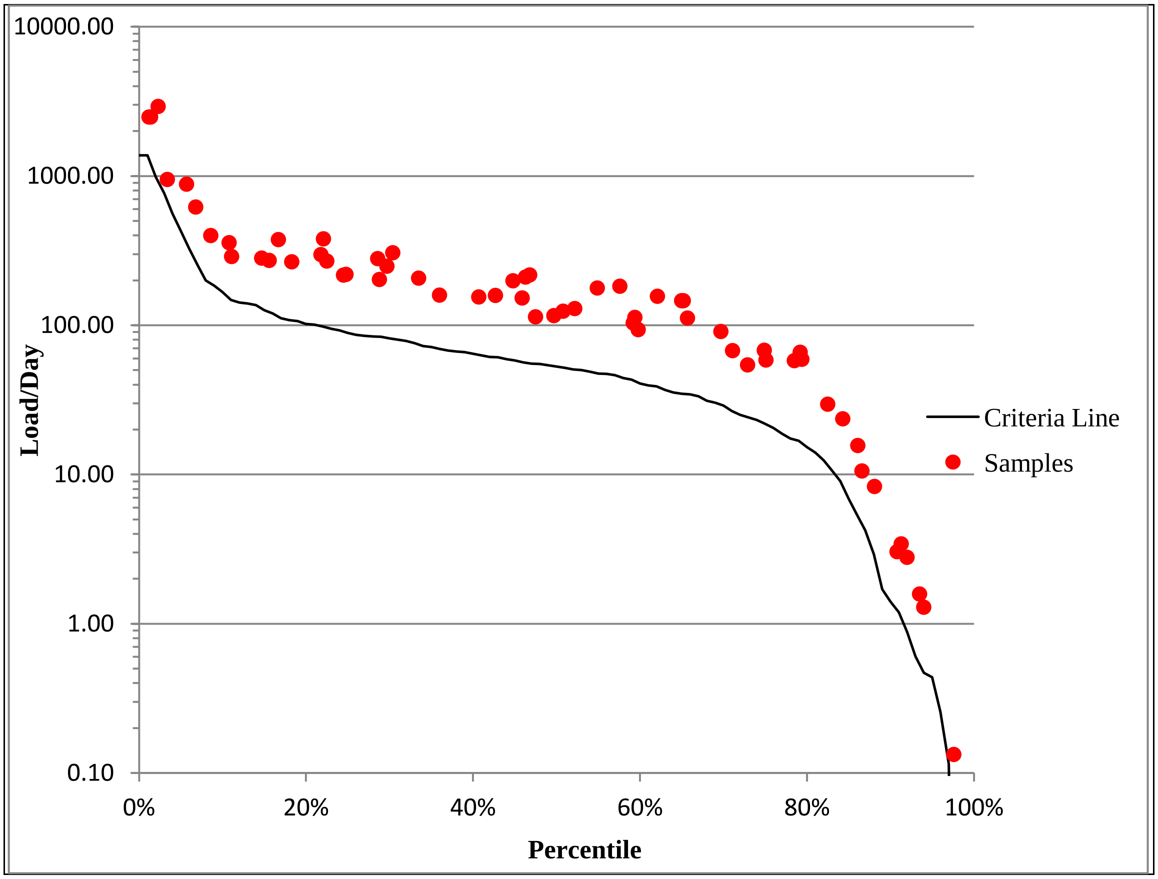

Figure 9. Total Nitrogen Load Duration Curve for the Sheyenne River Monitoring Station 385503 (The curve reflects flow data from 2009 and 2010).

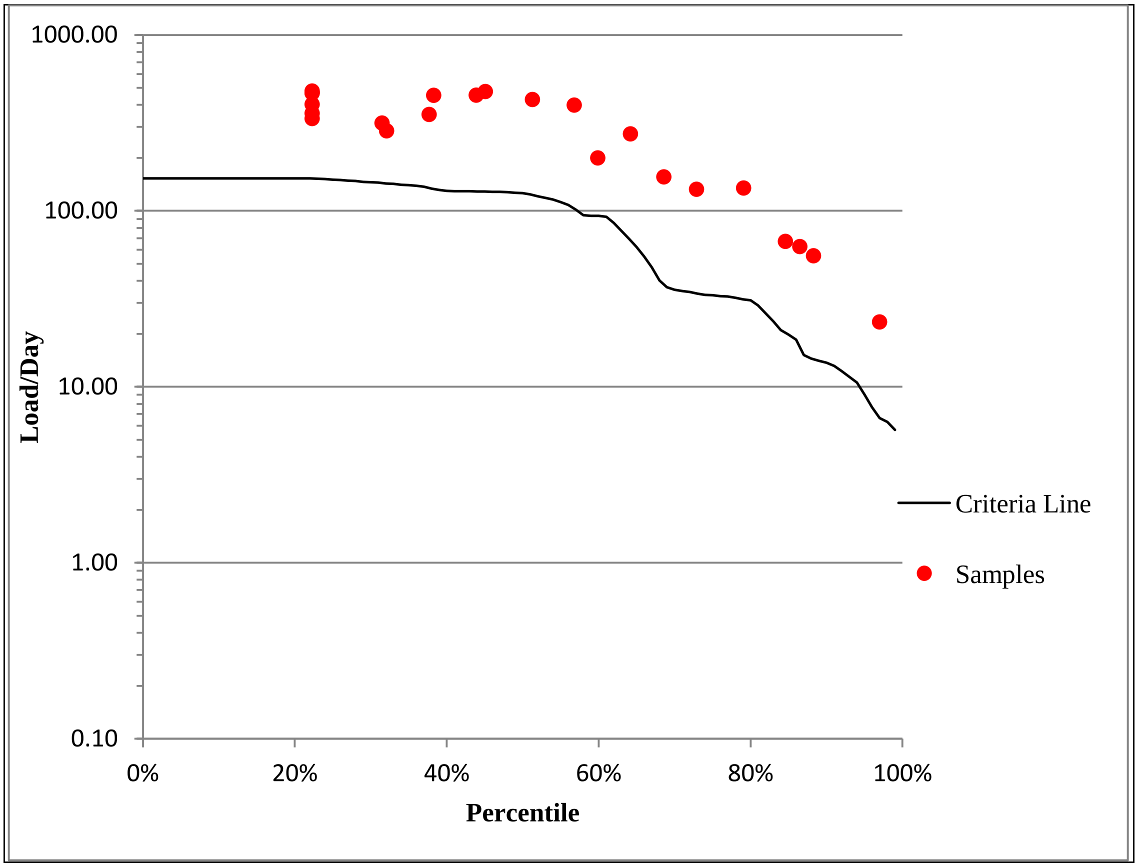

Figure 10. Total Nitrogen Load Duration Curve for the Sheyenne River Monitoring Station 385504 (The curve reflects flow data from 2009 and 2010).

3.2.3 Total Phosphorus

Total phosphorus (TP) is also an essential nutrient for plants and animals. In waterbodies, phosphorus occurs in two forms, dissolved and particulate. Dissolved phosphorus comes in both soluble reactive and soluble organic (non-reactive) forms. Particulate phosphorus is formed when phosphorus becomes incorporated into particles of soil, algae and small animals that are suspended in the water. Both dissolved and particulate phosphorus can change from one form to another very quickly (called cycling) in a waterbody. This is important because algal cells and plants can only use phosphorus in certain forms. Use is also influenced by factors such as pH, hardness of the water, the amount of dissolved oxygen in the water and thermal stratification (layers of water having different temperatures).

While phosphorus is naturally limiting in most fresh water systems because it is not as abundant as carbon and nitrogen, North Dakota sees elevated concentrations in its waters due to its abundance in most soils and intensive agriculture land use across the state. Particulate phosphorus naturally bonds to soil particles and as a result can be transported over long distances with eroded soil. Because of this binding property phosphorus often settles with soil particles on the bottom of streams, rivers, and lakes where it becomes unavailable for use by plants until it is both re-suspended and mixed with the appropriate concentrations of nitrogen. Soluble phosphorus remains in the water column, available for plant use. Sources of phosphorus include soil and rock, wastewater treatment plants, runoff from cropland, fertilized lawns, animal manure storage areas, disturbed land areas, drained wetlands, water treatment, decomposition of organic matter, storm water runoff, and commercial cleaning preparations (USEPA, 2009).

The negative consequences of large amounts of phosphorus in a water body are similar to those of large amounts of nitrogen which has been discussed in the previous section. Excessive amounts of phosphorus is associated with algae blooms, accelerated plant growth, low dissolved oxygen from the decomposition of additional vegetation, and increased costs associated with drinking water infrastructure.

3.2.4 Total Phosphorus Load Duration Curve Analysis

Based on the draft report *An Ecological Assessment of Perennial, Wadeable Streams in the Red River Basin*, (Larsen, 2012), a total phosphorus reference value of 0.115 mg/L was estimated for the Northern Glaciated Plains Ecoregion (46). This reference value was developed based on data collected at "least disturbed" reference sites located in the Northern Glaciated Plains Ecoregion. Again, the reference value of 0.115 mg/L is not a water quality standard, but is provided as a point of reference when evaluating the data.

Observed in-stream total phosphorus data obtained from monitoring sites 385503 and 385504 in 2009 and 2010 were converted to phosphorus loads by multiplying the observed total phosphorus concentration for each sampling event by the mean daily flow observed on the day the sample was collected and a conversion factor. These loads are plotted against the percent exceeded of the flow on the day of sample collection (Figures 11 and 12). Points depicting the daily load estimates plotted above the criteria line of 0.115 mg/L depict observed concentrations that exceed the reference concentration value for that flow.

Those concentrations also exceeded the phosphorus load of a least impaired reference stream given their flow rates at the time of collection. As in the case with the nitrogen load curve, values that are close to the line indicate a phosphorus load in the stream that is similar to the least impacted streams in this ecoregion. The further away from the criteria line, the larger the negative impact to the stream becomes. If watershed restoration activities are desired at the conclusion of this report, appropriate target values for total nitrogen and phosphorus may be discussed.

In Figure 11, the load duration curve for site 385503 indicates that the total phosphorus load is closely related to flow conditions. This would suggest that sources of phosphorus could be overland flow related to nonpoint source pollution runoff. Further indication that transport is primarily an overland runoff process is indicated by how close the sample values are to the criteria line. These values are very close to those of "least disturbed" sites in the ecoregion.

For site 385504 (Figure 12), most of the sampled values fall below the "least disturbed" criteria line. Caution should be taken in assuming that this area is not impaired however as the discharge curve includes water from both the main stem of the Sheyenne and the

North Fork of the Sheyenne, while the phosphorus values reflect the North Fork of the Sheyenne only.

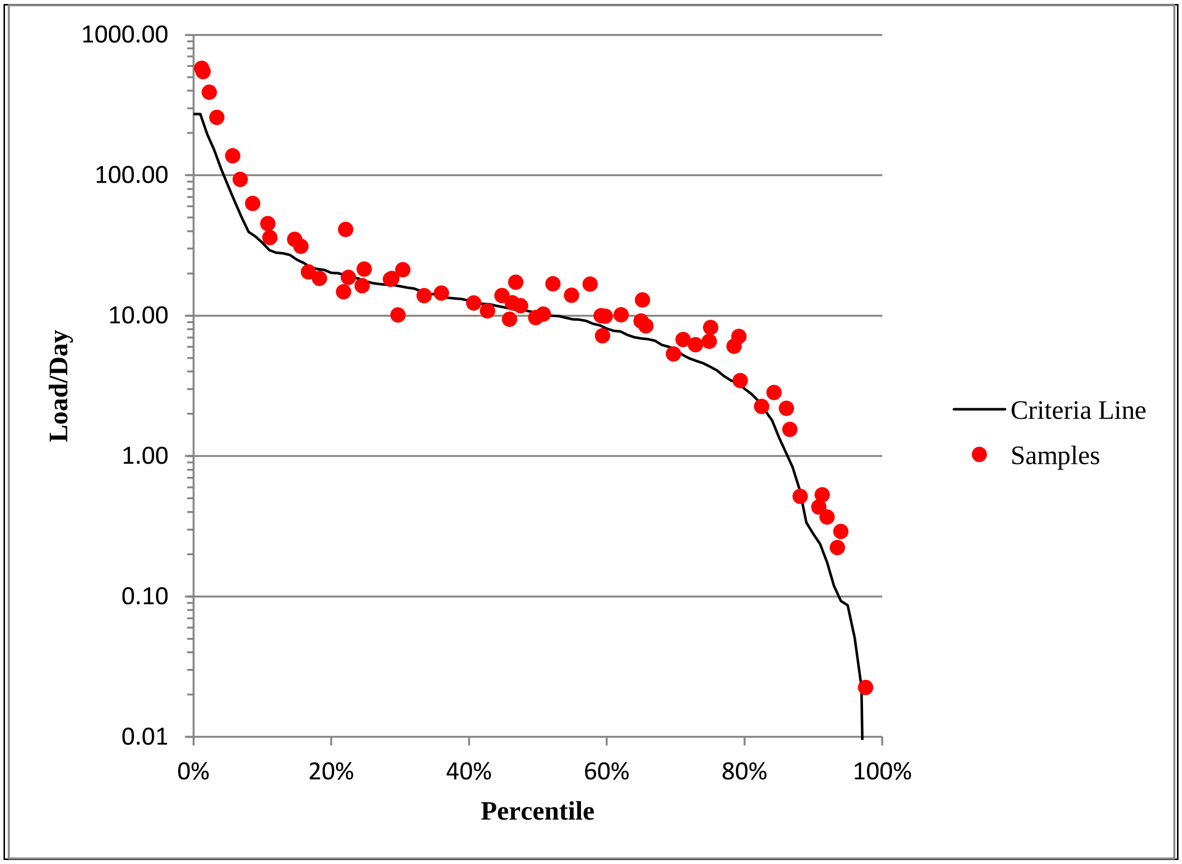

Figure 11. Total Phosphorus Load Duration Curve for the Sheyenne River Monitoring Station 385503 (The curve reflects flow data from 2009 and 2010).

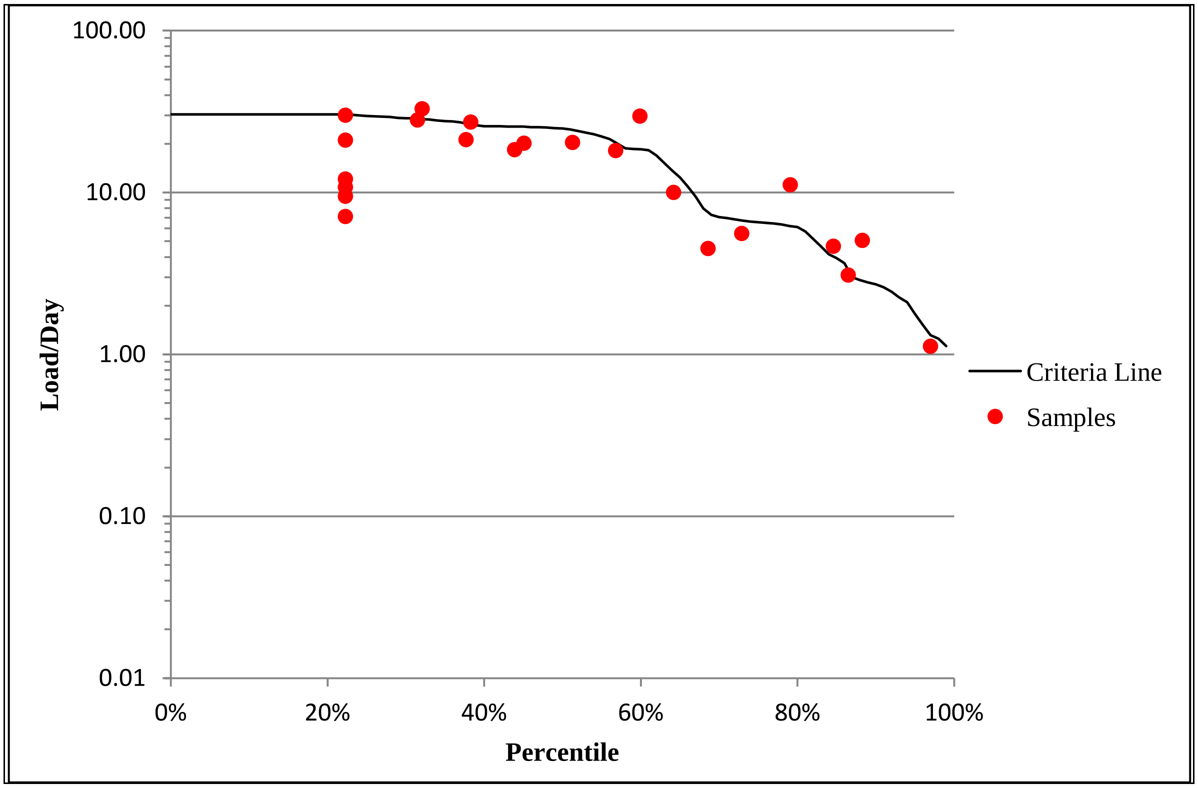

Figure 12. Total Phosphorus Load Duration Curve for the Sheyenne River Monitoring Station 385504 (The curve reflects flow data from 2009 and 2010).

3.3 Total Suspended Solids

Total suspended solids (TSS) are organic and inorganic solid materials that are suspended in the water and include silt, plankton, and industrial wastes. If high concentrations of suspended solids exist in the waterbody it can lower water quality by absorbing light. The waterbody then becomes warmer and reduces the ability of the water to hold oxygen necessary for aquatic life. When aquatic plants receive less light, photosynthesis decreases and less oxygen is produced. The combination of warmer water, less light and lower oxygen makes it impossible for some forms of life to exist (NDDoH, 1997).

Suspended solids can also affect fish by clogging gills, reducing growth rates, decreasing resistance to disease, and preventing egg and larval development. Particles that settle out can smother fish and aquatic insect eggs and suffocate newly-hatched larvae. Suspended solid material settles into microhabitats such as the spaces between rocks that aquatic insects like mayfly and stonefly nymphs and caddis fly larva inhabit (NDDoH, 1997).

Suspended solids are a result of erosion from agricultural land, bank erosion, algae growth, urban runoff, industrial waste, and wastewater discharges (NDDoH, 1997). The State of North Dakota has no numeric water quality standard or reference value for TSS.

3.4 Total Nitrogen, Total Phosphorus and Total Suspended Solids Box and Whisker Plots

A box and whisker plot is a convenient way of graphically depicting groups of numerical data through their five-number summaries: 1) the sample minimum; 2) lower quartile; 3) median; 4) upper quartile; 5) sample maximum. The box plot may also indicate which observations, if any might be considered outliers. For further information on box and whisker plots please refer to Appendix C.

The box and whisker plots represented in Figures 13-15 show all water quality sites along the Sheyenne River that were sampled for total nitrogen, total phosphorus, and total suspended solids. The box and whisker plots allow the reader to compare and contrast water quality sites upstream to downstream throughout the Upper and Middle Sheyenne sub-basins.

Total nitrogen for sites 385503 and 385504 can be compared with the rest of the water quality sampling sites along the Upper and Middle Sheyenne River (Figure 13). The height of the box identifies the spread of the data, indicating the smallest and largest observations. In the case of site 385503 the height of the box is longer than most which indicates that the data had significant fluctuation between the smallest and largest observations, in other words there is variation in total nitrogen concentrations at site 385503. Most of this variation corresponds to the variation in discharge values with higher values occurring during higher flows (Figure 9). When comparing site 385503 to the rest of the Upper and Middle Sheyenne River, the mean values (shown by the blue diamonds) are similar, while the number of outliers increase as you move downstream. This could indicate a strong correlation between agricultural land use activities and the proximity of those activities to the river. Data for site 385504 is very similar to site 385503. All of the sites have average values that exceed the reference value of 0.581 mg/L.

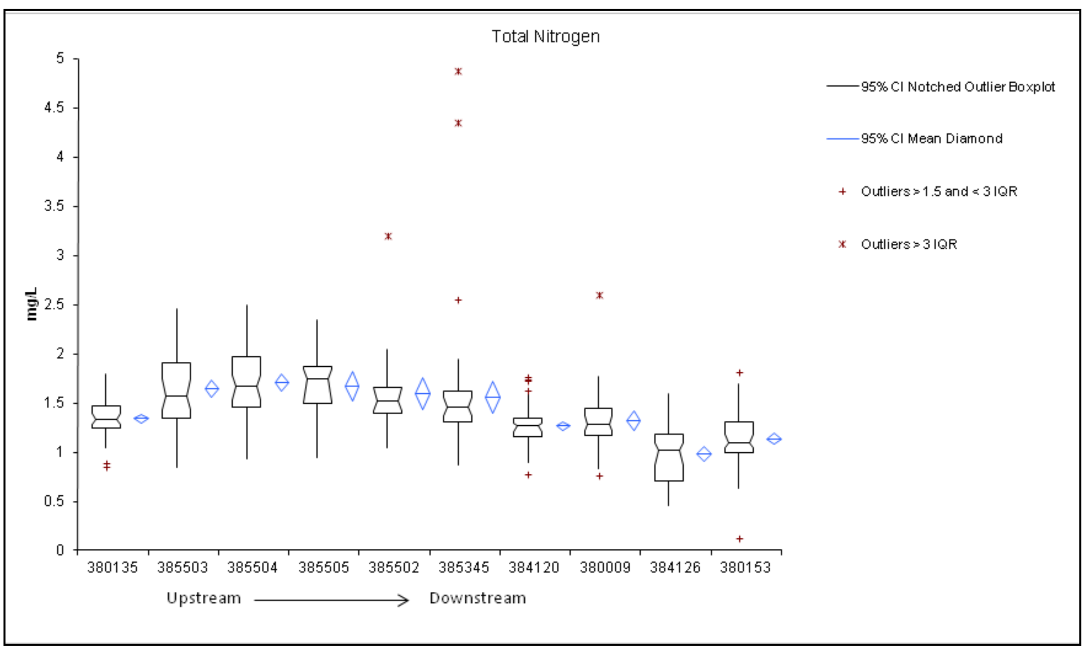

Figure 13. Box and Whisker Plot of Total Nitrogen for all Water Quality Sampling Sites in the Upper and Middle Sheyenne River.

Phosphorus values for site 385503 are similar to those of the upstream site 385135, and lower than most of the rest of the sites along the Sheyenne River (Figure 14). With the exception of site 385504, the phosphorus values show increasing average concentrations as you move downstream. Site 385504 has lower total phosphorus values than the rest of the sampling sites. Its location along the North Fork of the Sheyenne functions as a headwater stream with the cumulative effects being lower. This lower mean would also indicate that more of the agriculture in this area is livestock related, which is supported by the land use data (Figure 3). While site 385504 is close, all of the sites have average values higher than the reference value of 0.115 mg/L

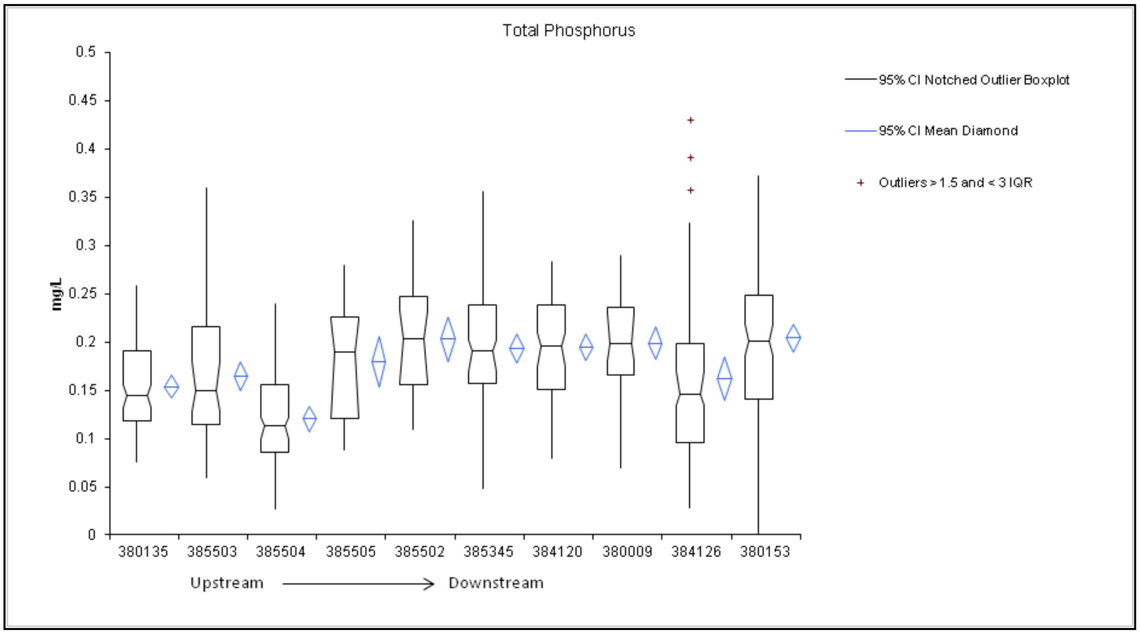

Figure 14. Box and Whisker Plot of Total Phosphorus for all Water Quality Sampling Sites in the Upper and Middle Sheyenne River.

Suspended solids are a combination of organic matter and sediment that is suspended in the water column. It is an indication of water clarity. As shown in Figure 15, total suspended solid values for both sites 385503 and 385504 are very low compared to the other sites along the river. There are however some very large outliers. This suggests that most of the time the water is fairly clear but occasionally there is disturbance the drops the clarity. This can be related to livestock activity in close proximity to the river or large storm events that move through the area.

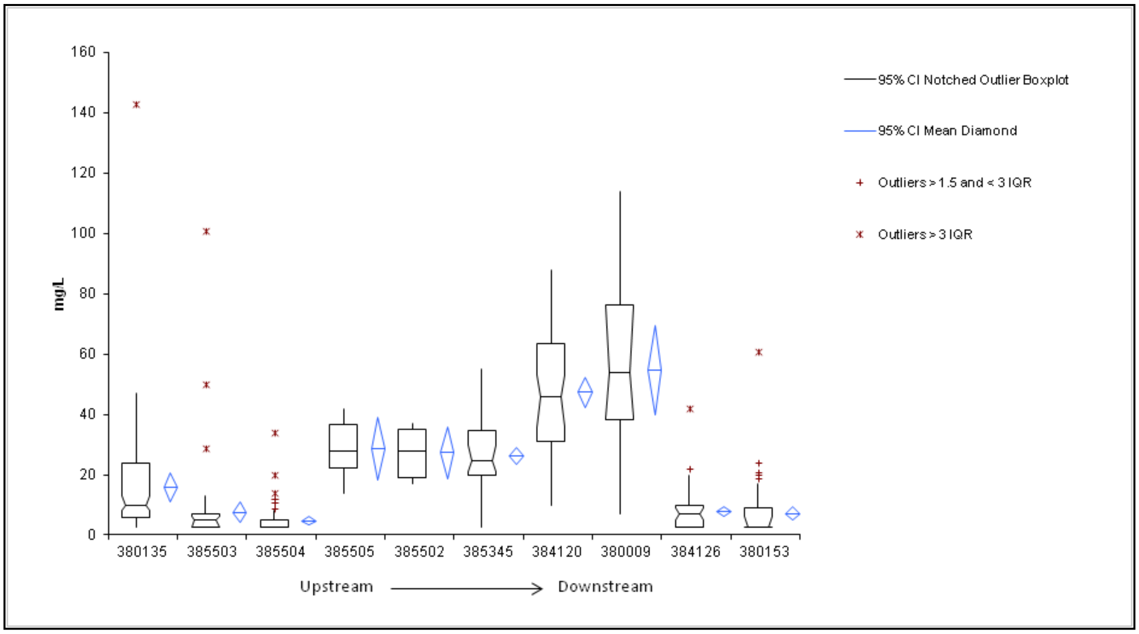

Figure 15. Box and Whisker Plot of Total Suspended Solids for all Water Quality Sampling Sites in the Upper and Middle Sheyenne River.

3.5 Pathogens

Excessive amounts of fecal bacteria in surface waters used for recreation have been known to indicate an increased risk of pathogen-induced illness to humans. Infections due to pathogen contaminated waters include gastrointestinal, respiratory, eye, ear, nose, throat, and skin disease (EPA, 1986). The fecal bacteria known to cause the most harm to humans is E. coli bacteria and is the parameter now used in NDDoH water quality standards (refer to Section 1.3.3).

3.5.1 Recreational Use Support Assessment Methodology

Recreation use is any activity that relies on water for sport and enjoyment. Recreation use includes primary contact activities such as swimming and wading and secondary contact activities such as boating, fishing, and bathing. Recreation use in rivers and streams is considered fully supporting when there is little or no risk of illness through either primary or secondary contact with the water. The State's recreation use support assessment methodology for rivers and streams is based on the State's numeric water quality standards for E. coli bacteria (Section 1.3.3).

For each assessment based solely on E. coli data, the following criteria are used:

- Assessment Criteria 1: For each assessment unit, the geometric mean of samples collected during any month from May 1 through September 30 does not exceed a density of 126 colony forming units (CFUs) per 100 milliliters (mL). A minimum of five monthly samples are required to compute the geometric mean. If necessary, samples may be pooled by month across years.

- Assessment Criteria 2: For each assessment unit, less than 10 percent of samples collected during any month from May 1 through September 30 may exceed a density of 409 CFUs per 100 mL. A minimum of five monthly samples is required to compute the percent of samples exceeding the criteria. If necessary, samples may be pooled by month across years.

The two criteria are then applied using the following use support decision criteria:

- Fully Supporting: Both criteria 1 and 2 are met

- Fully Supporting but Threatened: Criteria 1 not met while is 2 met

- Not Supporting: Criterion 1 and 2 are not met

3.5.2 Recreational Use Assessments for Sites 385503 and 385504

Within the Pierce Model watershed, E. coli data were collected at two sites (Figure 6). Data were collected during the recreation season of May 1 through September 30 in 2009 and 2010. Recreational beneficial use attainment was determined for each site and is summarized in Table 6 and the complete set of data is available in Appendix B.

Analysis of E. coli bacteria data collected at sites 385503 and 385504 in 2009 and 2010, demonstrated that both sites were fully supporting the recreational beneficial uses for the entire recreation season.

Table 6. Summary of E. coli Data for Sites 385503 and 385504; Pierce Model Sites; 2009 and 2010.

385503					
Recreational Season	**May**	**June**	**July**	**August**	**September**
Number of Samples	7	9	8	9	9
Geometric Mean	13	34	31	55	84
% Exceeded 409 CFU/100 mL	0%	0%	0%	0%	0%
Recreational Use Assessment	FS	FS	FS	FS	FS
385504					
Recreational Season	**May**	**June**	**July**	**August**	**September**
Number of Samples	7	9	8	9	9
Geometric Mean	13	17	18	67	93
% Exceeded 409 CFU/100 mL	0%	0%	0%	0%	0%
Recreational Use Assessment	FS	FS	FS	FS	FS

FS – Fully Supporting; FSbT- Fully Supporting but Threatened; NS – Not Supporting; INSFD – Insufficient Data

4.0 WATERSHED ASSESSMENT

4.1 Riparian Vegetation and Streambank Stability

Riparian areas are the vegetative buffers adjacent to a river or stream. The riparian area includes the stream, stream banks, and wetlands adjacent to streams. Riparian areas protect water quality by capturing, storing and filtering water through their soils before it gets to streams. A thick growth of diverse vegetation, plant residues covering the soil surface and non-compacted soils facilitate water capture and storage. Stream banks with high water tables provide water storage capacity. Healthy growing plants take up nutrients transported into the riparian areas. Soil organic matter captures or facilitates degradation of contaminants. Healthy riparian vegetation captures water and filters the water through the soil. Riparian areas with a high diversity of plant species are most effective in slowing the flow of water and storing it for future use (Bellows, 2003).

Riparian vegetation has an important effect in stabilizing stream banks. In general, all root systems reinforce the soil and increase stability. Fine roots are more effective than thick roots, but a diversity of plants works together to hold stream bank soils in place and protect them from erosion and undercutting by floodwaters, transported woody debris, or ice jams. The deep, penetrating roots of sedges, rushes, willow, grasses, and other herbaceous plants provide structural support for stream banks, while the thicker, harder roots of woody plants protect stream banks against bank scouring by floods and ice jams (Winward, 2000). Banks devoid of vegetation and saturated with water are more likely to collapse; however riparian vegetation improves the drainage of bank soils through plant uptake of water resulting in increased stability. Riparian vegetation such as grasses may also serve to decrease water flow velocity and the erosive action of water. The weight of the vegetation usually does not have an effect on bank stability unless it is located on steep banks that are not capable of supporting themselves (USACOE, 2001).

Bank erosion and failure are natural stream channel process. Bank erosion is the particle-by-particle loss of the bank material due to the shear stress exerted by the water on the banks. The particle-by-particle loss can be observed along exposed streambanks that are devoid of vegetation. Bank failure is the sudden collapse of a portion of the bank material into the river. Bank failures are most easily observed along cutbanks in meander bends and occur due to the removal of the bank material along the toe. Although bank erosion and failure are natural processes, the rate of bank erosion or failure can be accelerated by anthropogenic (human impact) changes in hydraulic and geomorphic variables (e.g. dams, drainage, and channelization) (USACOE, 2001).

4.1.1 Rapid Geomorphic Assessment (RGA)

The Rapid Geomorphic Assessment (RGA) method was used to evaluate the channel-stability conditions and stage of channel evolution of the mainstem Upper and Middle Sheyenne River using the Channel-Stability Ranking Scheme. The RGA uses diagnostic criteria of channel form to infer dominant channel processes and the magnitude of channel instabilities through a series of nine criteria. Evaluations of this sort do not include an evaluation of the watershed or upland conditions; however, stream channels act as conduits for energy, flow and materials as they move through the watershed and will reflect a balance or imbalance in the delivery of sediment. The RGA provides a rapid characterization of stream stability conditions.

The RGA procedure for the Upper and Middle Sheyenne River consisted of three steps completed at each site:

1. Determine the "reach". The "reach" is described as the length of channel covering 6-20 channel widths, and thus is a scale dependent and covers at least two pool-riffle sequences.
2. Take photographs looking upstream, downstream and across the reach; for quality assurance and quality control purposes. Photographs are used with the RGA forms to review the field evaluations
3. Make observations of channel conditions and diagnostic criteria listed on the channel-stability ranking scheme.

A field form containing nine criteria (Appendix D) was used to record observations of field conditions during the RGAs. Each criterion was ranked from zero to four and all values summed to provide an index of relative channel stability with higher numbers related to greater instability. Sites with values greater than 20 are considered instable, while stable sites generally rank 10 or less. Intermediate values denote reaches of moderate instability. The process of filling out the form enables the final decision of "Stage of Channel Evolution." For purposes of the Upper and Middle Sheyenne River assessment, sites with total scores of 0 to 10 are considered stable and sites with scores of 20 to 30 are unstable, recognizing that scores which fall in the range of 10 to 20 have moderate instability and will rely on specific assessment values to determine the trend toward improvement or greater instability.

Sixty sites were randomly selected throughout the entire Upper and Middle Sheyenne River watershed, thirty in the Upper Sheyenne River sub-basin (09020202) and thirty in the Middle Sheyenne River sub-basin (09020203). While some sites occurred in the Pierce Model sub watershed (Figure 16), there were not enough sites located in each of the sub watersheds to determine geomorphic assessments at that level. Therefore, for the purposes of this assessment, the results apply to the entire mainstem of the Upper and Middle Sheyenne River. At each site numeric values were assigned to each of the nine RGA criteria and then summed to calculate an overall RGA score for each site. By analyzing the scores for the 60 randomly selected sites, an overall assessment of stream stability can be made for the Upper and Middle Sheyenne River.

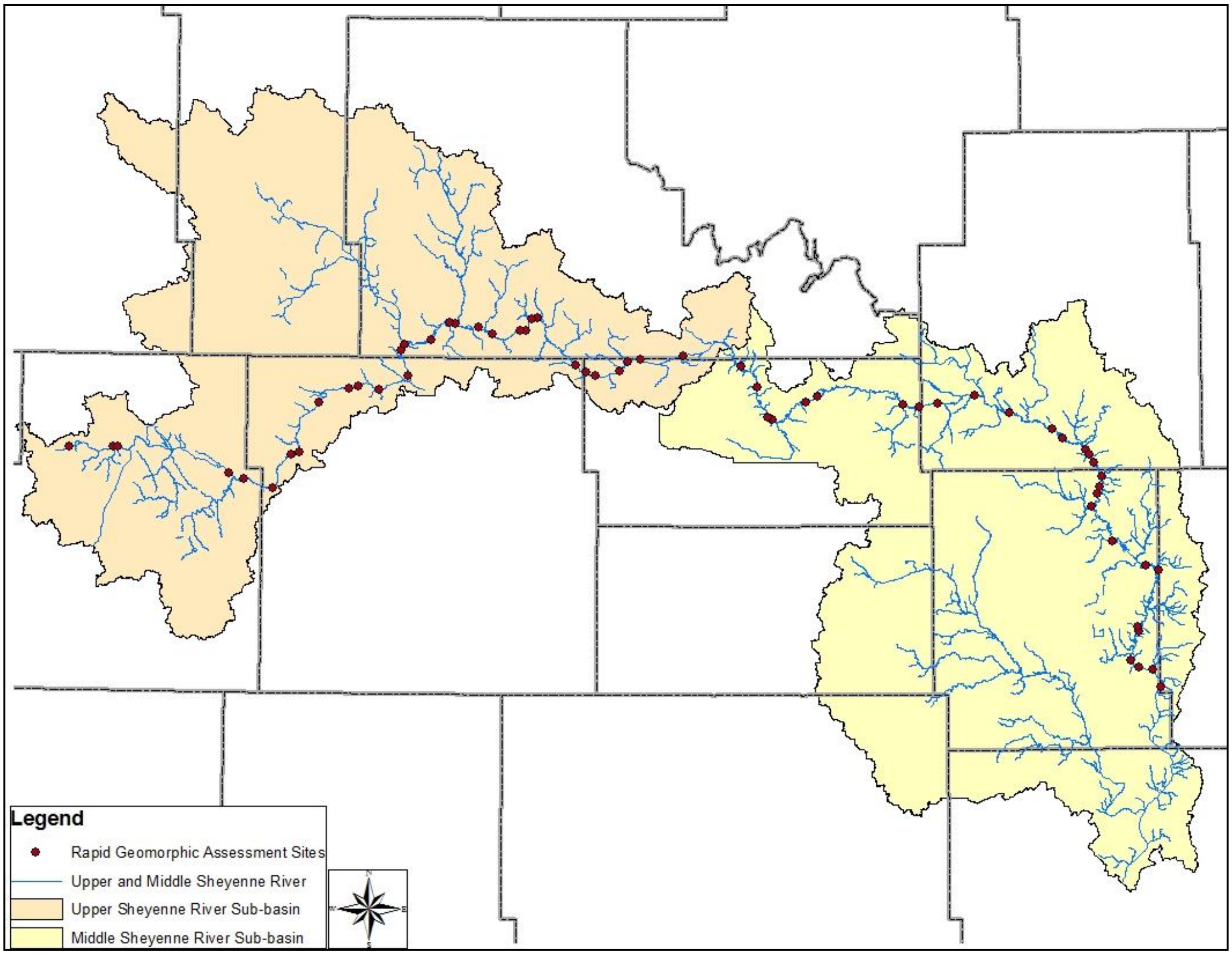

Figure 16. RGA Assessment Sites on the Upper and Middle Sheyenne River Mainstem.

Table 7. Rapid Geomorphic Assessment Scoring Ranges and Percentages of the Upper and Middle Sheyenne River.

RGA Scoring Range	0-10	10-20	20-30
Classification	Stable	Moderate Instability	Unstable
Percentage of Stream Sites	10	55	35

The RGA scores indicate that 35 percent of the sites sampled were unstable, with only 10 percent stable, with the remaining 55 percent were assessed as moderately unstable (Table 7). The unstable sites are located throughout the mainstem which indicates active channel processes occurring throughout the Upper and Middle Sheyenne River and not just in isolated areas. These active channel processes include deepening of the channel bed and widening of the channel, this was evident in the unstable sites. While the moderately unstable sites usually exhibited some channel widening with some aggradation as the sediments deposited out raising the channel bed.

4.2 Macroinvertebrate Index of Biotic Integrity (IBI)

Aquatic macroinvertebrates are the most common organisms used in water quality assessments because: 1) they are extremely common; 2) they exhibit high diversity rates; 3) they are fairly sedentary in any given waterbody; 4) they are rapid colonizers; 5) they exhibit variability in tolerance values; and 6) they are extremely vital links in the transfer of energy through the food web. Human disturbance of streams and watersheds alter key attributes of the aquatic environment, (i.e., water quality, flow regime, habitat structure) which elicits a response from the macroinvertebrate community and can ultimately result in decreased biotic integrity. For example, if pollutants enter a waterway, sensitive species will suffer while tolerant species will continue to thrive. Changes in species composition such as this can easily be detected through biological monitoring using macroinvertebrates as indicators of water quality.

In order to develop biological indicators capable of assessing the biological condition of the state's rivers and streams, the North Dakota Department of Health (NDDoH) is developing an index of biotic integrity (IBI) based on aquatic macroinvertebrate data for each ecoregion. A previous monitoring effort in the Northern Glaciated Plains Ecoregion has produced a preliminary IBI for the region (Larsen 2012). Final metrics for this region and values used to standardize these metrics are shown in Table 8.

Once the final metrics were determined, raw metric values were transformed into standardized metric scores using the following equations developed by Minns et al. (1994) that standardized metrics on a scale of 0 to 100.

Metrics that decrease with impairment:

$$Ms = (M_R/M_{MAX}) \times 100$$

Metrics that increase with impairment:

$$Ms = (M_{MAX} - M_R) / (M_{MAX} - M_{MIN}) \times 100;$$

Where Ms = standardized metric value;
M_R = the raw metric value;
M_{MAX} = the maximum metric value; and
M_{MIN} = the minimum metric value.

Once an IBI has been developed, it becomes a valuable assessment tool. An IBI produces a "multi-metric" index, which assumes that multiple measures of the biological community, also known as metrics (e.g., species richness, species composition, tolerance levels, trophic structure), will respond to increased pollution or habitat alterations. Metric development reduces the number of biological community attributes that need evaluation to only those that are sensitive to impairment or habitat degradation. Metrics selected for the IBI are given a standardized score based on their response to disturbance. Individual metric scores are then combined into an overall IBI score (Table 9). These overall IBI scores can be matched with a qualitative rating such as those associated with a biological condition gradient (e.g., excellent, good, fair, poor) or with aquatic life use support (e.g., least disturbed, moderately disturbed, and most disturbed).

There were not enough sites in each Model watershed (Figure 17) to determine specific IBIs for that watershed, so they are combined for the entire Upper and Middle Sheyenne River. Threshold values for the Northern Glaciated Plains (46) Ecoregion were determined based on the statistical distribution of reference, or best available, site IBI scores in the region and are provided in Table 10.

Table 8. Northern Glaciated Plains Ecoregion (46) of the Red River Basin Maximum and Minimum Values Used to Standardize Metrics.

Final Metric	Category	Reaction to Perturbation	Minimum Value	Maximum Value
Percent EPT	Composition	Decrease	2.37	75.59
Percent Non-Insect	Composition	Increase	0.97	78.23
Percent Univoltine	Life Cycle/Composition	Decrease	3.48	76.69
Tolerant Taxa	Tolerance	Increase	1	12
Hilsenhoff Biotic Index (HBI)	Tolerance	Increase	4.52	7.31
Swimmer Taxa	Habit	Increase	0	8

Table 9 Standardized Metric Scores and Final IBI Scores for the Upper and Middle Sheyenne River.

Site	Date	Percent EPT	Percent Non-Insect	Percent Univoltine	Tolerant Taxa	HBI	Swimmer Taxa	IBI Score
551443	9/21/2009	0	28.72171	5.680578	9.090909	9.32257	25	13
551444	9/21/2009	2.705371	81.13911	2.39991	72.72727	36.9682	75	45
551445	9/21/2009	8.801727	72.02868	2.628933	27.27273	33.7483	37.5	30
551446	9/21/2009	0	0	0.773093	54.54545	12.1012	50	20
551447	9/22/2009	0.515756	0	0.762544	63.63636	0	75	23
551448	9/22/2009	69.58745	68.71019	70.85052	54.54545	57.5075	75	66
551449	9/22/2009	1.054125	0	2.857263	54.54545	21.0433	75	26
551450	9/22/2009	10.1165	0	8.948683	36.36364	0	37.5	15
551451	9/22/2009	11.53871	8.840805	20.89495	9.090909	5.02387	37.5	15
551452	9/22/2009	25.1986	64.27462	24.31972	45.45455	37.5099	62.5	43
551532	9/28/2010	25.98132	98.14288	100	36.36364	63.086	0	54
551533	9/28/2010	68.22149	100	100	63.63636	85.2329	0	70
551534	9/28/2010	23.17142	95.45606	97.46436	36.36364	46.4424	0	50
551535	9/28/2010	31.26917	96.54884	100	36.36364	30.6069	0	49
551536	9/29/2010	32.02322	93.55115	100	36.36364	47.3861	0	52
551537	9/29/2010	66.67549	97.11364	100	27.27273	61.1891	0	59
551538	9/29/2010	41.34145	91.0783	100	9.090909	47.7596	0	48
551539	9/29/2010	26.93862	99.68978	100	45.45455	11.7627	0	47
551540	9/29/2010	17.81901	98.08571	100	54.54545	20.8323	0	49
551541	9/30/2010	47.47598	94.99261	100	72.72727	31.9373	0	58

Table 10. Threshold Index of Biotic Integrity Values for the Northern Glaciated Plains Ecoregion 46.

	Least Disturbed	Moderately Disturbed	Most Disturbed
IBI Score	>70	$\leq$ 70 and $\geq$ 59	< 59

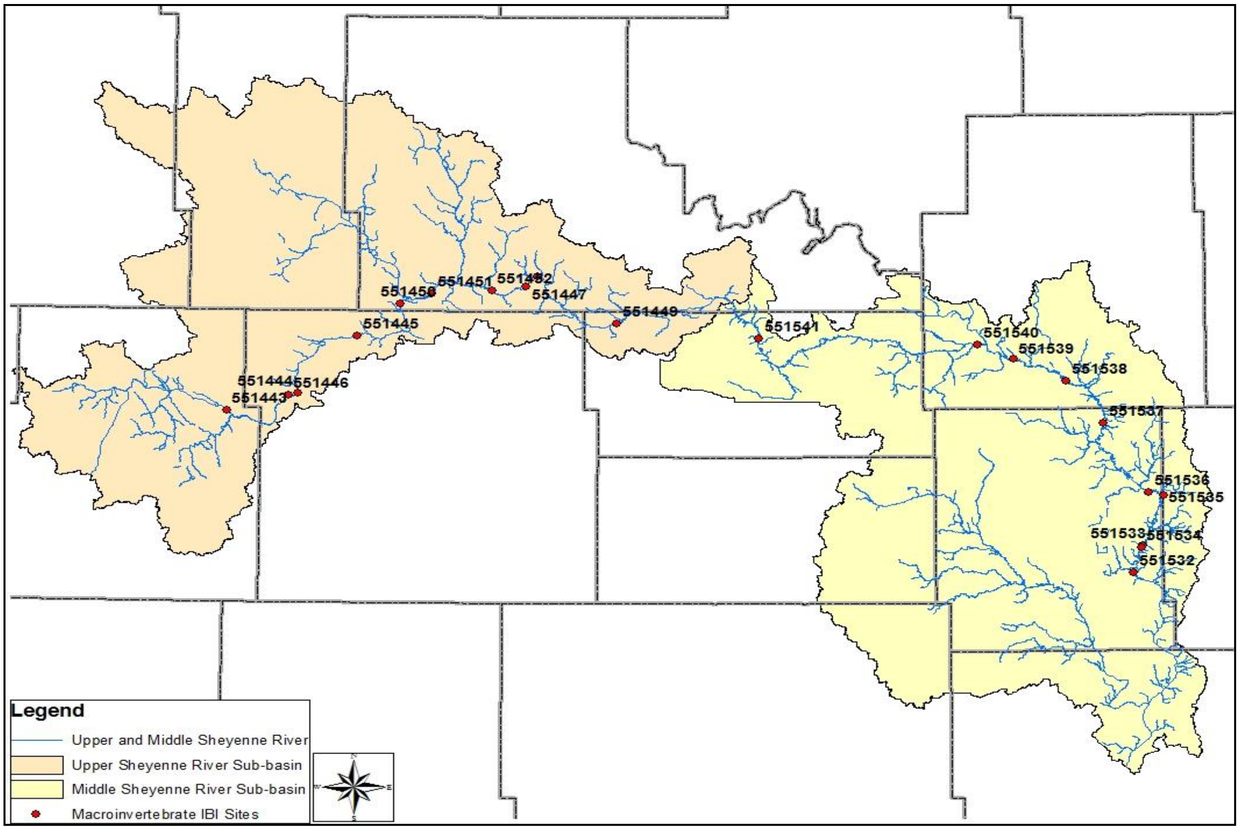

Figure 17. Macroinvertebrate Index of Biotic Integrity Sites on the Upper and Middle Sheyenne River.

4.3 Annualized Agricultural Non-Point Source Pollution Model (AnnAGNPS)

The Annualized Agricultural Non-Point Source Pollution (AnnAGNPS) Model, Version 5.1, developed by the USDA's Agricultural Research Service (ARS) and Natural Resource Conservation Service (NRCS) was used in the Upper and Middle Sheyenne River watershed assessment (Moore Engineering, 2011). The AnnAGNPS Model consists of a system of computer models used to predict nonpoint source pollution (NPS) loadings within agricultural watersheds. The Continuous Simulation Surface Runoff Model contains programs for: 1) input generation and editing; 2) "annualized" pollutant loading model; and 3) output reformatting and analysis.

The AnnAGNPS Model uses batch processing, continual-simulation, and surface runoff pollutant loading to generate amounts of water, sediment, and nutrients moving from land areas (cells) and flowing into the watershed stream network at user specified locations (reaches) on a daily basis. The water, sediment, and chemicals travel throughout the specified watershed outlets. Feedlots, gullies, point sources, and impoundments are special components that can be included in the cells and reaches. Each component adds water, sediment, or nutrients to the reaches.

The AnnAGNPS Model is able to partition soluble nutrients between surface runoff and infiltration. Sediment-attached nutrients are also calculated in the stream system.

Sediment is divided into five particle size classes (clay, silt, sand, small aggregate, and large aggregate) and are moved separately through the stream reaches.

AnnAGNPS uses various models to develop an annualized load in the watershed. These models account for surface runoff, soil moisture, erosion, nutrients, and reach routing. Each model serves a particular purpose and function in simulating the NPS processes occurring in the watershed.

To generate surface runoff and soil moisture, the soil profile is divided into two layers. The top layer is used as the tillage layer and has properties that change (bulk density etc.). While the remaining soil profile makes up the second layer with properties that remain static. A daily soil moisture budget is calculated based on rainfall, irrigation, and snow melt runoff, evapotranspiration, and percolation. Runoff is calculated using the NRCS Runoff Curve Number equation. These curve numbers can be modified based on tillage operations, soil moisture, and crop stage.

Overland sediment erosion was determined using a modified watershed-scale version of (Revised Universal Soil Loss Equation) RUSLE (Geter and Theurer, 1998).

Daily mass balances for nitrogen (N), phosphorus (P), and organic carbon (OC) are calculated for each cell. Major components of N and P considered include plant uptake of N and P, fertilization, residue decomposition, and N and P transport. Soluble and sediment absorbed N and P are also calculated. Nitrogen and phosphorus are then separated into organic and mineral phases. Plant uptake of N and P are modeled through a crop growth stage index (Bosch et. al., 1998).

The reach routing model moves sediment and nutrients through the watershed. Sediment routing is calculated based upon transport capacity relationships using the Bagnold Stream Power Equation (Bagnold, 1966). Routing of nutrients through the watershed is accomplished by subdividing them into soluble and sediment attached components and are based on reach travel time, water temperature, and decay constant. Infiltration is also used to further reduce soluble nutrients. Both the upstream and downstream points of the reach are calculated for equilibrium concentrations by using a first order equilibrium model.

AnnAGNPS uses 34 different categories of input data and over 400 separate input parameters to execute the model. The necessary datasets used for the AnnAGNPS Model include topography, soil layers, land cover layers, crop management, and climate (weather) data. These are a collection of geographical information systems (GIS) layers, publications, and management routines from other agricultural sources. All the input parameters for the AnnAGNPS input data are in metric units. The datasets generated from the AnnAGNPS program are also in metric units. However, the tables and figures shown in this report are presented in English units.

4.3.1 AnnAGNPS Results for the Pierce Model Watershed

Results from the AnnAGNPS Model for the Sheyenne River watershed above Baldhill Dam were determined using five years of data from January 2005 through December 2009.

The results of the AnnAGNPS Model will be discussed separately for each of the seven watershed water quality reports. For each of these seven models, the average annual load for a parameter (water, nitrogen, phosphorus and sediment) was determined for an individual cell.

The Pierce Model contains 3,510 cells encompassing 529,982 acres (Figure 18 and Table 11). For each one of the cells, the annual average parameter load divided by the cell's area was determined resulting in average annual yield, or amount of each parameter expected to be produced by the entire sub-watershed. The following summarizes how these parameters are presented:

- Water as Runoff – inches per year (in/yr)
- Nitrogen – pounds per acre per year (lb/acre/yr)
- Phosphorus – pounds per acre per year (lb/acre/yr)
- Sediment – pounds per acre per year (lb/acre/yr)

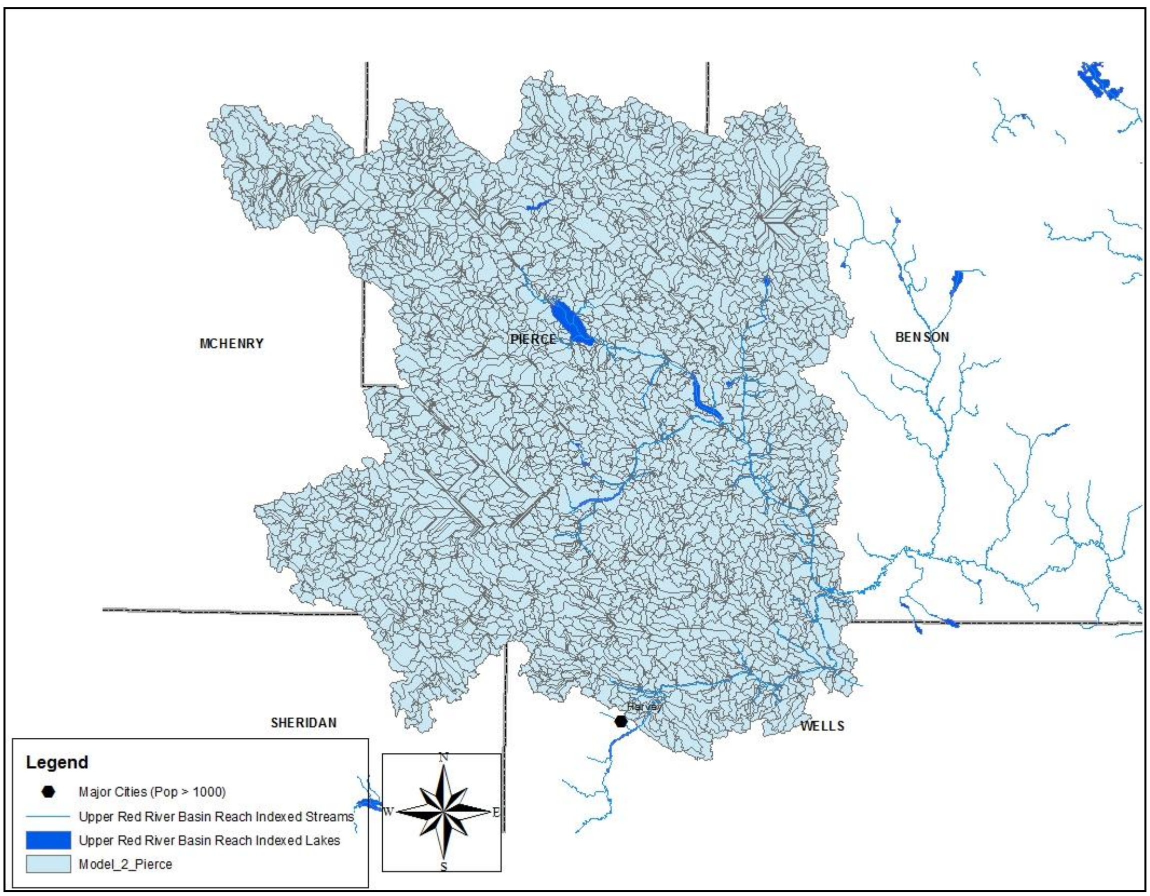

Figure 18. AnnAGNPS Model Watershed Delineation for the Pierce Model.

Table 11. Watershed Area and Number of AnnAGNPS Cells.

Watershed Model	Area (mi^2)	Area (acres)	AnnAGNPS Cells
Model 1 - Sheridan	543.6	347,914	2,260
Model 2 - Pierce	**828.1**	**529,982**	**3,510**
Model 3 - Benson	535.7	342,826	2,227
Model 4 - Eddy	438.0	280,303	1,833
Model 5 - Griggs	762.7	488,125	3,162
Model 6 - Barnes	159.5	102,069	648
Model 7 - Nelson	645.0	412,887	2,517
Total	3,912.6	2,504,106	16,157

Table 12 provides a summary of the average annual yields for the Pierce Model and each subwatershed as an annual average yield for runoff, nitrogen, phosphorus, and sediment yields, along with how each subwatershed ranks compared to all the others.

Table 12. Average Annual Yields and Watershed Comparisons for all Watershed Models.

	Area		Runoff		Nitrogen		Phosphorus		Sediment	
Watershed Model	Acres	Rank	in/yr	Rank	lb/acre/yr	Rank	lb/acre/yr	Rank	lb/acre/yr	Rank
Model 1 - Sheridan	347,914	4	0.14	7	6.76	7	1.5	5	70	6
Model 2 - Pierce	**529,982**	**1**	**0.15**	**6**	**6.89**	**6**	**1.46**	**7**	**81**	**5**
Model 3 - Benson	342,826	5	0.17	3	10.05	3	2.22	2	119	1
Model 4 - Eddy	280,303	6	0.16	5	7.23	5	1.5	5	119	1
Model 5 - Griggs	488,125	2	0.31	1	10.55	2	2.21	3	64	7
Model 6 - Barnes	102,069	7	0.17	3	9.62	4	2.1	4	99	3
Model 7 - Nelson	412,887	3	0.18	2	10.68	1	2.28	1	98	4

The Pierce Watershed Model was compared with the other six watershed models to evaluate watershed size, average annual runoff and average annual contributions of nitrogen, phosphorus, and sediment to the watershed (Table 12). The Pierce Watershed Model ranked first in watershed size (529,982 acres) among all the other watershed models. Average annual runoff from the watershed and average total nitrogen contributions both ranked sixth, average annual phosphorus contributions ranked seventh, and average sediment load ranked fifth.

These results indicate that land use has a specific correlation to average annual contributions of nutrients and sediment in the watershed. In this case the Pierce Watershed Model has a significant portion of the watershed consisting of pasture/grassland grazing (Figure 3). The vegetation present in the watershed acts as a buffer to nutrients and sediment entering the river by slowing and filtering runoff.

Figures 19 through 22 show the distribution of water, nitrogen, phosphorus, and sediment yields for each of the cells in the model's watershed. Green and light green colors indicate a lower yield, light orange a middle level of yield, while the dark orange and red colors indicate the highest yields of water (runoff), nitrogen, phosphorus, and sediment. White indicates a zero value and is either water or solid rock.

In Figure 19 annual runoff yields for the Pierce Model indicate that a majority of the watersheds cells contribute yields ranging from 0.11-0.25 inches per year. Figure 20 shows annual contributions of phosphorus which identified a majority of the watershed cells in the 1.01-2.50 lb/acre/yr range. Figure 21 shows a majority of watershed cells contributing nitrogen yields ranging from 5.01-15.00 lb/acre/yr. Figure 22 indicates very little sediment contributions from runoff to the Pierce Model watershed, with a majority of the watershed cells having a sediment yield range of 0-100 lb/acre/yr. These values correspond to the average values listed in Table 12.

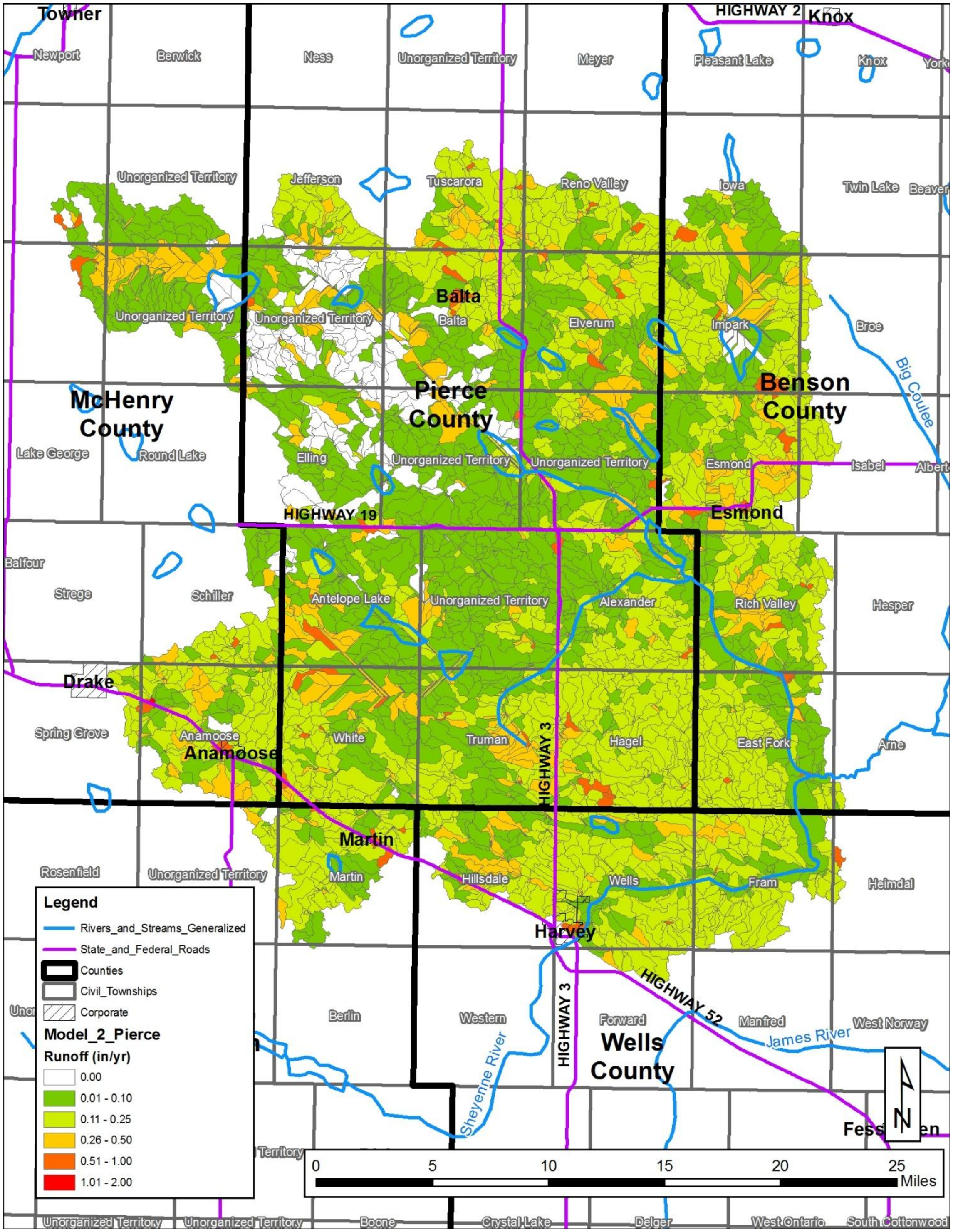

Figure 19. AnnAGNPS Model Predicted Water Runoff for the Pierce Model (Moore Engineering, 2010).

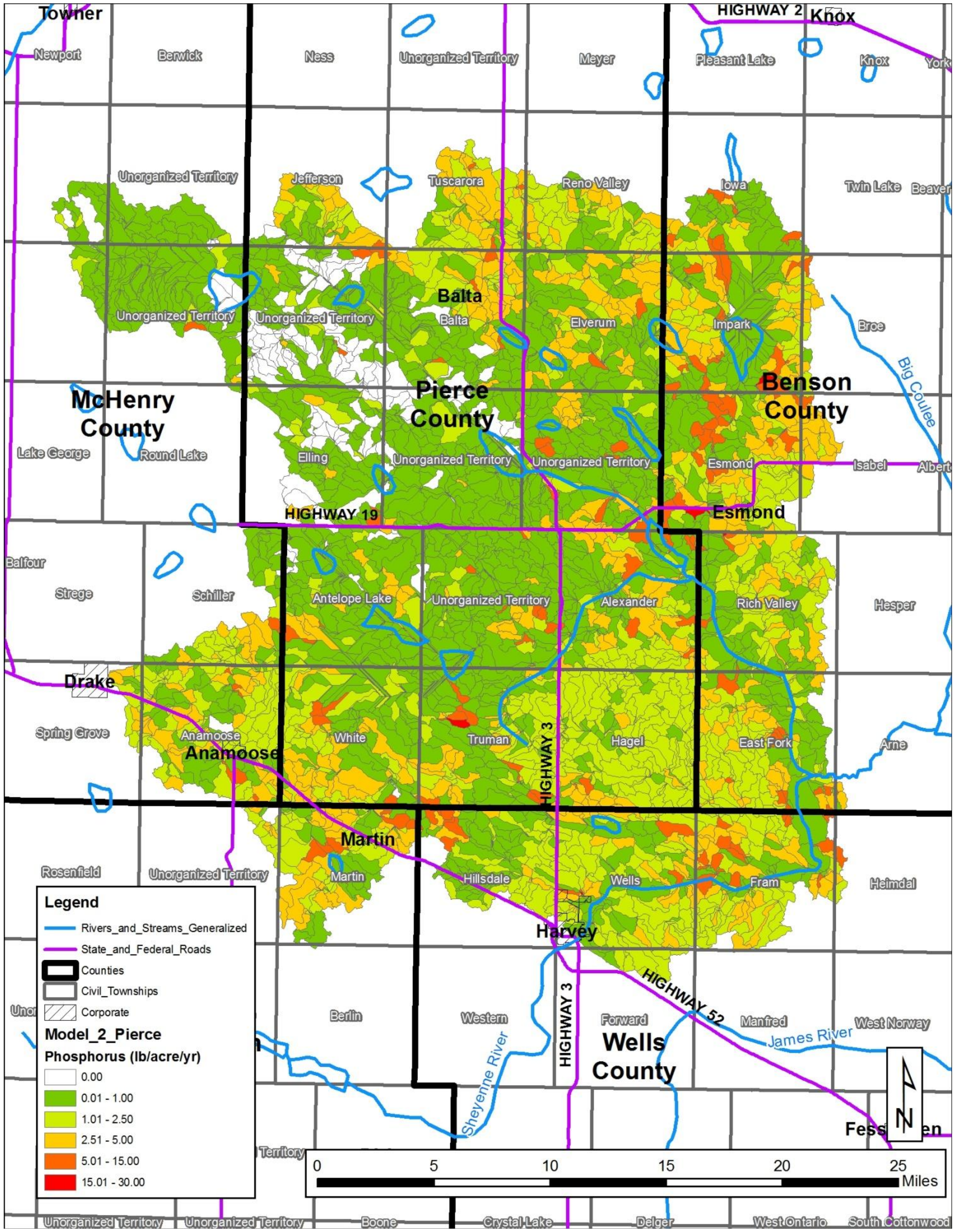

Figure 20. AnnAGNPS Model Predicted Phosphorus Yield for the Pierce Model (Moore Engineering, 2010).

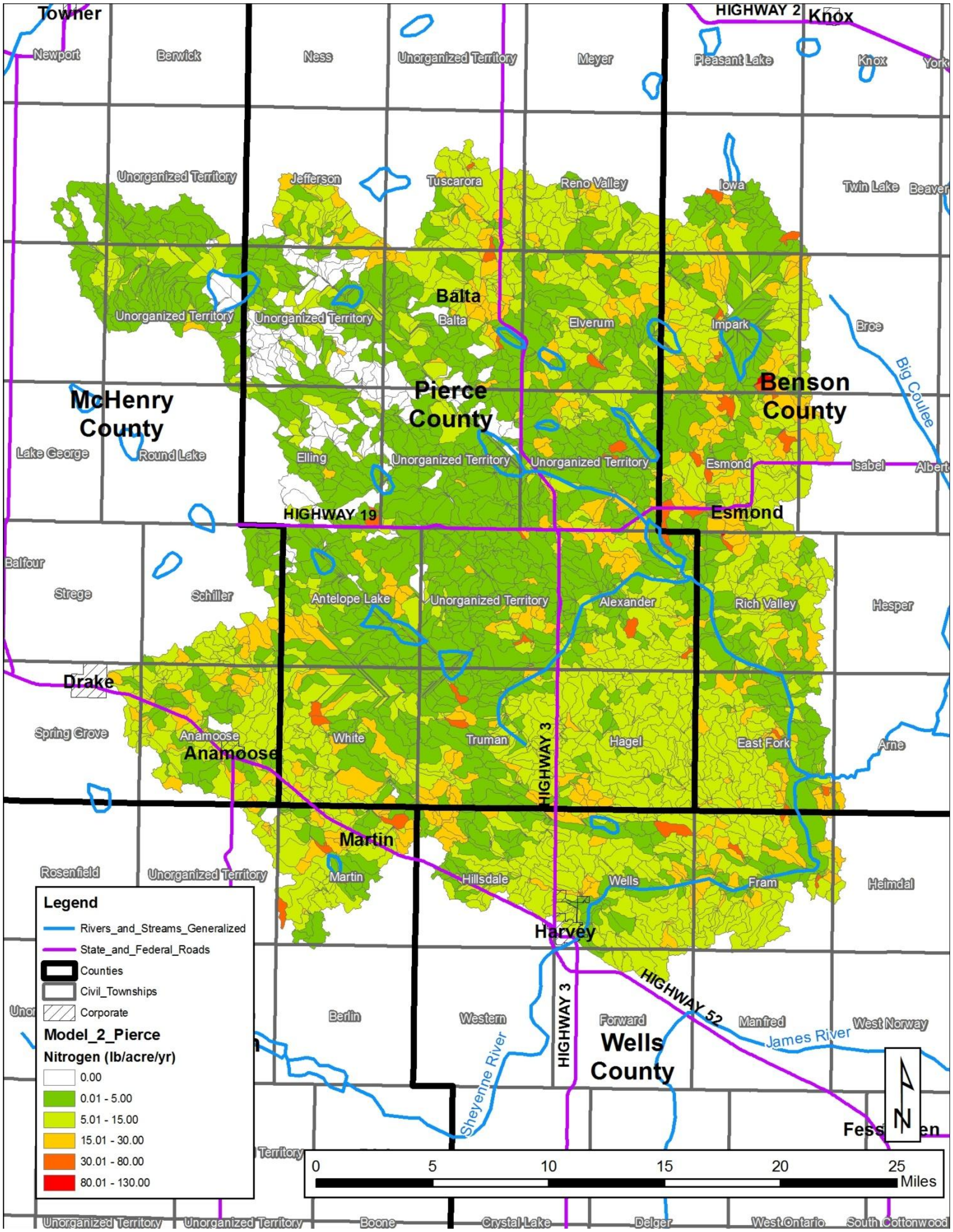

Figure 21. AnnAGNPS Model Predicted Nitrogen Yield for the Pierce Model (Moore Engineering, 2010).

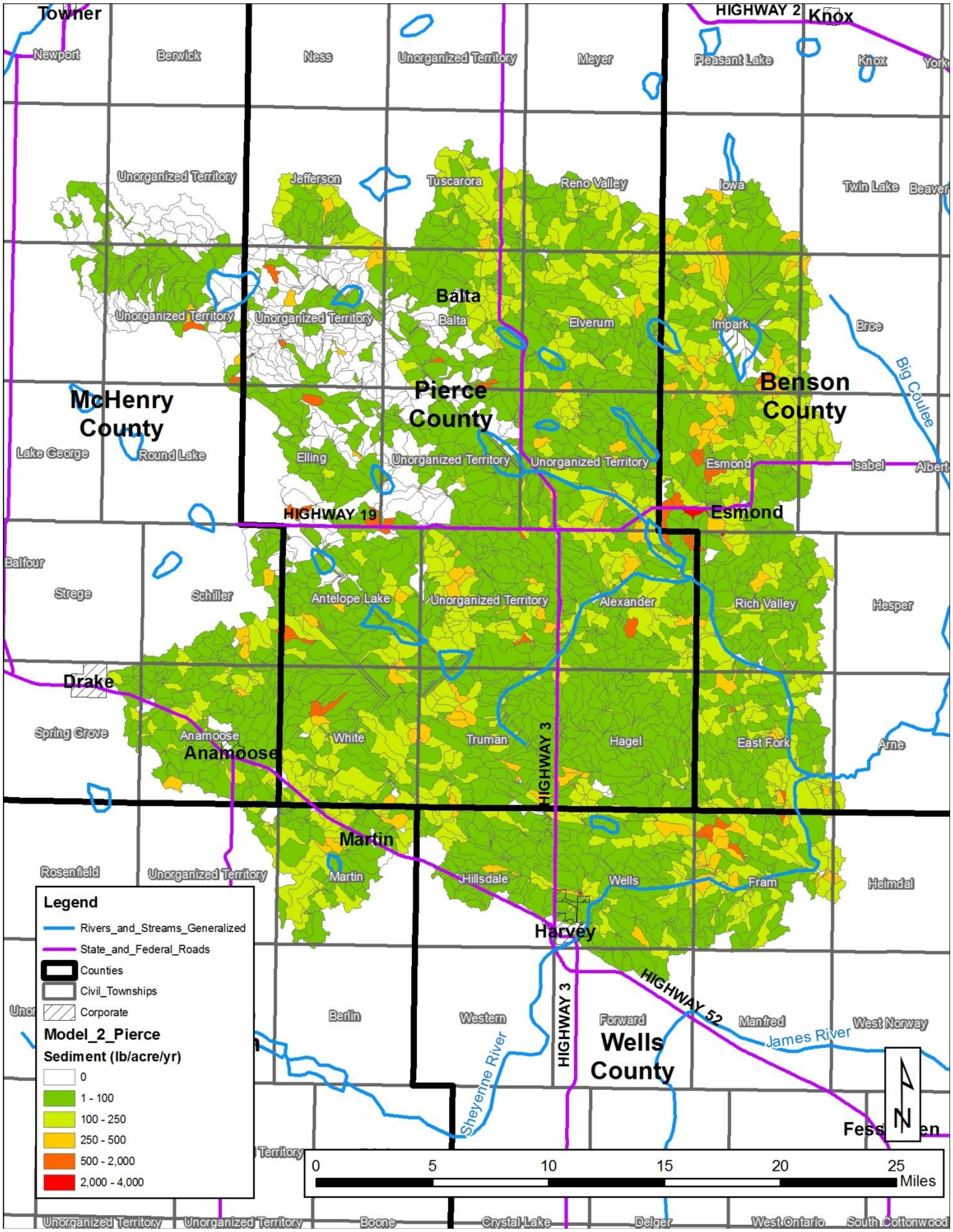

Figure 22. AnnAGNPS Model Predicted Sediment Yield for the Pierce Model (Moore Engineering, 2010).

5.0 CONCLUSION

5.1 Nutrients (Total Phosphorus and Total Nitrogen)

Water moving through soils will leave most nutrients attached to soil particles. However, nitrate is especially soluble in water, and will transport through soils via water flow. Coarse textured soils have lower water-holding capacity and will have a higher potential to lose nitrate via leaching, when compared with fine-textured soils. Some sandy soils, for instance, may retain only one half inch of water per cubic foot of soil, whereas, some silty loam or clay loam soils may retain up to two inches of water per cubic foot. However, nitrate can be leached from any soil if excess rainfall or irrigation saturates the soil and causes water to move through the root zone or if sub-surface drainage is enhanced through tile drainage (NDSU, 2005).

Particulate phosphorus tends to stay attached to soil particles and settle to the bottom of a waterbody unless mixing occurs. Soluble phosphorus will produce excessive algae when in the presence of sufficient amounts of inorganic (reactive) nitrogen compounds.

Nutrient loads for the Pierce Model watershed are primarily proportional to flow and suggest that pollution transport is flow dominated (Figures 9-12) with possible secondary sources from in-stream processes such as algae blooms, riparian grazing, or septic systems. The highest TN and TP yields occur in areas of high runoff (Figures 19-22) which also suggests a transport by overland runoff during high precipitation events. These areas coincide with the most actively cropped acres in the watershed (Figure 3) indicating that best management practices for cropped land and addition of buffer strips and riparian condition improvement would improve water quality. The Pierce Model watershed is within the optimum TN:TP ratio range of 10-17. This means that this portion of the watershed has the optimum levels for both N and P for aquatic vegetation production which can lead to eutrophication (greening of the river). The TN:TP ratios for each sampling site for 2009 and 2010 are given in Table 13.

Table 13. TN:TP Ratios for Sites 305503 and 385504.

Site	Average TN:TP Ratio, 2009	Average TN:TP Ratio, 2010
385503	10.77	9.36
385504	16.70	12.33

The watershed contains cropland buffered by large areas of grass/pasture which also help to lessen the effects of overland erosion (Figure 3). Since particulate phosphorus lasts longer in the erosion process by attaching to soil particles, where reactive nitrogen changes form including into that of a gas, the slightly higher total nitrogen numbers suggest that by addressing sources near the riparian zone, improvement will be more effective. No long term trends in nitrogen or phosphorus yields were noted, suggesting that agriculture production activities and runoff are variable from year to year.

5.2 Pathogens (E. coli Bacteria)

Escherichia coli, commonly known as E. coli, is one of the most common species of coliform bacteria. It is a normal component of the large intestines in humans and other warm blooded animals. E. coli is used as an indicator species because it is not feasible to test water for each possible type of disease-causing pathogen. Fecal indicator bacteria such as E. coli are used to indicate on a statistical basis, the likelihood of contracting a disease by ingesting or recreating in such waters.

Pathogens such as E. coli undergo a poorly defined process of dispersion, transport, and inactivation. The transport of pathogens overland in surface runoff is clearly responsible for high flow/precipitation event related increases in the concentrations of in-stream waterborne pathogens in many watersheds. However, there are significant gaps in our understanding of the life cycle and propagation of these pathogens in soils and surface water. This is part of the reason for the two-part values of the State water quality standards. The monthly means help address chronic E. coli concentrations over time to account for reproduction within the waterbody, and the acute high limit addresses spikes that may dissipate, but present health concerns in their initial values.

For the Pierce Model watershed, two sites were sampled for E. coli bacteria. As this entire watershed is near the headwaters of the Sheyenne River, it is expected that flow will decrease in the summer months. As depicted in Figure 3, a large portion of the watershed in close proximity to the river is involved in crop production. Land use also indicates that a significant portion of the riparian area is in vegetative cover. The sediment map in Figure 22 shows most of this area to have very low sediment runoff values, between 1 and 100 lbs/acre/year. This suggests that there are few areas where livestock have direct access to the river. Limited livestock operations near the riparian area and adequate vegetative along the river contribute to keeping E. coli bacteria concentrations within water quality standard limits.

5.3 Other Watershed Data

Other watershed-wide data indicate possible negative impacts to water quality. A majority of the rapid geomorphic assessments (RGAs) scored in the moderately unstable and unstable categories (Table 7). These changes to the physical condition of the stream often represent the first cues that negative impacts are occurring. Riparian areas with healthy slopes and a variety of vegetation may provide buffers that can trap nonpoint source pollution runoff and prevent much of it from entering the waterway. In addition, most of the IBI scores fell into the ranges associated with most disturbed threshold values (Table 10). Aquatic insects also serve as one of the first indicators to show stress from disturbed habitat and water pollution, and can be an indicator that overall riparian health is beginning to fail. Both of these indicators should be acknowledged when developing a water quality improvement plan.

6.0 IMPLEMENTATION STRATEGY

When beginning a water quality improvement project the implementation of conservation practices, most often called Best Management Practices (BMPs), is one step in a plan towards achieving a healthy watershed. It is first important to identify the problems and possible sources of impairment. This report is designed to provide that tool. Then it is necessary to identify critical areas, which are areas where BMPs will have the greatest impact. Examples are riparian areas adjacent to the river, areas of high erosion or nutrient loads, etc. After that it is just a matter of finding the right tool for the job. In order to initiate discussion and provide a starting point for ideas that could lead towards water quality improvement, several BMPs and their effects are described below. This list is not comprehensive and NRCS also has several BMPs for use throughout the watershed. As always, it is up to a project sponsor, like a water board or soil conservation district, to decide which tools they wish to use.

6.1 Livestock Management

Livestock management BMPs are designed to promote healthy water quality and riparian areas through management of livestock and associated grazing land. Fecal matter and nutrient wastes from livestock, erosion from poorly managed grazing land and riparian areas can be significant sources of E. coli bacteria and nutrient loading to surface water. Precipitation, plant cover, number of animals, and soils are factors that affect the amount of nonpoint source pollution delivered to a waterbody because of livestock. Several BMPs are known to reduce nonpoint source pollution from livestock. These BMPs include:

<u>Livestock exclusion from riparian areas</u>: This practice is established to remove livestock from grazing riparian areas and watering in the stream. Livestock exclusion is accomplished through fencing. A reduction in stream bank erosion can be expected by minimizing or eliminating hoof trampling. A stable stream bank will support vegetation that will hold banks in place and serve a secondary function as a filter from nonpoint source runoff. Added vegetation will create aquatic habitat and shading for macroinvertebrates and fish. Direct deposit of fecal matter into the stream and stream banks will be eliminated as a result of livestock exclusion by fencing, reducing bacteria and nutrient loads.

<u>Water well and tank development</u>: Fencing animals from stream access requires an alternative water source. Installing water wells and tanks satisfies this need. Installing water tanks provides a quality water source and keeps animals from wading and defecating in streams. This will reduce the probability of pathogenic infections to livestock and the public, as well as reduce the amount of nutrients and sediment entering the waterbody.

<u>Prescribed grazing</u>: This practice is used to increase ground cover and ground stability by rotating livestock throughout multiple fields. Grazing with a specified rotation minimizes overgrazing and resulting erosion. The Natural Resource Conservation Service (NRCS) recommends grazing systems to improve and maintain water quality and quantity. Duration, intensity, frequency, and season of grazing can be managed to enhance

vegetation cover and litter, resulting in reduced runoff, improved infiltration, increased quantity of soil water for plant growth, and better manure distribution and increased rate of decomposition (NRCS, 1998). In a study by Tiedemann et al. (1988), as presented by USEPA (1993), the effects of four grazing strategies on bacteria levels in thirteen watersheds in Oregon were studied during the summer of 1984. Results of the study (Table 14) showed that when livestock are managed at a stocking rate of 19 acres per animal unit month, with water developments and fencing, bacteria levels were reduced significantly.

Table 14. Bacterial Water Quality Response to Four Grazing Strategies (Tiedemann et al., 1988).

Grazing Strategy		Geometric Mean Bacteria Count
Strategy A:	Ungrazed	40/L
Strategy B:	Grazing without management for livestock distribution; 20.3 ac/AUM.	150/L
Strategy C:	Grazing with management for livestock distribution: fencing and water developments; 19.0 ac/AUM	90/L
Strategy D:	Intensive grazing management, including practices to attain uniform livestock distribution and improve forage production with cultural practices such as seeding and fertilizing 6.9 ac/AUM	950/L

Vegetative filter strip: Vegetated filter strips are used to reduce the amount of sediment, particulate organics, dissolved contaminants, nutrients, and E. coli bacteria to streams. The effectiveness of filter strips and other BMPs in removing pollutants is quite successful. Results from a study by Pennsylvania State University (1992a) as presented by USEPA (1993), suggest that vegetative filter strips are capable of removing up to 55 percent of bacteria, 65 percent of sediment, and 85 percent of total phosphorus loading to rivers and streams (Table 15). The ability of the filter strip to remove contaminants is dependent on field slope, filter strip slope, erosion rate, amount and particulate size distribution of sediment delivered to the filter strip, density and height of vegetation, and runoff volume associated with erosion producing events (NRCS, 2001).

Waste management system: Waste management systems can be effective in controlling up to 90 percent of bacteria loading originating from confined animal feeding areas (Table 15). A waste management system is made up of various components designed to control nonpoint source pollution from concentrated animal feeding operations (CAFOs) and animal feeding operations (AFOs). Diverting clean water from the feeding area and containing dirty water from the feeding area in a pond are typical practices of a waste management system. Manure handling and application of manure to cropland is designed to be adaptive to environmental, soil, and plant conditions to minimize the probability of contamination of surface water.

Table 15. Relative Gross Effectiveness[a] of Confined Livestock Control Measures (Pennsylvania State University, 1992a).

Practice[b] Category	Runoff[c] Volume	Total[d] Phosphorus (%)	Total[d] Nitrogen (%)	Sediment (%)	Fecal Bacteria (%)
Animal Waste System[e]	-	90	80	60	85
Diversion System[f]	-	70	45	NA	NA
Filter Strips[g]	-	85	NA	60	55
Terrace System	-	85	55	80	NA
Containment Structures[h]	-	60	65	70	90

NA Not Available.
a Actual effectiveness depends on site-specific conditions. Values are not cumulative between practice categories.
b Each category includes several specific types of practices.
c - = reduction; + = increase; 0 = no change in surface runoff.
d Total phosphorus includes total and dissolved phosphorus; total nitrogen includes organic-N, ammonia-N, and nitrate-N.
e Includes methods for collecting, storing, and disposing of runoff and process-generated wastewater.
f Specific practices include diversion of uncontaminated water from confinement facilities.
g Includes all practices that reduce contaminant losses using vegetative control measures.
h Includes such practices as waste storage ponds, waste storage structures, waste treatment lagoons.

Septic System: Septic systems provide an economically feasible way of disposing of household wastes where other means of waste treatment are unavailable (e.g., public or private treatment facilities). The basis for most septic systems involves the treatment and distribution of household wastes through a series of steps involving the following:

1. A sewer line connecting the house to a septic tank
2. A septic tank that allows solids to settle out of the effluent
3. A distribution system that dispenses the effluent to a leach field
4. A leaching system that allows the effluent to enter the soil

Septic system failures are caused when one or more components of the septic system do not work properly and untreated waste or wastewater leaves the system. Wastes may pond in the leach field and ultimately run off directly into nearby streams or percolate into groundwater. Untreated septic system waste is a potential source of nutrients (nitrogen and phosphorus), organic matter, suspended solids, and E. coli bacteria. Land application of septic system sludge, although unlikely, may also be a source of contamination.

Septic system failure can occur for several reasons, although the most common reason is improper maintenance (e.g., age, inadequate pumping). Other reasons for failure include improper installation, location, and choice of system. Harmful household chemicals can also cause failure by killing the bacteria that digest the waste. While the number of systems that are not functioning properly is unknown, it is estimated that 28 percent of the systems in North Dakota are failing (USEPA, 2002).

6.2 Farmland Management

No-Till Farming: This crop residue management technique increases the amount of water and organic matter (nutrients) in the soil and decreases erosion, by growing crops from year to year without disturbing the soil through tillage. Excessive tillage can lead to soil compaction, loss of organic matter, degradation of soil aggregates, harm to soil microbes and other organisms, and soil erosion where topsoil is blown or washed away, often carrying with it nutrients and bacteria that end up in the river. Less tillage reduces labor, fuel and machinery costs while increasing the water content of the soil. No-till also has carbon sequestration potential through storage of soil organic matter

Nutrient Management: A nutrient management is defined by the NRCS as a plan to manage the amount, source, placement, form and timing of the application of nutrients and soil amendments. The purpose is to meet the nutrient needs of the crops being grown while minimizing the loss of nutrients to surface and ground water. It helps to manage commercial fertilizer and animal manure input costs while protecting water quality.

Buffer Strips/Grassed Waterways: Buffer strips are strips of land designed to intercept storm water and minimize runoff and soil erosion from crop fields. Buffers reduce the amount of sediment and pollutants carried by runoff to nearby rivers and lakes. Grassed waterways are generally broad, shallow, grassed channels, designed to prevent soil erosion while draining runoff water from adjacent cropland. As water travels down the waterway the grass vegetation prevents erosion that would otherwise result from concentrated flows. The soil microbes and grass in these practices also facilitate the transformation and uptake of nutrients to protect surface waters.

Cover Crops: Cover crops are planted primarily to manage soil fertility and quality, water, weeds, pests, diseases, and biodiversity. By reducing soil erosion, cover crops reduce both the rate and quantity of water that drains off the field. The increased soil organic matter enhances the soil structure, as well as the water and nutrient hold and buffering capacity of soil.

Critical Area Planting: Critical area planting is the planting of grass, legumes or other vegetation to protect small, badly eroding areas. The permanent vegetation stabilizes areas such as gullies, over-grazed hillsides or terrace backslopes. By stabilizing the soil, it reduces damage from sediment and nutrient runoff to waterbodies.

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Appendix A
Summary of General Chemistry and Trace Metals for Sites 385503 and 385504

Parameter	Units	Samples	Mean	Min	Max	Median
Total Phosphorus (TP)	mg/L	66	0.164379	0.06	0.36	0.149
Total Nitrogen (TN)	mg/L	66	1.561288	0.815	2.42	1.46
Total Kjeldahl Nitrogen (TKN)	mg/L	66	1.561288	0.815	2.42	1.46
Nitrate + Nitrite (N+N)	mg/L	66	0.076439	0.015	0.42	0.0225
Ammonia (NH_3)	mg/L	66	0.093242	0.015	0.493	0.0695
Total Suspended Solids (TSS)	mg/L	65	7.5	2.5	101	5
Calcium (Ca)	mg/L	16	44.675	23.5	62.2	43.75
Chloride (Cl)	mg/L	16	13.35125	3.47	18.4	13.35
Potassium (K)	mg/L	16	12.6875	7.1	15.5	13.25
Sodium (Na)	mg/L	16	155.9	34.2	227	165
Aluminum (Al)	ug/L	16	191.25	25	876	95
Antimony (Sb)[1]	ug/L	16	2.5	2.5	2.5	2.5
Arsenic (As)	ug/L	16	4.414375	2.5	6.66	5.295
Barium (Ba)	ug/L	16	61.8375	48.6	76.6	64.05
Beryllium (Be)[1]	ug/L	16	2.5	2.5	2.5	2.5
Boron (B)	ug/L	16	496.5625	121	720	560.5
Cadmium (Cd)[1]	ug/L	16	2.5	2.5	2.5	2.5
Chromium (Cr)[1]	ug/L	16	2.5	2.5	2.5	2.5
Copper (Cu)[1]	ug/L	16	2.5	2.5	2.5	2.5
Iron (Fe)	mg/L	16	0.224438	0.052	1.04	0.139
Lead (Pb)[1]	ug/L	16	2.5	2.5	2.5	2.5
Magnesium (Mg)	mg/L	16	57.1125	15	72.9	61.05
Manganese (Mn)	mg/L	16	0.090625	0.005	0.331	0.0495
Nickel (Ni)[1]	ug/L	16	2.5	2.5	2.5	2.5
Selenium (Se)[1]	ug/L	16	2.5	2.5	2.5	2.5
Silver (Ag)[1]	ug/L	16	2.5	2.5	2.5	2.5
Thallium (Tl)[1]	ug/L	16	2.5	2.5	2.5	2.5
Zinc (Zn)	ug/L	16	10.68	2.5	37.8	10.5
pH	N/A	16	8.34	7.52	8.7	8.41
Sulfate as (SO_4)	mg/L	16	290.4313	58.9	355	322

[1]Antimony, Beryllium, Cadmium, Chromium, Copper, Lead, Nickel, Selenium, Silver, and Thallium were all under the lower detection limit of 5.0 ug/L.

Appendix B
E. coli Sample Results and Recreational Use Attainment for Sites 385503 and 385504

385503										
	May		June		July		August		September	
	5/12/2009	10	6/3/2009	10	7/8/2009	30	8/4/2009	10	9/1/2009	10
	5/20/2009	10	6/10/2009	10	7/14/2009	60	8/11/2009	50	9/8/2009	90
	5/27/2009	10	6/16/2009	80	7/21/2009	30	8/18/2009	20	9/15/2009	200
	5/5/2010	10	6/23/2009	20	7/28/2009	100	8/25/2009	20	9/22/2009	40
	5/11/2010	10	6/30/2009	20	7/6/2010	10	8/2/2010	280	9/29/2009	90
	5/18/2010	10	6/1/2010	40	7/12/2010	50	8/10/2010	180	9/8/2010	340
	5/24/2010	50	6/14/2010	30	7/20/2010	30	8/16/2010	40	9/14/2010	70
			6/22/2010	100	7/28/2010	10	8/24/2010	80	9/20/2010	230
			6/30/2010	150			8/30/2010	140	9/28/2010	60
N		7		9		8		9		9
Geometric Mean		12.58498951		33.80148896		30.80070288		54.88016318		84.20478732
% Exceeded 409 CFU/100mL		0		0		0		0		0
Recreational Use Assessment	Fully Supporting		Fully Supporting		Fully Supporting		Fully Supporting		Fully Supporting	

385504										
	May		June		July		August		September	
	12-May-09	10	03-Jun-09	20	08-Jul-09	20	04-Aug-09	20	01-Sep-09	30
	20-May-09	10	10-Jun-09	10	14-Jul-09	20	11-Aug-09	50	08-Sep-09	80
	27-May-09	20	16-Jun-09	10	21-Jul-09	20	18-Aug-09	70	15-Sep-09	220
	05-May-10	10	23-Jun-09	10	28-Jul-09	20	25-Aug-09	40	22-Sep-09	70
	11-May-10	10	30-Jun-09	10	06-Jul-10	10	02-Aug-10	90	29-Sep-09	110
	18-May-10	10	01-Jun-10	10	12-Jul-10	10	10-Aug-10	160	08-Sep-10	210
	24-May-10	40	14-Jun-10	20	20-Jul-10	20	16-Aug-10	190	14-Sep-10	60
			22-Jun-10	30	28-Jul-10	40	24-Aug-10	20	20-Sep-10	110
			30-Jun-10	80			30-Aug-10	170	28-Sep-10	90
N		7		9		8		9		9
Geometric Mean		13.45900193		16.60551538		18.34008086		66.676464		92.73351243
% Exceeded 409 CFU/100mL		0		0		0		0		0
Recreational Use Assessment	Fully Supporting		Fully Supporting		Fully Supporting		Fully Supporting		Fully Supporting	

Appendix C
Further Information on Box and Whisker Plots

The Technical Definition

In descriptive statistics, a box plot or boxplot (also known as a box-and-whisker diagram or plot) is a convenient way of graphically depicting groups of numerical data through their five-number summaries: the smallest observation (sample minimum), lower quartile (Q1), median (Q2), upper quartile (Q3), and largest observation (sample maximum). A boxplot may also indicate which observations, if any, might be considered outliers.

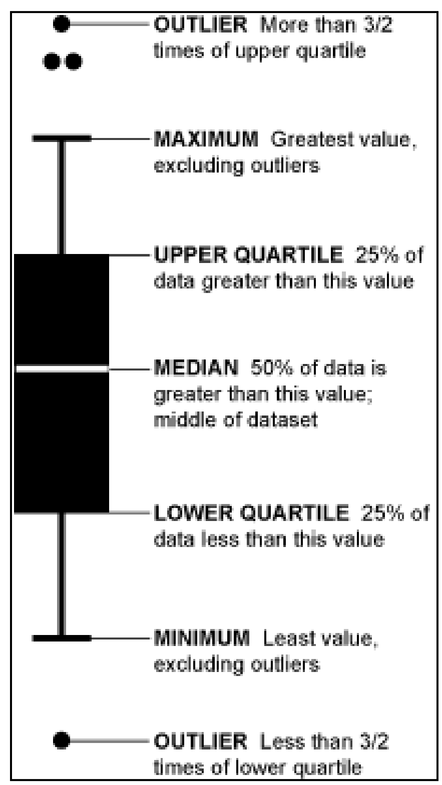
Box plots display differences between populations without making any assumptions of the underlying statistical distribution: they are non-parametric. The spacings between the different parts of the box help indicate the degree of dispersion (spread) and skewness in the data, and identify outliers. Boxplots can be drawn either horizontally or vertically.

Box and whisker plots are uniform in their use of the box: the bottom and top of the box are always the 25th and 75th percentile (the lower and upper quartiles, respectively), and the band near the middle of the box is always the 50th percentile (the median).

Any data not included between the whiskers should be plotted as an outlier with a dot, small circle, or star, but occasionally this is not done.Some box plots include an additional character to represent the mean of the data.On some box plots a crosshatch is placed on each whisker, before the end of the whisker.

How to Read (and Use) a Box-and-Whisker Plot

February 15, 2008 to Statistical Visualization by Nathan Yau



The box-and-whisker plot is an exploratory graphic, created by John W. Tukey, used to show the distribution of a dataset (at a glance). Think of the type of data you might use a histogram with, and the box-and-whisker (or box plot, for short) could probably be useful.

Reading a Box-and-Whisker Plot

Let's say we ask 2,852 people (and they miraculously all respond) how many hamburgers they've consumed in the past week. We'll sort those responses from least to greatest and then graph them with our box-and-whisker.

Take the top 50% of the group (1,426) who ate more hamburgers; they are represented by everything above the median (the white line). Those in the top 25% of hamburger eating (713) are shown by the top "whisker" and dots. Dots represent those who ate a lot more than normal or a lot less than normal (outliers). If more than one outlier ate the same number of hamburgers, dots are placed side by side.

Find Skews in the Data

The box-and-whisker of course shows you more than just four split groups. You can also see which way the data sways. For example, if there are more people who eat a lot of burgers than eat a few, the median is going to be higher or the top whisker could be longer than the bottom one. Basically, it gives you a good overview of the data's distribution.

For more information you can also visit: www.worsleyschool.net/science/files/box/plot.html

Appendix D
Rapid Geomorphic Assessment (RGA) Methodology

Rapid Geomorphic Assessments: RGA's

To evaluate channel-stability conditions and stage of channel evolution of a particular reach, a Rapid Geomorphic Assessment (RGA) will be carried out using the Channel-Stability Ranking Scheme. RGAs utilize diagnostic criteria of channel form to infer dominant channel processes and the magnitude of channel instabilities through a series of nine questions. Granted, evaluations of this sort do not include an evaluation of watershed or upland conditions; however, stream channels act as conduits for energy, flow and materials as they move through the watershed and will reflect a balance or imbalance in the delivery of sediment. RGA's provide a rapid characterization of stability conditions.

The RGA procedure consists of four steps to be completed on site:

1. Determine the 'reach'. The 'reach' is described as the length of channel covering 6-20 channel widths, thus is scale dependent and covers at least two pool-riffle sequences.
2. Take photographs looking upstream, downstream and across the reach; for quality assurance and quality control purposes. Photographs are used with RGA forms to review the field evaluation
3. Make observations of channel conditions and diagnostic criteria listed on the channel-stability ranking scheme.
4. Sample bed material.

Channel-Stability Index

A field form containing nine criteria (Figure J.1) will be used to record observations of field conditions during RGAs. Each criterion was ranked from zero to four and all values summed to provide an index of relative channel stability. The higher the number the greater the instability: sites with values greater than 20 exhibit considerable instability; stable sites generally rank 10 or less. Intermediate values denote reaches of moderate instability. However, rankings are not weighted, thus a site ranked 20 is not twice as unstable as a site ranked 10. The process of filling out the form enables the final decision of 'Stage of Channel Evolution'.

CHANNEL-STABILITY RANKING SCHEME

River_________________________ Site Identifier____________________________________

Date _____________ Time_______ Crew _______________ Samples Taken_________________________

Pictures (circle) U/S D/S X-section Slope__________ Pattern: Meandering / Straight / Braided

1. Primary bed material

	Bedrock	Boulder/Cobble		Gravel	Sand	Silt Clay	
	0	1		2	3	4	______

2. Bed/bank protection

	Yes	No	(with)	1 bank protected	2 banks	
	0	1		2	3	______

3. Degree of incision (Relative elevation of "normal" low water; floodplain/terrace @ 100%)

	0-10%	11-25%	26-50%	51-75%	76-100%	
	4	3	2	1	0	______

4. Degree of constriction (Relative decrease in top-bank width from up to downstream)

	0-10%	11-25%	26-50%	51-75%	76-100%	
	0	1	2	3	4	______

5. Stream bank erosion (Each bank)

	None	Fluvial	Mass wasting (failures)	
Left	0	1	2	______
Right	0	1	2	______

6. Stream bank instability (Percent of each bank failing)

	0-10%	11-25%	26-50%	51-75%	76-100%	
Left	0	0.5	1	1.5	2	______
Right	0	0.5	1	1.5	2	______

7. Established riparian woody-vegetative cover (Each bank)

	0-10%	11-25%	26-50%	51-75%	76-100%	
Left	2	1.5	1	0.5	0	______
Right	2	1.5	1	0.5	0	______

8. Occurrence of bank accretion (Percent of each bank with fluvial deposition)

	0-10%	11-25%	26-50%	51-75%	76-100%	
Left	2	1.5	1	0.5	0	______
Right	2	1.5	1	0.5	0	______

9. Stage of channel evolution

	I	II	III	IV	V	VI	
	0	1	2	4	3	1.5	______

Figure J.1 - Channel stability ranking scheme used to conduct rapid geomorphic assessments (RGA's). The channel stability index is the sum of the values obtained for the nine criteria.

Characterizing Channel Geomorphology

1. Primary bed material

Bedrock	The parent material that underlies all other material. In some cases this becomes exposed at the surface. Bedrock can be recognized by appearing as large slabs of rock, parts of which may be covered by other surficial material.
Boulder/Cobble	All rocks greater than 64 mm median diameter.
Gravel	All particles with a median diameter between 64.0 – 2.00 mm
Sand	All Particles with a median diameter between 2.00 – 0.63 mm
Silt Clay	All fine particles with a median diameter of less than 0.63 mm

2. Bed/bank protection

Yes	Mark if the channel bed is artificially protected, such as with rip rap or concrete.
No	Mark if the channel bed is not artificially protected and is composed of natural material.
1 bank protected	Mark if one bank is artificially protected, such as with rip rap or concrete.
2 banks	Mark if two banks are artificially protected.

3. Degree of incision (Relative elevation Of "normal" low water; floodplain/terrace @ 100%)

Calculated by measuring water depth at deepest point across channel, divided by bank height from bank top to bank base (where slope breaks to become channel bed). This ratio is given as a percentage and the appropriate category marked.

4. Degree of constriction (Relative decrease in top-bank width from up to downstream)

Often only found where obstructions or artificial protection are present within the channel. Taking the reach length into consideration, channel width at the upstream and downstream parts of the reach is measured and the relative difference calculated.

5. Stream bank erosion (Each bank)

The dominant form of bank erosion is marked separately for each bank, left and right, facing in a downstream direction.

If the reach is a meandering reach, the banks are viewed in terms of ‘Inside, Outside’ as opposed to ‘Left, Right’ (appropriate for questions 5-8). Inside bank, being the inner bank of the meander, if the stream bends to the left as you face downstream, this would be the left bank. Outside bank, being the outer bank, on your right as you face downstream in a stream meandering left.

None	No erosion
Fluvial	Fluvial processes, such as undercutting of the bank toe, cause erosion.
Mass Wasting	Mass movement of large amounts of material from the bank is the method of bank erosion. Often characterized by high, steep banks with shear bank faces. Debris at the bank toe appears to have

fallen from higher up in the bank face. Includes, rotational slip failures and block failures.

6. Stream bank instability (Percent of each bank failing)
   If the bank exhibits mass wasting, mark percentage of bank with failures over the length of the reach. If more than 50% failures are marked, the dominant process is mass wasting (see question 5).

7. Established riparian woody-vegetative cover (Each bank)
   Riparian woody-vegetative cover is the more permanent vegetation that grows on the stream banks, distinguished by its woody stem, this includes trees and bushes but does not include grasses. Grasses grow and die annually with the summer and thus do not provide any form of bank protection during winter months whilst permanent vegetation does.

8. Occurrence of bank accretion (Percent of each bank with fluvial deposition)
   The percentage of the reach length with fluvial deposition of material (often sand, also includes fines and gravels) is marked.

9. Stage of channel evolution
   Stage of channel evolution are given by Simon and Hupp, 1986 (see diagram below). All of the above questions help lead to an answer to this question. Refer bank to previously answered questions for guidance. See Table 2 for guidelines of what features are often found with each stage of channel evolution.

Total Score — Total up the responses to the 9 questions.

Stages of Channel Evolution

The channel evolution framework set out by Simon and Hupp (1986) is used to assess the stability of a channel reach (Figure J.2; Table J.1). With stages of channel evolution tied to discrete channel processes and not strictly to specific channel shapes, they have been successfully used to describe systematic channel-adjustment processes over time and space in diverse environments, subject to various disturbances such as stream response to: channelization in the Southeast US Coastal Plain (Simon, 1994); volcanic eruptions in the Cascade Mountains (Simon, 1999); and dams in Tuscany, Italy (Rinaldi and Simon, 1998). Because the stages of channel evolution represent shifts in dominant channel processes, they are systematically related to suspended-sediment and bed-material discharge (Simon, 1989a; Kuhnle and Simon, 2000), fish-community structure, rates of channel widening (Simon and Hupp, 1992), and the density and distribution of woody-riparian vegetation (Hupp, 1992).

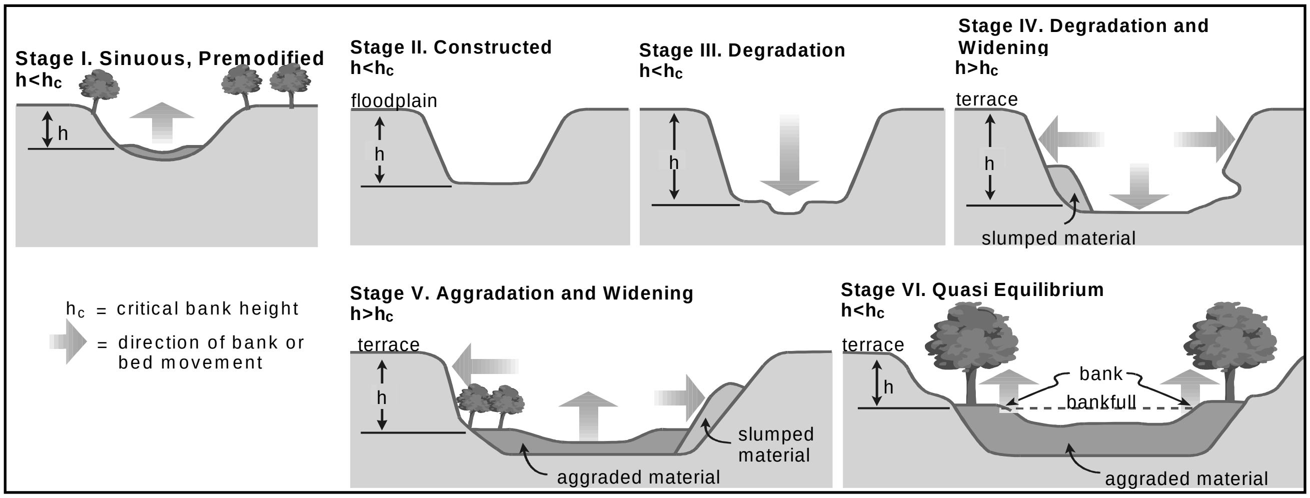


Figure J.2 - Six stages of channel evolution from Simon and Hupp (1986) and Simon (1989b) identifying Stages I and VI as "reference" conditions for given Ecoregions

Table J.1 – Summary of conditions to be expected at each stage of channel evolution.

Stage	Descriptive Summary
I	*Pre-modified* – Stable bank conditions, no mass wasting, small, low angle bank slopes. Established woody vegetation, convex upper bank, and concave lower bank.
II	*Constructed* – Artificial reshaping of existing banks. Vegetation often removed, banks steepened, heightened and made linear.
III	*Degradation* – Lowering of channel bed and consequent increase of bank heights. Incision without widening. Bank toe material removed causing an increase in bank angle.
IV	*Threshold* – Degradation and basal erosion. Incision and active channel widening. Mass wasting from banks and excessive undercutting. Leaning and fallen vegetation. Vertical face may be present.
V	*Aggradation* – Deposition of material on bed, often sand. Widening of channel through bank retreat; no incision. Concave bank profile. Filed material re-worked and deposited. May see floodplain terraces. Channel follows a meandering course.
VI	*Restabilization* – Reduction in bank heights, aggradation of the channel bed. Deposition on the upper bank therefore visibly buried vegetation. Convex shape. May see floodplain terraces.

An advantage of a process-based channel-evolution scheme is that Stages I and VI represent true "reference" conditions. In some cases, such as in the Midwestern United States where land clearing activities near the turn of the 20th Century caused massive changes in rainfall-runoff relations and land use, channels are unlikely to recover to Stage I, pre-modified conditions. Stage VI, a re-stabilized condition, is a much more likely target under present regional land use and altered hydrologic regimes (Simon and Rinaldi, 2000) and can be used as a "reference" condition. Stage VI streams can be characterized as a 'channel-within-a-channel', where the previous floodplain surface is less frequently inundated and can be described as a terrace. This morphology is typical of recovering and re-stabilized stream systems following incision. In pristine areas, where disturbances have not occurred or where they are far less severe, Stage I conditions can be appropriate as a reference.

Unfortunately it is not uncommon that suspended-sediment sampling was carried out over twenty years ago. It may also be the case that the stage of channel evolution relevant to a given site now, was not relevant at the time of suspended-sediment sampling. As we cannot readily create a rating equation to fit the current stability of a given site, plotting certain stream morphology characteristics against a range of discharges over time can help us to establish the stability of the channel at the time of suspended-sediment sampling.