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| Watershed Assessment and Non-Point Source Management Plan Recommendations for Streams Monitored in 2012 - 2013 |
| Prepared for |
| **Oglala Sioux Tribe**  **Environmental Protection Program**  **P.O. Box**  **Pine Ridge, SD 57770**  **P:\OST\OST flag 6.17.08.JPG** |

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# 1.0 Introduction

The Oglala Sioux Tribe (OST) Water Pollution Control Program is responsible for developing watershed based plans for water quality restoration, identifying impacts to water quality, implementing the monitoring program and to identify best management practices.

In September 2005 Tetra Tech, Inc. developed an NPS Assessment Report and NPS Management Program Plan for the Environmental Protection Agency (EPA) and the OST. The NPS plan complies with guidelines associated with Section 319 of the Clean Water Act. Matrix Consulting reviewed the NPS Assessment Report and NPS Management Plan in 2010 and analyzed water quality data for the Wounded Knee and Porcupine subwatersheds for 2005-2009.

The Oglala Lakota College (OLC) Science Technology Engineering and Mathematics (STEM) Department reviewed the Matrix Consulting report and analyzed water quality for 2008-2011 and macroinvertebrate data for 1993-2011 as a service-learning project. The goal of our report is to provide guidance to the OST Water Pollution Control Program on stream health on the Pine Ridge Reservation (Figure 1). The specific objectives of the report are: 1) analyze water quality data collected by the Oglala Sioux Tribe (OST) Water Quality Program from 2008-2011, 2) integrate macroinvertebrate sampling data collected by the OST from 1993-2008 and by the OST and OLC STEM Department 2010 – 2011, 3) refine recommendations for future monitoring and implementation of best management practices (BMPs).

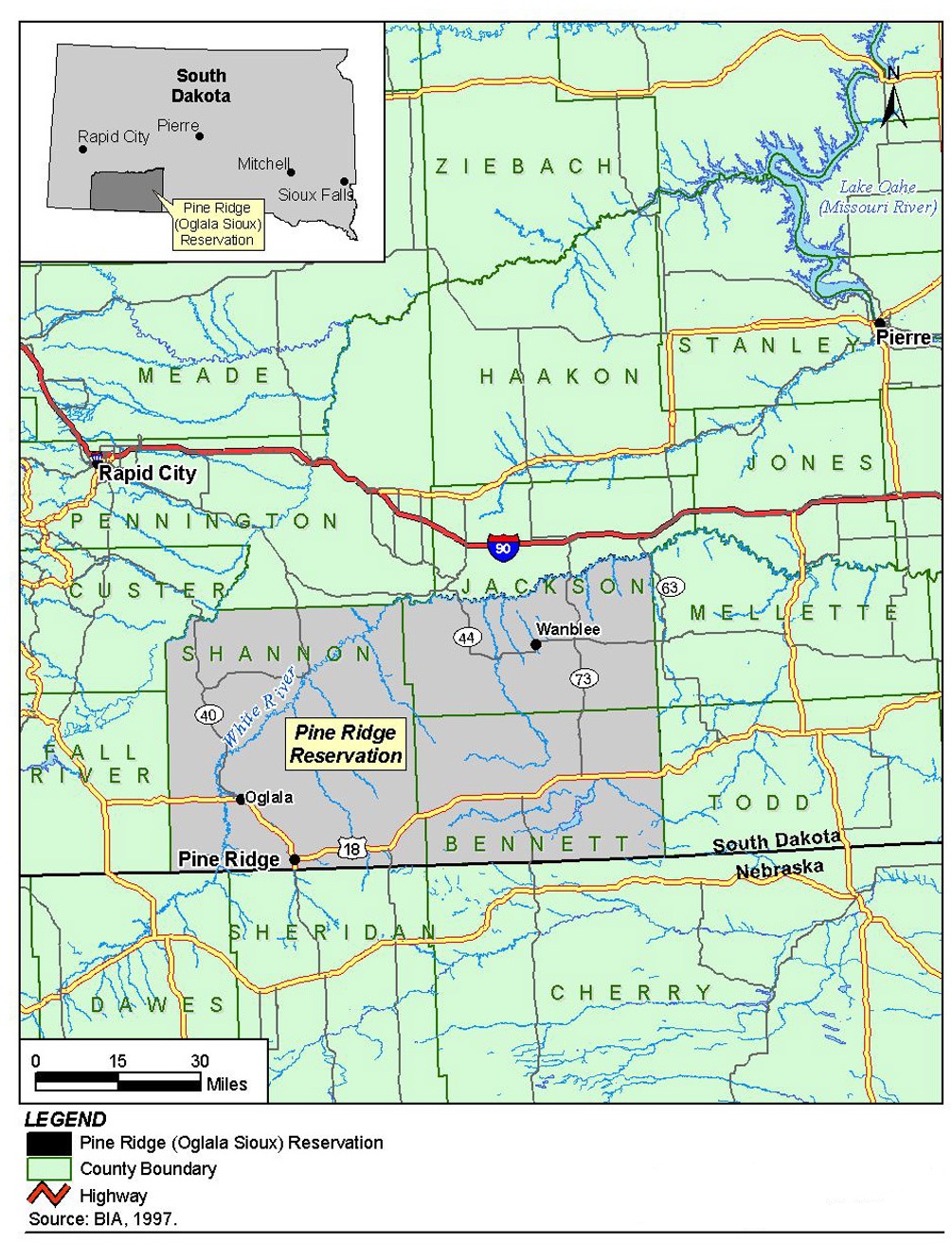


Figure : Map of Pine Ridge Indian Reservation (BIA 1997)

## 1.1 Watershed descriptions

The White River Basin is the most southern of five major drainages in South Dakota that enter the Missouri River from the west (Matrix 2010). The watershed divide with the Cheyenne River is along the northwest corner of the Pine Ridge Reservation (PRR). The upper White River Basin extends south to the southern border of the PRR. Watersheds were subdivided into the following sub watersheds for the NPS Management Program Plan (Figure 2):

* Cheyenne River Tributaries- The Cheyenne River drains the northwestern corner of the reservation with the Cheyenne River itself forming 17.2 miles of the reservation boundary. The Cheyenne River drains to the Missouri River; the confluence is northeast of the reservation boundary (Tetra tech 2005).
* Upper White River- Upper White River watershed drains the southwestern corner of the reservation including the towns of Oglala and Pine Ridge falls. The White River enters the reservation from the south and flows north through the Upper White River watershed. The White River’s confluence with White Clay Creek, which is northwest of the town of Oglala, is the boundary of the Upper White River watershed and the White River/Wounded Knee Creek watershed (Tetra tech 2005).
* White River/Wounded Knee Creek- The White River/Wounded Knee Creek subwatershed drains the western portion of the reservation from the Upper White River subwatershed to the south to the Cheyenne River watershed to the northwest. The southeastern portion of the White River/Wounded Knee Creek subwatershed extends south to the southern border of the reservation. The White River flows into the White River/Wounded Knee Creek subwatershed from the Upper White River watershed and flows approximately 67.3 miles north and northeast to the boundary with the White River/Medicine Root Creek watershed near the White River confluence with Porcupine Creek (Tetra tech 2005).
* White River/Medicine Root Creek-The White River/Medicine Root Creek subwatershed drains the reservation from the northwestern corner of Bennett County to the northern border of the reservation and west to the boundary of the Cheyenne River watershed. The White River flows into the White River/Medicine Root Creek subwatershed from the White River/Wounded Knee Creek subwatershed and flows approximately 37.1 miles northeast to the boundary with the White River/Bear-in-the-Lodge Creek subwatershed near the White River’s confluence with Red Water Creek (Tetra tech 2005).
* White River/Bear-in-the-Lodge Creek- The White River/Bear-in-the Lodge Creek subwatershed encompasses approximately 734 square miles of the reservation from north of Highway 18 in Bennett County north to the White River at the northern border of the reservation. The White River flows into the White River/Bear-in-the-Lodge Creek subwatershed from the White River/Medicine Root Creek subwatershed and flows approximately 44.2 miles east to the boundary with the White River/Pass Creek subwatershed near the White River confluence with Eagle Nest Creek.
* White River/Pass Creek- The White River/Pass Creek subwatershed encompasses approximately 746 square miles of the reservation from just north of Highway 18 in Bennett County north to the White River at the northern border of the reservation and east to the eastern border of the reservation (see Figure 2). The White River flows into the White River/Pass Creek subwatershed from the White River/Bear-in-the-Lodge Creek subwatershed and flows approximately 40.5 miles along the northern border of the reservation east to the reservation boundary.

White River/Little White River- The Little White River watershed encompasses approximately 604 square miles of the reservation from the southern boundaries of the White River/Medicine Root Creek/Bear-in-the-Lodge Creek/Pass Creek subwatersheds south to the northern boundary of the Niobrara River Tributaries watershed and from the southeastern boundary of the White River/Wounded Knee Creek subwatershed east to the eastern reservation border. The Little White River flows through the watershed from west to east. The river’s headwaters are in Shannon County, near U.S. Highway 18. The Little White River flows off the reservation near the southeastern corner. The Little White River flows to the White River; the rivers’ confluence is east of the reservation in Mellette County, just downstream of U.S. Highway 83.

The Little White River watershed, within reservation boundaries, includes LaCreek Migratory Waterfowl Refuge, tribal and non-tribal ranching activities, dryland and irrigated agriculture, and the communities of Martin (population approximately 2,500), Batesland, Tuthill (approximately

10 to 15 houses), and Swett. The communities of Martin, Tuthill, Batesland, and Swett are non-

Indian and do not fall under tribal jurisdiction; however, there are tribal housing developments

near Batesland and Swett. The water table tends to be very shallow in this watershed.

### 1.1.1 Communities and Economy

The major economic land uses in the White River watershed are agriculture-related with rangeland and cropland dominating in the Little White River subwatershed and rangeland and hay farming dominating all other subwatersheds. Community wastewater collection systems with treatment lagoons are used to treat municipal waste in PRR communities (Tetra Tech, Inc. 2005, Matrix 2011).

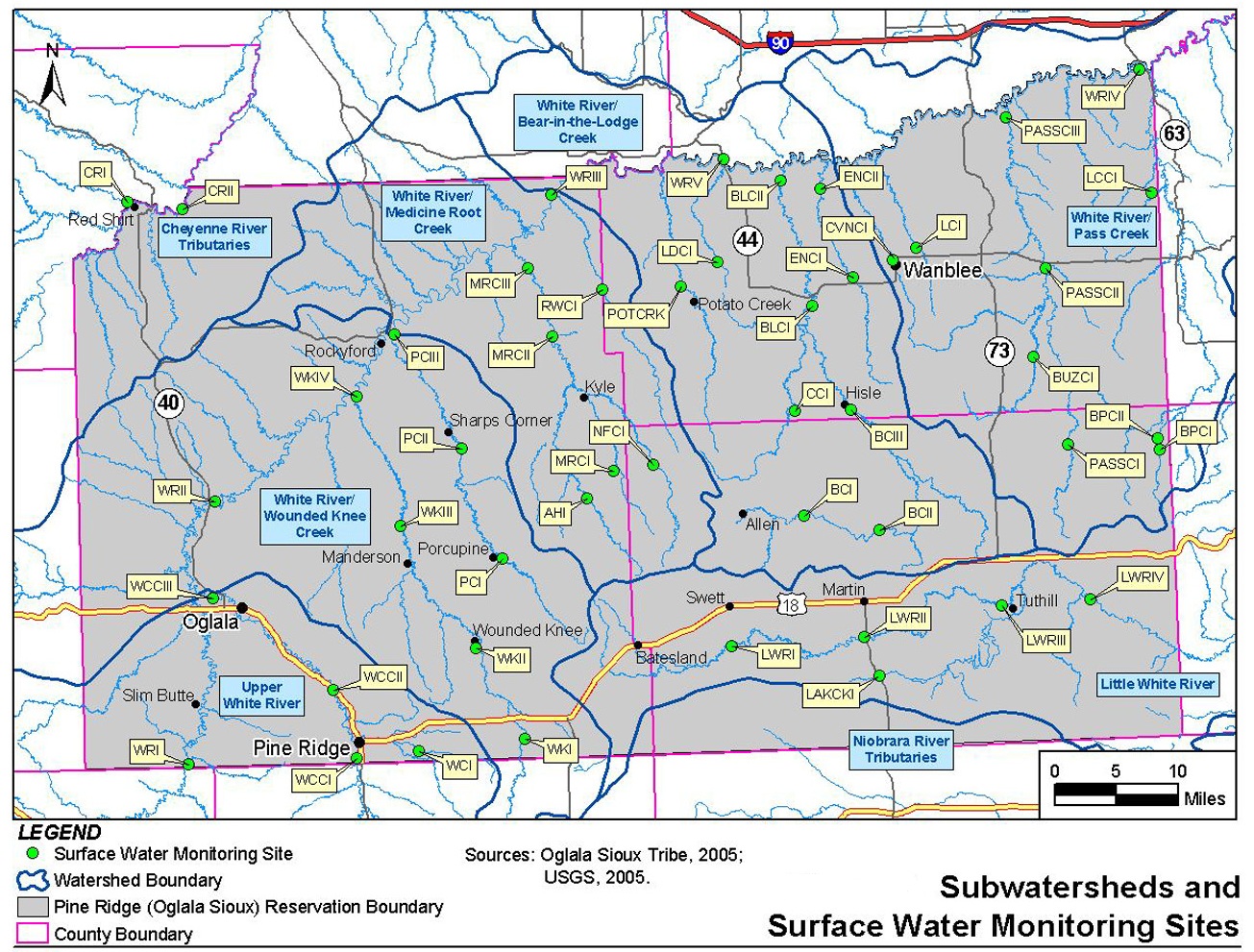


Figure : Subwatersheds and Surface Water Monitoring Sites on the Pine Ridge Reservation

The Upper White River subwatershed, which extends within reservation boundaries from the southern border of the Pine Ridge Reservation to above the confluence with Wounded Knee Creek, includes tribal and nontribal ranching activities and the communities of Oglala (population approximately 2,000) and Pine Ridge (population approximately 4,000). Both Oglala and Pine Ridge are served by community wastewater collection systems; there at least four treatment lagoons between these two communities. The Prairie Wind Casino, near the town of Oglala, is also served by a sewage collection and treatment lagoon system (Tetra tech 2005, Matrix 2011)

The White River/Wounded Knee Creek subwatershed, within reservation boundaries, includes southern portions of the Badlands, tribal and non-tribal ranching activities, hay farming, and the communities of Rockyford, Sharps Corner (population approximately 150), Porcupine (population approximately 1,000), Manderson (population approximately 1,000), and Wounded Knee (population approximately 800). All of these communities are served by community wastewater collection systems with treatment lagoons (Tetra tech 2005, Matrix 2011).

The White River/Medicine Root Creek subwatershed, within reservation boundaries, includes portions of Badlands National Park, including portions of the Badlands Bombing Range, tribal and non-tribal ranching activities, and the community of Kyle (population approximately 2,000). Kyle is one of the fastest-growing communities on the reservation (Tetra tech 2005). Kyle is served by a community wastewater collection system with treatment lagoons (Matrix 2011). An infiltration gallery for the Mni Wiconi Drinking Water project is located along the American Horse Creek alluvium.

The White River/Bear-in-the-Lodge Creek subwatershed, within reservation boundaries, includes portions of Badlands National Park and portions of the Badlands Bombing Range, tribal and non-tribal ranching activities, and the communities of Potato Creek, Allen, and Hisle (population approximately 20) (Matrix 2011).

The Cheyenne River watershed, within reservation boundaries, includes western portions of Badlands National Park, including the Badlands Bombing Range, tribal and non-tribal ranching activities, irrigated crop production, and the community of Red Shirt Village (population approximately 150) (Tetra tech 2005, Matrix 2011).

The White River/Pass Creek subwatershed, within reservation boundaries, includes portions of Badlands National Park, tribal and non-tribal ranching activities, irrigated agriculture including alfalfa and corn production, and the communities of Wanblee (population approximately 1,500), Long Valley (population approximately 100), and Vetal (population approximately 50). The communities of Long Valley and Vetal are non-Indian and do not fall under tribal jurisdiction (Matrix 2011).

### 1.1.2 Climate and Geology

The climate is typical of the Northern Great Plains with a median temperature of 50F in January and 730F in July (SDSU climate website, accessed March 6, 2013). The average annual precipitation between the years 1971 and 2000 at the Manderson 3 NE station is 19.3 inches with January as the driest month (0.39 inches) and June as the wettest month (3.18 inches). The Manderson station is slightly drier than the rest of the south-central region of South Dakota, which has an average precipitation of 21.6 +/-4.5 inches (standard deviation) (SDSU climate website, accessed March 6, 2013). The Keya Paha Tablelands receives a mean annual precipitation of 16-20 inches while the Pine Ridge Escarpment receives 16-17 inches (Bryce et al., 1998). The Great Plains has an historical record of major drought ([Meyer et al., 1999](#_ENREF_20)). The 2012 drought resulted in zero flow conditions in the White River and a majority of White River tributary streams (Tinant personal observation).

The amount and frequency of hydrological exchange between the floodplain, groundwater and the stream depends on geology and alluvial composition.Upper White River tributaries begin in central Nebraska as springs. Middle White River tributaries begin in Arikaree Group sandstones and siltstones, and then flow across White River Group volcaniclastic claystones, before draining into the White River (Bryce et al. 1998, Heakin 1999). Sandier units of the Arikaree group form water table aquifers that sustain base flow in the upper reaches of White River tributaries (Heaken 1999). The hydrologic regime shifts from a mixed flow regime to an event-dominated regime as streams cross the Arikaree Group – White River Group contact as infiltration rates decrease and the volume of overland flow increases (Foreman 2006). Infiltration, percolation and ground water flow dominates Sandhills ecoregion hydrology in the Little White River watershed (Figure 3). Days of accrual which is shown on the figure refers to the average number of days between spates greater than 3-times the median flow rate.



Figure : Flow Duration Curves for the White River and Little White River Watersheds

### 1.1.3 Monitoring Sites

The Oglala Sioux Tribe (OST) currently maintains 38 water-quality monitoring stations. The Upper White River subwatershed includes three monitoring stations on White Clay Creek (WCC1 – WCC3), a station on Wolf Creek (WOL1), and a station on the White River (WHR1). The White River/Wounded Knee Creek subwatershed includes four stations on Wounded Knee Creek (WOK1 –WOK4), three stations on Porcupine Creek (POR1 – POR3) and a station on the White River (WHR2). The White River/Medicine Root Creek subwatershed includes three stations on Medicine Root Creek (MER1, MER3, MER4), a station on No Flesh Creek (NFL1), a station on American Horse Creek (AMH1), and a station on Red Water Creek (RED1). The White River/Bear-in-the-Lodge Creek subwatershed includes stations on the Bear Creek and Bear in the Lodge Creek complex (BEA1 – BEA3, BLC1, BLC2), a station on Potato Creek (POT1), a station on Lost Dog Creek (LDC1), a station on Corn Creek (COR1), two stations on Eagle Nest Creek (EAN1, EAN2) and a station on the White River (WHR5). The White River/Pass Creek subwatershed contains a station on Corn Creek (COR1), a station on Craven Creek (CRA1), a station on Long Creek (LON1), a station on Buzzard Creek (BUZ1), three stations on Pass Creek (PAS1 – PAS3), and a station on the White River (WHR4). The Cheyenne River watershed contains two stations on the Cheyenne River (CHR1 and CHR2) (Tetra tech 2005, Matrix 2011).

### 1.1.4 Beneficial Uses and Water Quality Standards

“The purpose of water quality standards is to define the water quality goals of a water body, or portion thereof, by designating the use or uses and identifying criteria necessary to protect the uses. Each state adopts water quality standards to protect public health or welfare, enhance the quality of water and serve the purposes of the Clean Water Act, established by Congress in 1972” (The U.S. Government's Printing Office 2011). Water Quality Standards consist of Beneficial Uses, Water Quality Criteria, and Anti-degradation Clauses” (Matrix 2011). The Tetra-tech (2005) and Matrix (2011) reports describe OST and South Dakota administrative rules for beneficial uses, water quality criteria and anti-degradation clauses in effect for the Pine Ridge Reservation.

## 1.2 Goals and Objectives

The overall goals and objectives of the 106 Water Quality Program remain consistent with the NPS Management Program Plan (Tetra Tech 2005, Matrix 2011), which include:

* Restore and maintain the chemical, physical and biological integrity of the waters within the jurisdiction of OST to preserve and enhance the environment within the jurisdiction of the Tribe.
* Conserve waters within the jurisdiction of the Tribe by protecting, maintaining and improving the quality of water for public water supplies, wildlife, fish and aquatic life, recreation, agriculture, industry, cultural and other beneficial uses.
* Identify the BMPs and measures to be undertaken to reduce pollutant loading from each category and subcategory of nonpoint source pollution in each watershed, taking into account the impact of best management practices on groundwater quality.
* Identify programs to achieve BMPs.
* Develop a schedule, with milestones, for the implementation of BMPs in each water within the jurisdiction of the Tribe
* Identify sources of federal funding and other funding available to assist in controlling NPS pollution.
* Describe the involvement in NPS pollution control of local public and private agencies and organizations that have experience in controlling of NPS pollution

This report focuses on the following objectives:

* Report and evaluate water quality data collected from 2008-2011 and incorporate previous assessment results;
* Evaluate and integrate macroinvertebrate sampling data collected between 1993-2011 with water quality results
* Make recommendations on:
  + Current monitoring program
  + Identifying specific BMPs for implementation

# 2.0 Monitoring Strategy and Previous Results

The NPS Management Program Plan (Tetra Tech 2005b) describes the process the OST used for the period 2005-2009 to address NPS pollution on the Pine Ridge Reservation as identified in the NPS Assessment Report. Specific management activities and long-term goals identified in the NPS Management Plan include:

* Conducting the administrative activities, assessments, monitoring, and education activities to support and maintain the practices and programs that will be implemented to address NPS pollution
* Eliminating grazing-related nonpoint source pollutant contributions to surface waters
* Implementing appropriate BMPs to minimize NPS contributions of herbicides and other agricultural chemicals
* Eliminating illegal dumping and minimizing NPS pollutant contributions from the improper disposal of automobiles, appliances, and hazardous waste
* Rehabilitating failing septic systems and relocating poorly sited systems
* Integrating storm water and NPS pollution concerns into road planning and maintenance on the reservation
* Integrating storm water and NPS pollution concerns into construction planning and building activities on the reservation
* Minimizing the NPS pollutant contributions in urban runoff from towns and villages

The OST monitoring strategy is divided into two phases: a) monitoring between 1992-2005 and b) monitoring between 2005-2013 (the latest available data). Phase I activities focused on site identification, physical, chemical, and macroinvertebrate data collection. Monitoring of chemical parameters focused on nutrients, common inorganics and metals including heavy metals (Matrix 2011). Monitoring of physical parameters focused on conductivity, pH, dissolved oxygen, turbidity and temperature (Matrix 2011).

Tetra Tech (2005) analyzed historical water quality data pre-2005 and found widespread exceedences in several water quality parameters.

* Water quality exceedances for Cheyenne River stations occurring in greater than 10% of cases when less than 10 samples were collected (water bodies designated “Threatened”) include: pH (upper limit), dissolved oxygen, turbidity, selenium. Water quality exceedances for Cheyenne River stations occurring in greater than 10% of cases when greater than 10 samples (water bodies designated “Impaired”) include: arsenic, cadmium, iron, manganese, mercury, and total phosphorus.
* Water quality exceedances for Upper White River sub watersheds occurring in greater than 10% of cases when less than 10 samples were collected (water bodies designated “Threatened”) include: turbidity, pH (lower limit). Water quality exceedances for Upper White River sub watershed stations occurring in greater than 10% of cases when greater than 10 samples (water bodies designated “Impaired”) include: pH (upper limit), dissolved oxygen, arsenic, cadmium, iron, manganese, mercury, and total phosphorus.
* Water quality exceedances for White River/Wounded Knee Creek stations occurring in less than 10% of cases when less than 10 samples were collected (water bodies designated “Threatened”) include: temperature, pH (upper limit), dissolved oxygen, turbidity, selenium. Water quality exceedances for White River/Wounded Knee Creek stations occurring in greater than 10% of cases when greater than 10 samples (water bodies designated “Impaired”) include: arsenic, cadmium, iron, manganese, mercury, and total phosphorus.
* Water quality exceedances for White River/Medicine Root Creek stations occurring in greater than 10% of cases when less than 10 samples were collected (water bodies designated “Threatened”) include: dissolved oxygen, turbidity, and cadmium. Water quality exceedances for White River/Medicine Root Creek stations occurring in greater than 10% of cases when greater than 10 samples (water bodies designated “Impaired”) include: temperature, pH (upper limit), arsenic, cadmium, iron, manganese, mercury, and total phosphorus.
* Water quality exceedances for White River/Bear-in-the-Lodge Creek stations occurring in greater than 10% of cases when less than 10 samples were collected (water bodies designated “Threatened”) include: turbidity. Water quality exceedances for White River/ Bear-in-the-Lodge Creek stations occurring in greater than 10% of cases when greater than 10 samples (water bodies designated “Impaired”) include: temperature, pH (upper limit), dissolved oxygen, arsenic, cadmium, iron, manganese, mercury, and total phosphorus.
* Water quality exceedances for White River/Pass Creek stations occurring in greater than 10% of cases when less than 10 samples were collected (water bodies designated “Threatened”) include: temperature, turbidity, cadmium, selenium and zinc. Water quality exceedances for White River/Pass Creek stations occurring in greater than 10% of cases when greater than 10 samples (water bodies designated “Impaired”) include: pH (upper limit), dissolved oxygen, arsenic, iron, lead, manganese, mercury, and total phosphorus.
* Water quality exceedances for White River/Little White River stations occurring in greater than 10% of cases when less than 10 samples were collected (water bodies designated “Threatened”) include: pH (upper limit), dissolved oxygen, turbidity, cadmium, selenium, and silver. Water quality exceedances for White River/Little White River stations occurring in greater than 10% of cases when greater than 10 samples (water bodies designated “Impaired”) include: arsenic, iron, lead, manganese, mercury, zinc and total phosphorus.

Tetra Tech (2005a) concluded that many of the metals exceeding water quality standards in Pine Ridge reservation surface waters could originate from natural sources and proscribed best management practices aimed at reducing total suspended solids and nutrient loading for the following land uses:

**Agricultural runoff** - EPA determined in March 2004 there were approximately 20 cattle ranching operations across the reservation, with agricultural activities include cattle grazing, crop production, and winter feeding and calving areas (Matrix 2011). Crop agriculture, which consists primarily of dryland and irrigated faming for spring and winter wheat, is conducted primarily in the southeastern portion of the reservation.

**Septic Systems** - Approximately 50 percent of households on tribal land are served by individual septic systems (Tetra tech 2005).

**Storm water Runoff** - Most towns and villages across the reservation lack storm water collection systems. Pine Ridge and Martin have storm water collection systems, however, the Tribe is unaware of any BMPS being implemented to minimize pollutant loads (Tetra tech 2005, Matrix 2011).

**Illegal dumping** - Improper disposal of domestic solid waste, household appliances and automobiles continue to contribute pollutants to surface waters (Tetra tech 2005, Matrix 2011).

**Roads** - Many roads across the reservation are constructed of dirt and gravel, contributing significant sediment loads to surface waters (Tetra tech 2005, Matrix 2011).

**Construction -** Silt fences and other BMPS do not appear to be used for smaller construction projects.BMPs could be used to minimize sediment loads from construction projects into surface waters (Tetra tech 2005, Matrix 2011).

OST phase II monitoring activities included a reduction in sampling stations from 41 stations to 38 stations and a shift in parameters from metals and toxins to bacteria, nutrients, and inorganics (Matrix 2011). The physical parameters sampled include: pH, temperature, conductivity, dissolved oxygen, temperature, and turbidity; the conventional pollutants include: biochemical oxygen demand (BOD), total suspended solids (TSS), fecal coliform bacteria, and E-coli; and non-conventional pollutants include: ammonia-nitrogen, nitrate-nitrogen, hardness, and total phosphorus. Water quality samples are collected during three months with the highest annual precipitation, April, May and June, and four months with low precipitation, July, August, September, and October for water quality parameters reflecting parameters of concern based on criteria for beneficial uses. In 2011, in addition to parameters of concern, Soluble Reactive Phosphorus (SRP) and additional anions and cations were collected in order to better understand phosphorus sources and to develop a more complete understanding of the distribution of common inorganic ions in order to evaluate historical metals data (Table 8). The results of the additional sampling are given in sections 4.2 and 4.3 of this report.

Matrix Consulting (2011) analyzed physical and chemical data collected between 2005-2009 for the White River/Wounded Knee Creek watershed. Water quality exceedances for Wounded Knee Creek stations occurring in less than 10% of cases when less than 10 samples were collected (water bodies designated “Threatened”) include: Fecal coliform, E. coli, and TSS. Fecal coliform exceed water quality criteria at Wounded Knee Creek Station 1 (WOK1) with a 25% exceedances (1 of 4 samples), Wounded Knee Creek Station 3 (WOK3) with a 33% exceedance (1 of 3 samples), and Wounded Knee Creek Station 4 (WOK4) with a 50% exceedance (2 of 4 samples). Escherichia coli (E. coli) exceed water quality criteria at Wounded Knee Creek 2 (WOK2) with a 25% exceedance (1 of 4 samples), WOK3 with a 60% exceedance (3 of 5 samples), and WOK4 with a 100% exceedance (4 of 4 samples). Total suspended solids (TSS) exceed water quality criteria at WOK4 with a 25% exceedance (1 of 4 samples). No exceedances were found for Porcupine Creek monitoring stations during the sampling period.

Macroinvertebrate were incorporated into a NPS monitoring on the Pine Ridge Reservation in 1999 (Matrix 2011). Stream health monitoring using benthic macroinvertebrate began in 1993. Based on samples collected between 1993-1996, seven metric scoring criteria were chosen: Taxa Richness, EPT Index, % EPT, Family Biotic Index, % Dominant, Family, % Dipterans and Non-Insects, and % Collector-Gatherer. To determine the relationship between habitat quality and biological condition, biosurvey and habitat data collected from April to November 1998 for 38 monitoring stations. The study identified biological conditions for the White River/Porcupine Creek watershed ranging from severely impaired (WOK1), to moderately impaired (WOK2, WOK3, POR1), to unimpaired (POR2, POR3) and overall habitat ratings of sub-optimal. The report concluded nutrient enrichment to be the cause of reduced biological integrity (Matrix 2011).

# 3.0 Data Analysis

This section presents the chemical data analysis for streams monitored between 2008-2011. Physical data including pH, conductivity, temperature, and dissolved oxygen was collected as instantaneous measurements between 2008-2011, however these results will be published as part of individual watershed assessment reports beginning in 2014. Water quality is an indicator of the general condition of the watershed and pollutant source types, locations, and behavior (USEPA 2010). The process of conducting data analyses to characterize the watershed and its pollutant sources began with broad assessments evaluating the averages, minimums, and maximums of measured parameters at the monitoring sites (Matrix 2011).

Water quality data alone does not adequately characterize stream health (Shapiro 2008). Reports commissioned in early 2000 to address questions from the US Congress on the condition of US waters found that the US lacked the data necessary to report the current status of its ecological resources, trends in these conditions, and causes of environmental degradation (Heintz 2002, USEPA 2003, Shapiro 2008). The early 2000 reporting resulted in the development and application of standardized protocols focusing on biological indicators for sampling, processing and interpreting core indicators of biological condition and of key stressors (Barbour 1999, Shapiro 2008). Stream health is defined as “a desirable and sustainable ecosystem structure and function, or ecosystem integrity” (Merritt 1986, Karr 1989). Macroinvertebrate taxa are often used as an indicator of overall ecosystem integrity through a multi-metric approach that measure a wide range of gradients from individual health to landscape dynamics (Planfkin 1999). Metrics incorporate taxa richness, dominance of taxa that are sensitive or insensitive to pollution, balance of functional feeding groups (Rosenberg and Resh 1993, Merritt 1986).

## 3.1 Goals and Objectives

Samples collected by the OST Water Pollution Control Program were tested through Energy Labs in Rapid City, SD for chemical properties, outlined in Table 8. Energy Labs recorded samples with concentrations below the reporting limit as “Non-detect”.

Table 1. Chemical Property Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Analyses** | **Parameter** | **Units** | **Reporting Limit** |
| Microbiological | Bacteria, Fecal Coliform | CFU 100 ml | 1 |
| Bacteria, E-Coli Coliform | mpn/100 ml | 1 |
| Physical | Biochemical Oxygen Demand (BOD) | mg/L | 2 |
| Total Suspended Solids (TSS) | mg/L | 10 |
| Cations | Hardness as CaCO3 | mg/L | 1 |
| Calcium | mg/L | 1 |
| Magnesium | mg/L | 1 |
| Sodium | mg/L | 1 |
| Potassium | mg/L | 1 |
| Anions | Chloride | mg/L | 1 |
| Sulfate | mg/L | 1 |
| Nutrients | Phosphorus, Total as P | mg/L | 0.01 |
| Phosphorus, SRP | mg/L | 0.01 |
| Nitrogen, Ammonia as N | mg/L | 0.05 |
| Nitrogen, Nitrate as N | mg/L | 0.05 |

## 3.2 Water Quality Data

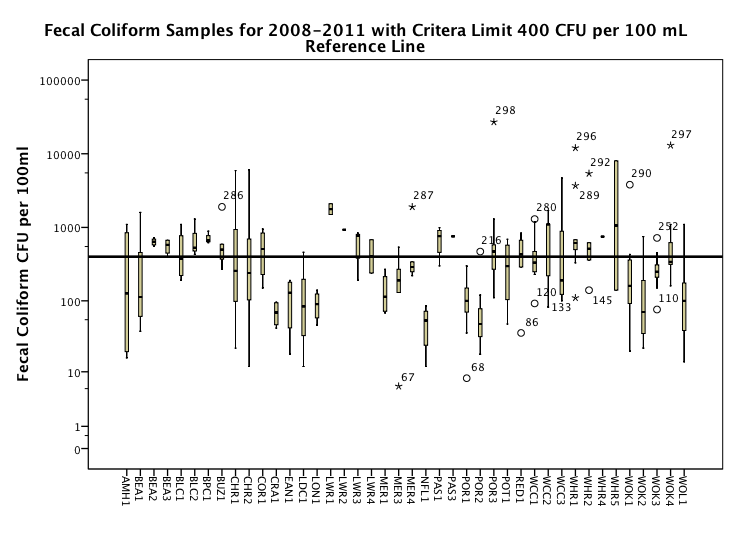


Figure : Fecal Coliform Samples for 2008-2011

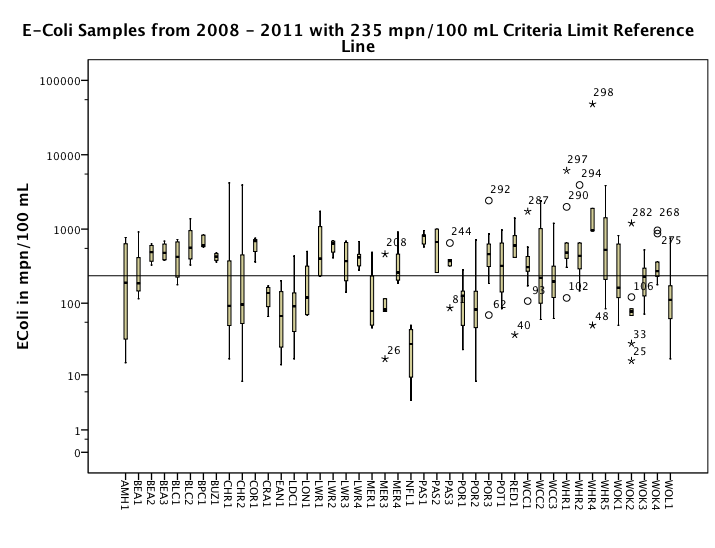


Figure : E-coli Samples for 2008-2011

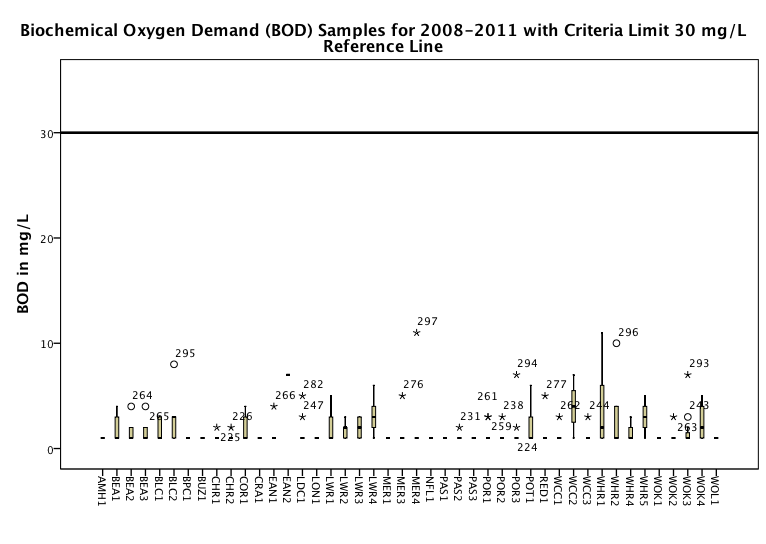


Figure : Biochemical Oxygen Demand Samples for 2008-2011

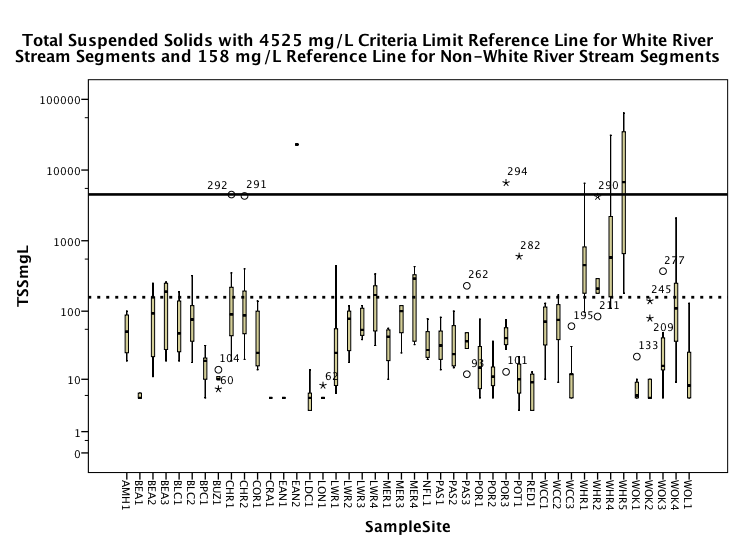


Figure : Total Suspended Samples for 2008-2011

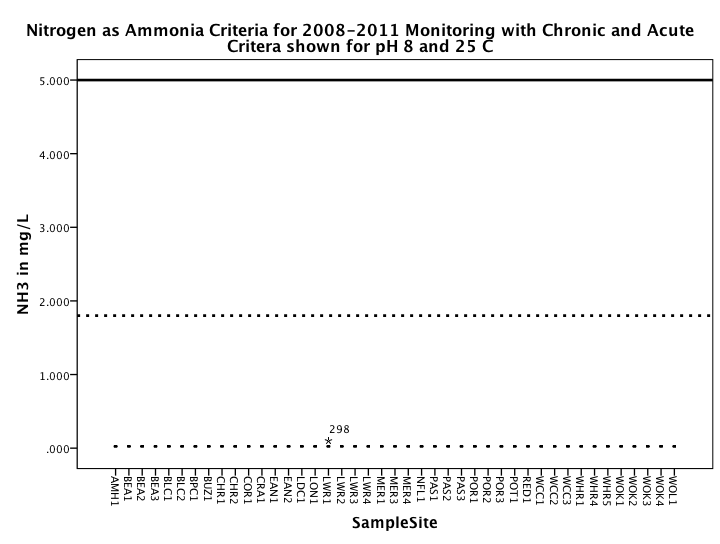


Figure : Nitrogen as Ammonia Samples for 2008-2011

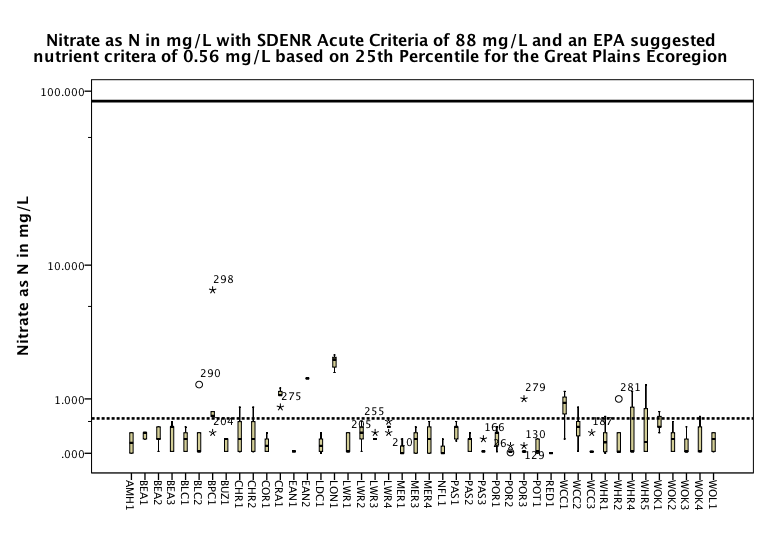


Figure : Nitrogen as Nitrate for 2008-2011 samples

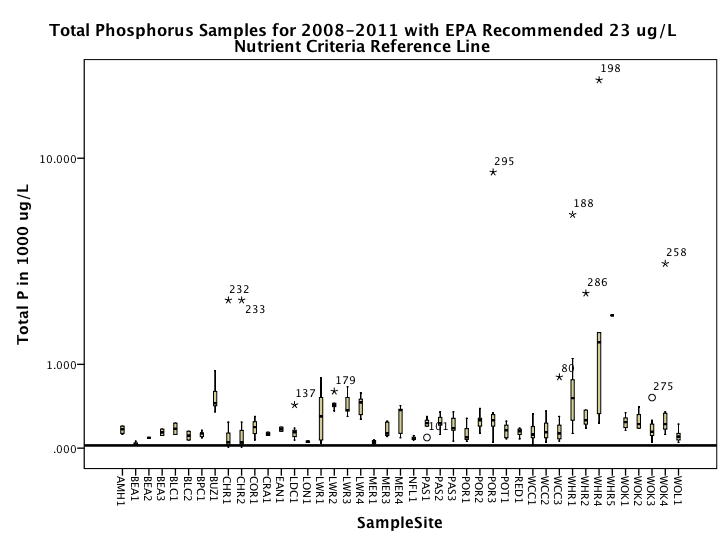


Figure : Total Phosphorus for 2008-2011 Samples

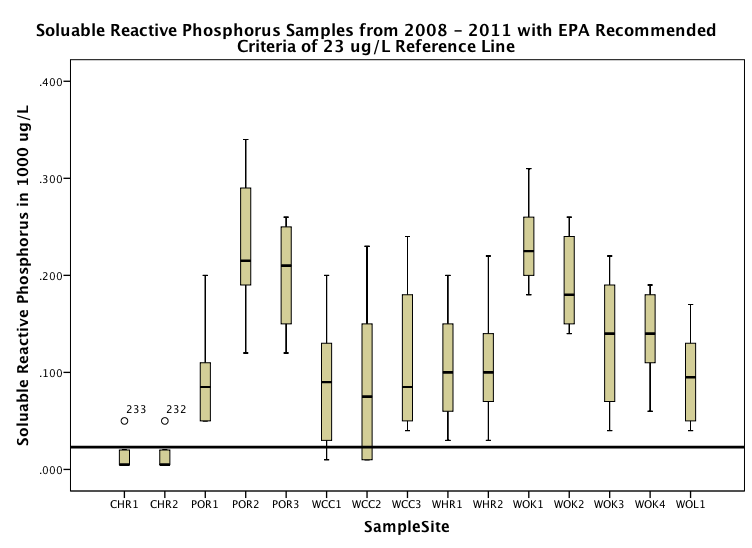


Figure : Soluble Reactive Phosphorus for 2008-2011 Samples











Table 5. White River / Bear-in-the-Lodge Stations

| **Name** | **Site #** | **Parameter** | **Criteria exceeded** | **# of Samples** | **Percent exceedance** |
| --- | --- | --- | --- | --- | --- |
| Bear in the Lodge Creek | BEA1  (2012 -2013) | Fecal Coliform | > 400 CFU/100mL | 3 of 6 | 50% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | 6 of 9 | 66% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | Zero of 5 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | Zero of 5 | 0% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | Zero of 5 | 0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 5  Zero of 5 | 0%  0% |
| Total Phosphorus | > 0.037 mg/L c  > 0.037 mg/L d | 1 of 3  Zero of 3 | 33%  0% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |
| BEA2  (2008) | Fecal Coliform | > 400 CFU/100mL | 4 of 4 | 100% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | 4 of 4 | 100% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | Zero of 5 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | 1 of 5 | 20% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | Zero of 5 | 0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 5  Zero of 5 | 0%  0% |
| Total Phosphorus | > 0.037 mg/L c  > 0.09 mg/L d | 2 of 2  Zero of 2 | 100%  0% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |
| BEA3  (2008) | Fecal Coliform | > 400 CFU/100mL | 3 of 4 | 75% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | 4 of 4 | 100% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | Zero of 5 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | 3 of 5 | 60% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | Zero of 5 | 0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 5  Zero of 5 | 0%  0% |
| Total Phosphorus | > 0.037 mg/L c  > 0.09 mg/L d | 2 of 2  2 of 2 | 100%  100% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |
| Bear in the Lodge | BLC1  (2008) | Fecal Coliform | > 400 CFU/100mL | 2 of 4 | 50% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | 2 of 4 | 50% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | Zero of 5 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | 1 of 5 | 20% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | Zero of 5 | 0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 5  Zero of 5 | 0%  0% |
| Total Phosphorus | > 0.037 mg/L c  > 0.037 mg/L d | 2 of 2  2 of 2 | 100%  100% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |
| BLC2  (2008) | Fecal Coliform | > 400 CFU/100mL | 3 of 3 | 100% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | 5 of 5 | 100% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | Zero of 5 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | 1 of 5 | 20% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | Zero of 5 | 0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 5  1 of 5 | 0%  20% |
| Total Phosphorus | > 0.037 mg/L c  > 0.037 mg/L d | 2 of 2  1 of 2 | 100%  50% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |
| Eagle Nest Creek | EAN1  (2008) | Fecal Coliform | > 400 CFU/100mL | Zero of 4 | 0% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | Zero of 4 | 0% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | Zero of 5 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | Zero of 5 | 0% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | Zero of 5 | 0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 5  Zero of 5 | 0%  0% |
| Total Phosphorus | > 0.037 mg/L c  > 0.09 mg/L d | 2 of 2  2 of 2 | 100%  100% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |
| EAN2  (2008) | Fecal Coliform | > 400 CFU/100mL | 1 of 1 | 100% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | 1 of 1 | 100% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | Zero of 1 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | 1 of 1 | 100% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | 0 of 1 | 0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 1  1 of 1 | 0%  100% |
| Total Phosphorus | > 0.037 mg/L c  > 0.09 mg/L d | No Data | No Data |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |
| Other Tributaries | Lost Dog Creek  (2008)  (2010) | Fecal Coliform | > 400 CFU/100mL | Zero of 3  1 of 4 | 0%  25% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | 1 of 4  1 of 4 | 25%  25% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | Zero of 5  Zero of 5 | 0%  0% |
| Total Suspended Solids (TSS) | > 158 mg/L | 1 of 5  0 of 5 | 20%  0% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | Zero of 1  Zero of 5 | 0%  0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 5  Zero of 4  Zero of 5  Zero of 4 | 0%  0%  0%  0% |
| Total Phosphorus | > 0.037 mg/L c  >0.09 mg/L d | 4 of 4  5 of 5  3 of 4  4 of 5 | 100%  100%  75%  80% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |
| POT1  (2008)  (2010) | Fecal Coliform | > 400 CFU/100mL | 1 of 3  2 of 5 | 33%  40% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | 3 of 5  3 of 5 | 60%  60% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | Zero of 5  Zero of 5 | 0%  0% |
| Total Suspended Solids (TSS) | > 158 mg/L | 1 of 5  0 of 5 | 20%  0% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | Zero of 1  Zero of 5 | 0%  0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 5  Zero of 5  Zero of 5  Zero of 5 | 0%  0%  0%  0% |
| Total Phosphorus | > 0.037 mg/L c  >0.09 mg/L d | 3 of 3  5 of 5  1 of 3  5 of 5 | 100%  100%  33%  100% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |
| COR1  (2008) | Fecal Coliform | > 400 CFU/100mL | 2 of 4 | 50% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | 4 of 4 | 100% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | Zero of 5 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | Zero of 5 | 0% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | 0 of 1 | 0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 5  Zero of 5 | 0%  0% |
| Total Phosphorus | > 0.037 mg/L c  >0.09 mg/L d | 3 of 3  2 of 3 | 100%  66% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |
| White River | WHR5  (2008) | Fecal Coliform | > 400 CFU/100mL | 3 of 4 | 75% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | 1 of 2 | 50% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | Zero of 4 | 0% |
| Total Suspended Solids (TSS) | > 4525 mg/L | 2 of 4 | 50% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | Zero of 4 | 0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 4  1 of 4 | 0%  25% |
| Total Phosphorus | > 0.037 mg/L c  >0.09 mg/L d | 1 of 1  1 of 1 | 100%  100% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No data | No data |

Table 6. White River / Pass Creek Stations

| **Waterbody** | **Site #** | **Parameter** | **Criteria exceeded** | **# of Samples** | **Percent exceedance** |
| --- | --- | --- | --- | --- | --- |
| Pass Creek | PAS1  (2009) | Fecal Coliform | > 400 CFU/100mL | 4 of 5 | 80% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | 5 of 5 | 100% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | Zero of 5 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | Zero of 5 | 0% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | Zero of 5 | 0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 5  Zero of 5 | 0%  0% |
| Total Phosphorus | > 0.037 mg/L c  > 0.09 mg/L d | 5 of 5  5 of 5 | 100%  100% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |
| PAS2  (2009) | Fecal Coliform | > 400 CFU/100mL | 3 of 5 | 60% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | 5 of 5 | 100% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | Zero of 5 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | Zero of 5 | 0% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | Zero of 5 | 0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 5  Zero of 5 | 0%  0% |
| Total Phosphorus | > 0.037 mg/L c  .0.09 mg/L d | 5 of 5  5 of 5 | 100%  100% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |
| PAS3  (2009) | Fecal Coliform | > 400 CFU/100mL | 1 of 5 | 20% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | 3 of 5 | 60% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | 0 of 5 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | 1 of 5 | 20% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | Zero of 5 | 0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 5  Zero of 5 | 0%  0% |
| Total Phosphorus | > 0.037 mg/L c  >0.09 mg/L d | 5 of 5  4 of 5 | 100%  80% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |
| Other Tributaries | CRA1  (2008) | Fecal Coliform | > 400 CFU/100mL | Zero of 5 | 0% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | Zero of 5 | 0% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | Zero of 5 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | Zero of 5 | 0% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | Zero of 5 | 0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 5  5 of 5 | 0%  100% |
| Total Phosphorus | > 0.037 mg/L c  >0.09 mg/L d | 2 of 2  2 of 2 | 100%  100% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |
| BUZ1  (2009) | Fecal Coliform | > 400 CFU/100mL | 3 of 4 | 75% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | 4 of 4 | 100% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | Zero of 5 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | Zero of 4 | 0% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | Zero of 4 | 0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 4  Zero of 4 | 0%  0% |
| Total Phosphorus | > 0.037 mg/L c  >0.09 mg/L d | 5 of 5  5 of 5 | 100%  100% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |
| BLP1  (2009) | Fecal Coliform | > 400 CFU/100mL | 5 of 5 | 100% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | 5 of 5 | 100% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | Zero of 5 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | Zero of 5 | 0% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | Zero of 4 | 0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 5  4 of 5 | 0%  100% |
| Total Phosphorus | > 0.037 mg/L c  >0.09 mg/L d | 5 of 5  4 of 5 | 100%  80% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No data | No data |
|  | LON1  (2008) | Fecal Coliform | > 400 CFU/100mL | Zero of 4 | 0% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | 1 of 4 | 25% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | Zero of 5 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | Zero of 5 | 0% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | Zero of 5 | 0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 5  5 of 5 | 0%  100% |
| Total Phosphorus | > 0.037 mg/L c >0.09 mg/L d | 2 of 2  Zero of 2 | 100%  0% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No data | No data |
| White River | WHR4  (2009) | Fecal Coliform | > 400 CFU/100mL | 4 of 5 | 80% |
| Escherichia coli (E-Coli) | > 235 mpn/100 ml | 4 of 5 | 80% |
| Biochemical Oxygen Demand (BOD) | 30 mg/L | Zero of 5 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | 4 of 5 | 80% |
| Total Ammonia (NH3) as N | > 1.8 mg/L a | Zero of 5 | 0% |
| Nitrate (NO3) as N | >88 mg/L  >0.56 mg/L b | Zero of 5  2 of 5 | 0%  40% |
| Total Phosphorus | > 0.037 mg/L c  > 0.09 mg/L d | 5 of 5  5 of 5 | 100%  100% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No data | No data |

Table 7. White River / Little White River Stations

| **Waterbody** | **Site #** | **Parameter** | **Criteria exceeded** | **# of Samples** | **Percent exceedance** |
| --- | --- | --- | --- | --- | --- |
| Little White River | LWR1  (2009) | Fecal Coliform | > 400 CFU / 100 ml | 3 of 5 | 60% |
| Escherichia coli (E-Coli) | > 235 mpn / 100 ml | 4 of 5 | 80% |
| Biochemical Oxygen Demand (BOD) | > 30 mg/L | Zero of 5 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | 1 of 5 | 20% |
| Total Ammonia (NH3) as N | >1.8 mg/L a | Zero of 5 | 0% |
| Nitrate (NO3) as N | 88 mg/L  >0.56 mg/L b | Zero of 5  Zero of 5 | 0%  0% |
| Total Phosphorus | > 0.037 mg/L c  > 0.09 mg/L d | 5 of 5  3 of 5 | 100%  60% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |
| LWR2  (2009) | Fecal Coliform | > 400 CFU / 100 ml | 3 of 5 | 60% |
| Escherichia coli (E-Coli) | > 235 mpn / 100 ml | 5 of 5 | 100% |
| Biochemical Oxygen Demand (BOD) | > 30 mg/L | Zero of 5 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | Zero of 5 | 0% |
| Total Ammonia (NH3) as N | >1.8 mg/L a | Zero of 5 | 0% |
| Nitrate (NO3) as N | 88 mg/L  >0.56 mg/L b | Zero of 5  Zero of 5 | 0%  0% |
| Total Phosphorus | > 0.037 mg/L c  > 0.09 mg/L d | 5 of 5  5 of 5 | 100%  100% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |
| LWR3  (2009) | Fecal Coliform | > 400 CFU / 100 ml | 2 of 5 | 40% |
| Escherichia coli (E-Coli) | > 235 mpn / 100 ml | 3 of 5 | 60% |
| Biochemical Oxygen Demand (BOD) | > 30 mg/L | Zero of 5 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | Zero of 5 | 0% |
| Total Ammonia (NH3) as N | >1.8 mg/L a | Zero of 5 | 0% |
| Nitrate (NO3) as N | 88 mg/L  >0.56 mg/L b | Zero of 5  Zero of 5 | 0%  0% |
| Total Phosphorus | > 0.037 mg/L c  > 0.09 mg/L d | 5 of 5  5 of 5 | 100%  100% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |
| LWR4  (2009) | Fecal Coliform | > 400 CFU / 100 ml | 2 of 5 | 40% |
| Escherichia coli (E-Coli) | > 235 mpn / 100 ml | 5 of 5 | 100% |
| Biochemical Oxygen Demand (BOD) | > 30 mg/L | Zero of 5  Zero of 5 | 0%  0% |
| Total Suspended Solids (TSS) | > 158 mg/L | 3 of 5 | 60% |
| Total Ammonia (NH3) as N | >1.8 mg/L a | Zero of 5 | 0% |
| Nitrate (NO3) as N | 88 mg/L  >0.56 mg/L b | Zero of 5  Zero of 5 | 0%  0% |
| Total Phosphorus | > 0.037 mg/L c  > 0.09 mg/L d | 5 of 5  5 of 5 | 100%  100% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No Data | No Data |

Table 8. Cheyenne River Stations

| **Waterbody** | **Site #** | **Parameter** | **Criteria exceeded** | **# of Samples** | **Percent exceedance** |
| --- | --- | --- | --- | --- | --- |
| Cheyenne River | CHR1  (2009)  (2011) | Fecal Coliform | > 400 CFU / 100 ml | Zero of 5  1 of 6 | 0%  17% |
| Escherichia coli (E-Coli) | > 235 mpn / 100 ml | 2 of 5  2 of 6 | 40%  33% |
| Biochemical Oxygen Demand (BOD) | > 30 mg/L | Zero of 5  Zero of 6 | 0%  0% |
| Total Suspended Solids (TSS) | > 158 mg/L | 2 of 5  2 of 6 | 40%  33% |
| Total Ammonia (NH3) as N | 1.8 mg/L a | Zero of 5  Zero of 6 | 0%  0% |
| Nitrate (NO3) as N | 88 mg/L  0.56 mg/L b | Zero of 5  Zero of 5  Zero of 6  3 of 6 | 0%  0%  0%  50% |
| Total Phosphorus | >0.037 mg/L c  >0.05 mg/L d | 3 of 5  2 of 5  2 of 5  3 of 5 | 60%  40%  40%  60% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | 1 of 6 | 17% |
| CHR2  (2009)  (2011) | Fecal Coliform | > 400 CFU / 100 ml | 5 of 5  2 of 6 | 100%  33% |
| Escherichia coli (E-Coli) | > 235 mpn / 100 ml | 2 of 5  3 of 6 | 40%  60% |
| Biochemical Oxygen Demand (BOD) | > 30 mg/L | Zero of 5  Zero of 6 | 0% |
| Total Suspended Solids (TSS) | > 158 mg/L | 1 of 5  2 of 6 | 20%  33% |
| Total Ammonia (NH3) as N | 1.8 mg/L a | Zero of 5  Zero of 6 | 0%  0% |
| Nitrate (NO3) as N | 88 mg/L  0.56 mg/L b | Zero of 5  Zero of 5  Zero of 5  3 of 5 | 0%  0%  0%  60% |
| Total Phosphorus | >0.037 mg/L c  >0.09 mg/L d | 4 of 5  3 of 5  2 of 5  1 of 5 | 80%  60%  40%  20% |
| Soluble Reactive Phosphorus | >0.037 mg/L e | No data  1 of 5 | No data  20% |

## 3.3 Macroinvertebrate Data

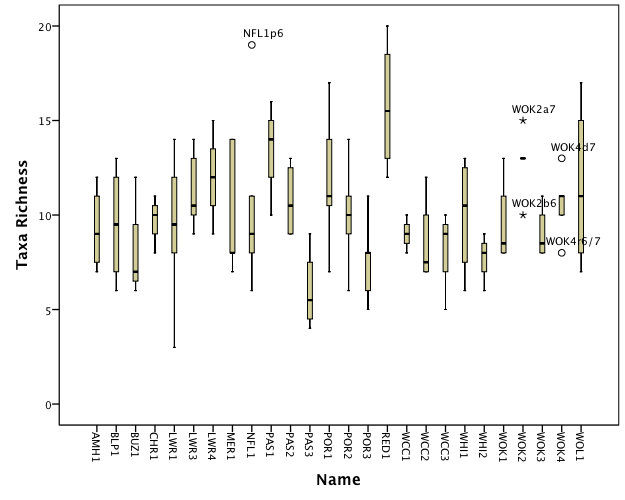


Figure : Macroinvertebrate Taxa Richness for 1993-2011 Samples

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Figure : Macroinvertebrate EPT Index for 1993-2011 Samples

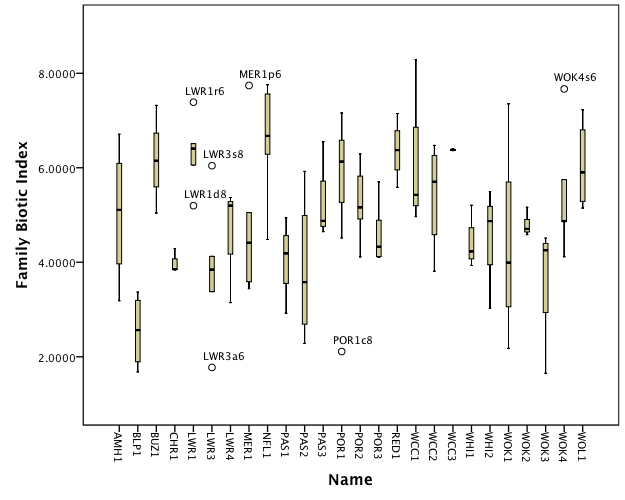


Figure : Macroinvertebrate Family Biotic Index for 1993-2011 Samples

# 

Figure : Macroinvertebrate %Dominant Family for 1993-2011 Samples

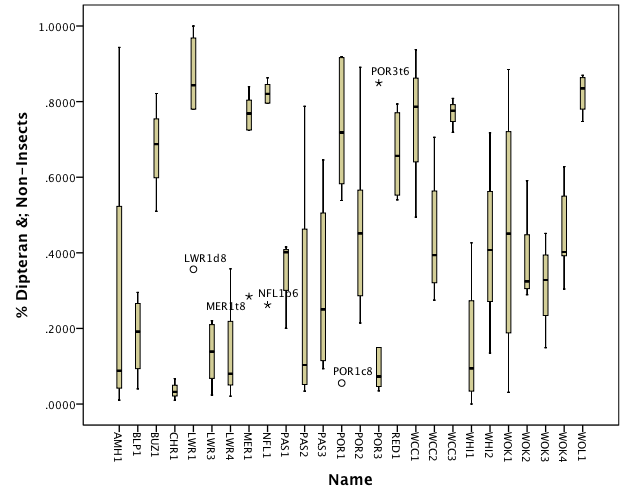


Figure : Macroinvertebrate %Dipteran and Non-Insect for 1993-2011 Samples

# 

Figure : Macroinvertebrate %Collector Gatherer for 1993-2011 Samples

# 

Figure : Macroinvertebrate Total Health Score for 1993-2011 Samples

Table 9. Upper White River Stations

| **Waterbody** | **Site #** | **Parameter** | **Value** | **Mean** | **StDev** |
| --- | --- | --- | --- | --- | --- |
| White Clay Creek | WCC1  (2011)  Oligichaeta  n = 3 years  Great Plains Ecoregion | Taxa Richness | 9 | 9 | 1 |
| EPT Index | 3 | 3.67 | .58 |
| % EPT | 6% | 23% | 23% |
| Family Biotic Index | 8.25 | 6.19 | 1.79 |
| % Dominant Family | 48% | 51% | 14% |
| % Dipteran & Non-insects | 94% | 74% | 23% |
| % Collector Gatherers | 66% | 46% | 25% |
| **Total Score**  **Max = 18** | **6** | **13** | **6.2** |
| WOL1  (2011)  Chironomidae  n = 4 years  Great Plains Ecoregion | Taxa Richness | 17 | 11.5 | 4.43 |
| EPT Index | 6 | 3.00 | 2.00 |
| % EPT | 6% | 9% | 4% |
| Family Biotic Index | 6.37 | 6.05 | 0.95 |
| % Dominant Family | 60% | 45% | 15% |
| % Dipteran & Non-insects | 81% | 82% | 6% |
| % Collector Gatherers | 69% | 69% | 18% |
| **Total Score**  **Max = 18** | **18** | **12.0** | **4.24** |
| WCC2  (2011)  Chironomidae  n = 4 years  Great Plains Ecoregion | Taxa Richness | 7 | 8.5 | 2.38 |
| EPT Index | 1 | 3.25 | 2.22 |
| % EPT | 22% | 48% | 19% |
| Family Biotic Index | 6.05 | 5.30 | 1.36 |
| % Dominant Family | 49% | 37% | 9% |
| % Dipteran & Non-insects | 71% | 47% | 19% |
| % Collector Gatherers | 75% | 57% | 24% |
| **Total Score**  **Max = 24** | **9** | **19.5** | **7.14** |
| WCC3  (2011)  Oligichaeta  n = 2 years  Great Plains Ecoregion | Taxa Richness | 5 | 7.0 | 2.83 |
| EPT Index | 1 | 2.00 | 1.41 |
| % EPT | 19% | 21% | 2% |
| Family Biotic Index | 7.23 | 6.74 | 0.70 |
| % Dominant Family | 40% | 44% | 5% |
| % Dipteran & Non-insects | 81% | 76% | 6% |
| % Collector Gatherers | 70% | 79% | 12% |
| **Total Score**  **Max = 12** | **6** | 9 | 4.2 |
| White River | WHR1  (2011)  n = 4 years  Baetidae  White River Ecoregion | Taxa Richness | 13 | 10.0 | 3.16 |
| EPT Index | 5 | 5.8 | 0.96 |
| % EPT | 56% | 78% | 0.2 |
| Family Biotic Index | 5.2 | 4.4 | 0.56 |
| % Dominant Family | 25% | 41% | 0.21 |
| % Dipteran & Non-insects | 43% | 15% | 0.19 |
| % Collector Gatherers | 57% | 55% | 0.15 |
| **Total Score**  **Max Score = 33** | **27** | **28.5** | **3.9** |
| WHR2  (2011)  n = 3 years  Simuliidae  White River Ecoregion | Taxa Richness | 9 | 7.7 | 1.53 |
| EPT Index | 4 | 4.33 | 0.58 |
| % EPT | 23% | 56% | 0.31 |
| Family Biotic Index | 5.5 | 4.46 | 1.28 |
| % Dominant Family | 70% | 56% | 0.15 |
| % Dipteran & Non-insects | 72% | 42% | 0.29 |
| % Collector Gatherers | 4% | 5% | 0.02 |
| **Total Score**  **Max Score = 30** | **15** | **22.0** | **7.55** |

Table 10. Wounded Knee/Porcupine Creek Stations

| **Waterbody** | **Site #** | **Parameter** | **Value** | **Mean** | **StDev** |
| --- | --- | --- | --- | --- | --- |
| Wounded Knee Creek | WOK1  (2010)  Brachycentridae  (2011)  Baetidae  n = 4 years  Sandhills Ecoregion | Taxa Richness | 11  13 | 10.25 | 2.22 |
| EPT Index | 5  4 | 3.25 | 1.71 |
| % EPT | 93%  64% | 51% | 36% |
| Family Biotic Index | 1.4  4.1 | 4.7 | 2.58 |
| % Dominant Family | 89%  36% | 62% | 25% |
| % Dipteran & Non-insects | 3%  35% | 46% | 36% |
| % Collector Gatherers | 7%  71% | 64% | 40% |
| **Total Score**  **Max = 33** | **33**  **21** | **18.75** | **12.34** |
| WOK2  (2010)  Elmidae  (2011)  Chironomidae  n = 4 years  Northwest Great Plains Ecoregion | Taxa Richness | 13  13 | 13.2 | 1.8 |
| EPT Index | 3  6 | 5.2 | 1.5 |
| % EPT | 23%  29% | 24% | 5% |
| Family Biotic Index | 4.7  4.6 | 4.80 | 0.24 |
| % Dominant Family | 44%  44% | 42% | 6% |
| % Dipteran & Non-insects | 32%  45% | 39% | 13% |
| % Collector Gatherers | 82%  84% | 85% | 5% |
| **Total Score**  **Max = 33** | 21  24 | 21 | 3.9 |
| WOK 3  (2010)  Elmidae  (2011)  Elmidae  n = 4 years  Northwest  Great Plains  Ecoregion | Taxa Richness | 11  8 | 9.0 | 1.4 |
| EPT Index | 3  5 | 3.25 | 1.7 |
| % EPT | 11%  19% | 32% | 30% |
| Family Biotic Index | 4.51  4.28 | 3.67 | 1.4 |
| % Dominant Family | 55%  49% | 56% | 20% |
| % Dipteran & Non-insects | 34%  32% | 31% | 10% |
| % Collector Gatherers | 74%  83% | 58% | 30% |
| **Total Score**  **Max = 27** | 21  15 | 21 | 4.9 |
| WOK4  (2010)  Brachycentridae  (2011)  Chironomidae  n = 5 years  White River Badlands | Taxa Richness | 8  11 | 10.6 | 1.8 |
| EPT Index | 4  5 | 5.60 | 1.1 |
| % EPT | 61%  29% | 46% | 18% |
| Family Biotic Index | 4.12  7.67 | 5.45 | 1.37 |
| % Dominant Family | 34%  41% | 33% | 9% |
| % Dipteran & Non-insects | 39%  63% | 46% | 13% |
| % Collector Gatherers | 54%  70% | 63% | 14% |
| **Total Score**  **Max = 33** | 21  12 | 22.2 | 7.5 |
| Porcupine Creek | POR 1  (2010)  Brachycentridae  (2011)  Simuliidae  Northwest Great Plains  Ecoregion | Taxa Richness | 9  10 | 11.4 | 3.6 |
| EPT Index | 3  1 | 2.5 | 2.1 |
| % EPT | 44%  1% | 25% | 30% |
| Family Biotic Index | 4.4  6.1 | 5.5 | 1.9 |
| % Dominant Family | 34%  83% | 49% | 25% |
| % Dipteran & Non-insects | 53%  92% | 63% | 32% |
| % Collector Gatherers | 51%  94% | 60% | 30% |
| **Total Score**  **Max = 33** | 24  6 | 15.9 | 7.9 |
| POR 2  (2010)  Simuliidae  (2011)  Elmidae  Northwest Great Plains  Ecoregion | Taxa Richness | 6  9 | 10.0 | 2.4 |
| EPT Index | 1  2 | 2.50 | 1.38 |
| % EPT | 8%  6% | 26% | 18% |
| Family Biotic Index | 6.3  5.2 | 5.3 | 0.7 |
| % Dominant Family | 50%  39% | 36% | 11% |
| % Dipteran & Non-insects | 89%  56% | 46% | 24% |
| % Collector Gatherers | 40%  91% | 41% | 26% |
| **Total Score**  **Max = 33** | 12  12 | 21.5 | 8.3 |
| POR 3  (2010)  Baetidae  (2011)  Baetidae  n = 5 samples  Northwest Great Plains  Ecoregion | Taxa Richness | 5  8 | 7.8 | 2.1 |
| EPT Index | 2  4 | 3.2 | 1.2 |
| % EPT | 96%  86% | 84% | 15% |
| Family Biotic Index | 4.10  4.30 | 4.6 | 0.6 |
| % Dominant Family | 91%  76% | 73% | 21% |
| % Dipteran & Non-insects | 3%  13% | 23% | 31% |
| % Collector Gatherers | 93%  83% | 80% | 16% |
| **Total Score**  **Max = 33** | **18**  **23** | 23.4 | 3.4 |

Table 11. Medicine Rook Creek Stations

| **Waterbody** | **Site #** | **Parameter** | **Value** | **Mean** | **StDev** |
| --- | --- | --- | --- | --- | --- |
| Medicine Root Creek | AMH1  (2008)  Chironomidae  n = 4 years  Great Plains Ecoregion | Taxa Richness | 10 | 9.25 | 2.22 |
| EPT Index | 1 | 2.75 | 1.26 |
| % EPT | 1% | 45% | 32% |
| Family Biotic Index | 6.7 | 5.03 | 1.47 |
| % Dominant Family | 46% | 45% | 8% |
| % Dipteran & Non-insects | 95% | 37% | 43% |
| % Collector Gatherers | 92% | 66% | 19% |
| **Total Score**  **Max Score = 30** | **9** | **22.50** | **9.33** |
| MER1  (2008)  Oligachaeta  n = 4 years  High Plains Ecoregion | Taxa Richness | 10 | 11.50 | 3.87 |
| EPT Index | 2 | 2.25 | 0.50 |
| % EPT | 5.6% | 0.13 | 0.09 |
| Family Biotic Index | 7.7 | 4.96 | 1.99 |
| % Dominant Family | 52% | 49% | 14% |
| % Dipteran & Non-insects | 79% | 76% | 2% |
| % Collector Gatherers | 88% | 23% | 43% |
| **Total Score**  **Max Score = 24** | **6** | **17.25** | **7.89** |
| NFL1  (2008)  Elmidae  n = 5 samples  Great Plains Ecoregion | Taxa Richness | 19 | 10.60 | 5.03 |
| EPT Index | 7 | 3.40 | 2.07 |
| % EPT | 11.3% | 0.10 | 0.07 |
| Family Biotic Index | 4.5 | 6.55 | 1.31 |
| % Dominant Family | 62% | 59% | 17% |
| % Dipteran & Non-insects | 26% | 72% | 26% |
| % Collector Gatherers | 77% | 83% | 13% |
| **Total Score**  **Max Score = 24** | **24** | **10.80** | **8.90** |
| MER3  (2008)  Chironomidae  n = 3 years  Badlands Ecoregion | Taxa Richness | 8 | 9 | 5 |
| EPT Index | 2 | 2 | 0 |
| % EPT | 7% | 0 | 0 |
| Family Biotic Index | 6.20 | 6 | 0 |
| % Dominant Family | 63% | 58% | 5% |
| % Dipteran & Non-insects | 81% | 71% | 27% |
| % Collector Gatherers | 96% | 52% | 44% |
| **Total Score**  **Max Score = 18** | **6** | **13** | **6.24** |
| MER4  (2008)  Baetidae  n = 1 year  Badlands Ecoregion | Taxa Richness | 5 | No Data | No Data |
| EPT Index | 4 | No Data | No Data |
| % EPT | 50% | No Data | No Data |
| Family Biotic Index | 4.00 | No Data | No Data |
| % Dominant Family | 47% | No Data | No Data |
| % Dipteran & Non-insects | 33% | No Data | No Data |
| % Collector Gatherers | 82% | No Data | No Data |
| **Total Score** | **24** | **No Data** | **No Data** |
| White River and Downstream Tributaries | WHR3  (2008)  Simulidae  n = 1 year  Badlands Ecoregion | Taxa Richness | 2 | No Data | No Data |
| EPT Index | 1 | No Data | No Data |
| % EPT | 1% | No Data | No Data |
| Family Biotic Index | 6 | No Data | No Data |
| % Dominant Family | 99% | No Data | No Data |
| % Dipteran & Non-insects | 99% | No Data | No Data |
| % Collector Gatherers | 1% | No Data | No Data |
| **Total Score** | **9** | **No Data** | **No Data** |
| RED1  (2008)  Simulidae  n = 4 years  Great Plains Ecoregion | Taxa Richness | 20 | 15.75 | 3.50 |
| EPT Index | 3 | 2.50 | 0.58 |
| % EPT | 12% | 0.10 | 0.07 |
| Family Biotic Index | 5.6 | 6.37 | 0.64 |
| % Dominant Family | 37% | 0.39 | 0.20 |
| % Dipteran & Non-insects | 75% | 0.66 | 0.13 |
| % Collector Gatherers | 46% | 0.58 | 0.20 |
| **Total Score**  **Max Score = 21** | **18** | **15.75** | **5.12** |

Table 12. Pass Creek Stations

| **Waterbody** | **Site #** | **Parameter** | **Value** | **Mean** | **StDev** |
| --- | --- | --- | --- | --- | --- |
| Pass Creek | PAS1  (2010)  Leptoceridae  n = 3 years  High Plains Ecoregion | Taxa Richness | 16 | 13.3 | 3.1 |
| EPT Index | 6 | 5.0 | 1 |
| % EPT | 66% | 59% | 6% |
| Family Biotic Index | 4.9 | 4.0 | 1.0 |
| % Dominant Family | 25% | 41% | 14% |
| % Dipteran & Non-insects | 42% | 34% | 12% |
| % Collector Gatherers | 53% | 44% | 12% |
| **Total Score**  **Max Score = 36** | **33** | **31** | **6.4** |
| PAS2  (2010)  Hydropsychidae  n = 4 years  Great Plains  Ecoregion | Taxa Richness | 12 | 10.8 | 2.1 |
| EPT Index | 4 | 3.5 | 1.0 |
| % EPT | 85% | 51% | 36% |
| Family Biotic Index | 4.1 | 3.8 | 1.6 |
| % Dominant Family | 59% | 52% | 10% |
| % Dipteran & Non-insects | 7% | 26% | 36% |
| % Collector Gatherers | 26% | 15% | 9% |
| **Total Score**  **Max Score = 36** | **33** | **27.8** | **6.7** |
| PAS3  (2010)  Baetidae  n = 3 years  Badlands Ecoregion | Taxa Richness | 6 | 6 | 2.2 |
| EPT Index | 2 | 2.25 | 2.1 |
| % EPT | 81% | 55% | 38% |
| Family Biotic Index | 4.9 | 5.24 | 0.88 |
| % Dominant Family | 75% | 60% | 22% |
| % Dipteran & Non-insects | 14% | 31% | 25% |
| % Collector Gatherers | 80% | 65% | 17% |
| **Total Score**  **Max Score = 36** | **18** | **15.75** | **0.17** |
| BUZ1  (2010)  Taltridae  n = 3 years  Great Plains Ecoregion | Taxa Richness | 7 | 8.33 | 3.21 |
| EPT Index | 5 | 2.33 | 2.31 |
| % EPT | 15% | 19% | 17% |
| Family Biotic Index | 7.3 | 6.17 | 1.14 |
| % Dominant Family | 65% | 48% | 14% |
| % Dipteran & Non-insects | 69% | 67% | 16% |
| % Collector Gatherers | 71% | 63% | 30% |
| **Total Score**  **Max Score = 15** | **3** | **9** | **6** |
| BLP1  (2010)  Brachycentridae  n = 4 years  Great Plains Ecoregion | Taxa Richness | 11 | 9.5 | 3.1 |
| EPT Index | 5 | 3.25 | 1.3 |
| % EPT | 70% | 71% | 12% |
| Family Biotic Index | 3.0 | 2.5 | 0.78 |
| % Dominant Family | 61% | 66% | 14% |
| % Dipteran & Non-insects | 24% | 18% | 11% |
| % Collector Gatherers | 29% | 18% | 8% |
| **Total Score**  **Max Score = 33** | **30** | **29.25** | **3.77** |

Table 13. Little White River Stations

| **Waterbody** | **Site #** | **Parameter** | **Value** | **Mean** | **StDev** |
| --- | --- | --- | --- | --- | --- |
| Little White River | LWR1  (2010)  Culcidae  (2011)  Taltridae  n = 6 samples  Sandhills  Ecoregion | Taxa Richness | 11  10 | 9.3 | 3.9 |
| EPT Index | 1  2 | 1.5 | 1.5 |
| % EPT | 10%  12% | 15% | 22% |
| Family Biotic Index | 7.4  6.4 | 6.3 | .71 |
| % Dominant Family | 64%  38% | 48% | 10% |
| % Dipteran & Non-insects | 89%  79% | 80% | 23% |
| % Collector Gatherers | 80%  76% | 47% | 36% |
| **Total Score**  **Max Score = 21** | **6**  **11** | **12** | **5.4** |
| LWR2  (2011)  Caenidae  n = 3 years  Sandhills Ecoregion | Taxa Richness | 16 | 12.7 | 4.9 |
| EPT Index | 10 | 7.3 | 3.1 |
| % EPT | 78% | 72% | 11% |
| Family Biotic Index | 4.0 | 4.3 | 0.32 |
| % Dominant Family | 24% | 28% | 4% |
| % Dipteran & Non-insects | 21% | 21% | 11% |
| % Collector Gatherers | 62% | 44% | 25% |
| **Total Score**  **Max Score = 33** | **33** | **31** | **1.7** |
| LWR3  (2010)  Polymitoreyidae  (2011)  Caenidae  n = 6 samples  Sandhills  Ecoregion | Taxa Richness | 12  10 | 11.2 | 1.9 |
| EPT Index | 6  5 | 5.8 | 0.8 |
| % EPT | 81%  60% | 81% | 12% |
| Family Biotic Index | 3.95  6.00 | 3.8 | 1.38 |
| % Dominant Family | 35%  39% | 41% | 16% |
| % Dipteran & Non-insects | 17%  21% | 13% | 8% |
| % Collector Gatherers | 66%  90% | 54% | 32% |
| **Total Score**  **Max Score = 36** | **33**  **24** | **32** | **4.1** |
| LWR4  (2010)  Simuliidae  n = 3 samples  Sandhills  Ecoregion | Taxa Richness | 15 | 12.0 | 3.0 |
| EPT Index | 8 | 6.7 | 1.53 |
| % EPT | 59% | 72% | 15% |
| Family Biotic Index | 5.2 | 4.6 | 1.24 |
| % Dominant Family | 29% | 45% | 14% |
| % Dipteran & Non-insects | 36% | 15% | 18% |
| % Collector Gatherers | 63% | 49% | 36% |
| **Total Score**  **Max Score = 36** | **27** | **29** | **3** |

Table 14. Cheyenne River Stations

| **Waterbody** | **Site #** | **Parameter** | **Value** | **Mean** | **Standard Deviation** |
| --- | --- | --- | --- | --- | --- |
| Cheyenne River | CHR1  (2011)  n = 3 years  Heptageniidae  Large River | Taxa Richness | 11 | 9.7 | 1.5 |
| EPT Index | 7 | 5.7 | 1.5 |
| % EPT | 89% | 87% | 6% |
| Family Biotic Index | 3.9 | 4.0 | 0.3 |
| % Dominant Family | 45% | 43% | 3% |
| % Dipteran & Non-insects | 7% | 4% | 3% |
| % Collector Gatherers | 38% | 40% | 5% |
| **Total Score**  **Max Score = 36** | **36** | **33** | **3** |
| CHR2  (2011)  n = 1 year  Hydropsychidae  Large River | Taxa Richness | 10 | N/A | N/A |
| EPT Index | 6 | N/A | N/A |
| % EPT | 80% | N/A | N/A |
| Family Biotic Index | 4.3 | N/A | N/A |
| % Dominant Family | 25% | N/A | N/A |
| % Dipteran & Non-insects | 20% | N/A | N/A |
| % Collector Gatherers | 36% | N/A | N/A |
| **Total Score** | **39** | **N/A** | **N/A** |

# 4.0 Results

## 4.1 Water Quality Results

The Pine Ridge Reservation stream impairment status between 2008-2011 is listed in Table 15. The criteria contributing to stream impairments are: fecal coliform bacteria (86%; 36 of 42 stations), E-coli bacteria (88%; 37 of 42 stations), total phosphorus (100%; 42 of 42 stations), and total suspended sediments (40%; 17 of 42 stations). There were no exceedances of biochemical oxygen demand (BOD), ammonia (NH3), or nitrate (NO3) at the 88 mg/L water quality standard.

Table 15: Impairment Status for Pine Ridge Reservation Streams 2008 – 2011.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Watershed Name** | **Station Name** | **Criteria** | **# Exceedances of # Samples** | **Impairment Status** |
| Upper White River | White Clay Creek 1 | Fecal Coliform Bacteria | 5 of 11 | Impaired |
| E-coli Bacteria | 9 of 11 | Impaired |
| Total Phosphorus | 11 of 11 | Impaired |
| Wolf Creek | E-coli Bacteria | 2 of 11 | Impaired |
| Total Phosphorus | 11 of 11 | Impaired |
| White Clay Creek 2 | Fecal Coliform Bacteria | 6 of 11 | Impaired |
| E-coli Bacteria | 5 of 11 | Impaired |
| Total Phosphorus | 11 of 11 | Impaired |
| White Clay Creek 3 | Fecal Coliform Bacteria | 3 of 9 | Threatened |
| E-coli Bacteria | 5 of 9 | Threatened |
| Total Phosphorus | 9 of 9 | Threatened |
| White River 1 | Fecal Coliform Bacteria | 5 of 6 | Threatened |
| E-coli Bacteria | 6 of 6 | Threatened |
| Total Phosphorus | 6 of 6 | Threatened |
| White River 2 | Fecal Coliform Bacteria | 4 of 6 | Threatened |
| E-coli Bacteria | 5 of 6 | Threatened |
| Total Phosphorus | 6 of 6 | Threatened |
| White River/ Wounded Knee Creek Sub Watershed | Wounded Knee Creek 1 | Fecal Coliform Bacteria | 2 of 9 | Threatened |
| E-coli Bacteria | 4 of 10 | Impaired |
| Total Phosphorus | 7 of 7 | Threatened |
| Wounded Knee Creek 2 | Fecal Coliform Bacteria | 1 of 8 | Threatened |
| E-coli Bacteria | 1 of 9 | Threatened |
| Total Phosphorus | 7 of 7 | Threatened |
| Wounded Knee Creek 3 | Fecal Coliform Bacteria | 2 of 9 | Threatened |
| E-coli Bacteria | 5 of 11 | Impaired |
| Total Phosphorus | 8 of 8 | Threatened |
| Wounded Knee Creek 4 | Fecal Coliform Bacteria | 2 of 8 | Threatened |
| E-coli Bacteria | 7 of 9 | Threatened |
| Total Phosphorus | 7 of 7 | Threatened |
| Total Suspended Solids | 4 of 10 | Impaired |
| Porcupine Creek 1 | Total Phosphorus | 8 of 8 | Threatened |
| Porcupine Creek 2 | Fecal Coliform Bacteria | 3 of 11 | Impaired |
| Total Phosphorus | 9 of 9 | Threatened |
| Porcupine Creek 3 | Fecal Coliform Bacteria | 5 of 9 | Threatened |
| E-coli Bacteria | 7 of 11 | Impaired |
| Total Phosphorus | 10 of 10 | Impaired |
| White River / Medicine Root Sub Watershed | American Horse Creek | Fecal Coliform Bacteria | 2 of 4 | Threatened |
| E-coli Bacteria | 2 of 4 | Threatened |
| Total Phosphorus | 4 of 4 | Threatened |
| No Flesh Creek | Total Phosphorus | 4 of 4 | Threatened |
| Medicine Root Creek 1 | E-coli Bacteria | 1 of 4 | Threatened |
| Total Phosphorus | 3 of 4 | Threatened |
| Medicine Root Creek 3 | Fecal Coliform Bacteria | 1 of 5 | Threatened |
| E-coli Bacteria | 1 of 5 | Threatened |
| Total Phosphorus | 5 of 5 | Threatened |
| Medicine Root Creek 4 | Fecal Coliform Bacteria | 1 of 5 | Threatened |
| E-coli Bacteria | 3 of 5 | Threatened |
| Total Phosphorus | 5 of 5 | Threatened |
| Total Suspended Solids | 3 of 5 | Threatened |
| White River 3 | Fecal Coliform Bacteria | 3 of 4 | Threatened |
| E-coli Bacteria | 4 of 4 | Threatened |
| Total Phosphorus | 4 of 4 | Threatened |
| Total Suspended Solids | 1 of 4 | Threatened |
| Red Water Creek | Fecal Coliform Bacteria | 3 of 5 | Threatened |
| E-coli Bacteria | 4 of 5 | Threatened |
| Total Phosphorus | 5 of 5 | Threatened |
| White River / Bear in the Lodge Subwatershed | Bear Creek 1 | Fecal Coliform Bacteria | 2 of 4 | Threatened |
| E-coli Bacteria | 1 of 4 | Threatened |
| Total Phosphorus | 1 of 3 | Threatened |
| Bear Creek 2 | Fecal Coliform Bacteria | 4 of 4 | Threatened |
| E-coli Bacteria | 4 of 4 | Threatened |
| Total Phosphorus | 2 of 2 | Threatened |
| Total Suspended Solids | 1 of 5 | Threatened |
| Bear Creek 3 | Fecal Coliform Bacteria | 3 of 4 | Threatened |
| E-coli Bacteria | 4 of 4 | Threatened |
| Total Phosphorus | 2 of 2 | Threatened |
| Total Suspended Solids | 1 of 5 | Threatened |
| Bear in the Lodge Creek 1 | Fecal Coliform Bacteria | 2 of 4 | Threatened |
| E-coli Bacteria | 2 of 4 | Threatened |
| Total Phosphorus | 2 of 2 | Threatened |
| Total Suspended Solids | 3 of 3 | Threatened |
| Bear in the Lodge Creek 2 | Fecal Coliform Bacteria | 3 of 3 | Threatened |
| E-coli Bacteria | 5 of 5 | Threatened |
| Total Phosphorus | 2 of 2 | Threatened |
| Total Suspended Solids | 1 of 5 | Threatened |
| Eagle Nest Creek 1 | Total Phosphorus | 2 of 2 | Threatened |
| Eagle Nest Creek 2 | Fecal Coliform Bacteria | 1 of 1 | Threatened |
| Total Suspended Solids | 1 of 1 | Threatened |
| Lost Dog Creek | Fecal Coliform Bacteria | 1 of 7 | Threatened |
| E-coli Bacteria | 1 of 8 | Threatened |
| Total Phosphorus | 8 of 8 | Threatened |
| Potato Creek | Fecal Coliform Bacteria | 3 of 8 | Threatened |
| E-coli Bacteria | 6 of 10 | Impaired |
| Total Phosphorus | 9 of 9 | Threatened |
| White River 5 | Fecal Coliform Bacteria | 3 of 4 | Threatened |
| E-coli Bacteria | 1 of 2 | Threatened |
| Total Phosphorus | 1 of 1 | Threatened |
| White River Pass Creek Watershed | Pass Creek 1 | Fecal Coliform Bacteria | 4 of 5 | Threatened |
| E-coli Bacteria | 5 of 5 | Threatened |
| Total Phosphorus | 5 of 5 | Threatened |
| Pass Creek 2 | Fecal Coliform Bacteria | 3 of 5 | Threatened |
| E-coli Bacteria | 5 of 5 | Threatened |
| Total Phosphorus | 5 of 5 | Threatened |
| Pass Creek 3 | Fecal Coliform Bacteria | 1 of 5 | Threatened |
| E-coli Bacteria | 3 of 5 | Threatened |
| Total Phosphorus | 5 of 5 | Threatened |
| Total Suspended Solids | 1 of 5 | Threatened |
| Buzzard Creek | Fecal Coliform Bacteria | 3 of 5 | Threatened |
| E-coli Bacteria | 5 of 5 | Threatened |
| Total Phosphorus | 5 of 5 | Threatened |
| Craven Creek | Total Phosphorus | 2 of 2 | Threatened |
| Long Creek | E-coli Bacteria | 1 of 4 | Threatened |
| Total Phosphorus | 2 of 2 | Threatened |
| White River 4 | Fecal Coliform Bacteria | 4 of 5 | Threatened |
| E-coli Bacteria | 4 of 5 | Threatened |
| Total Phosphorus | 1 of 1 | Threatened |
| Total Suspended Solids | 3 of 4 | Threatened |
| Black Pipe 1 | Fecal Coliform Bacteria | 5 of 5 | Threatened |
| E-coli Bacteria | 5 of 5 | Threatened |
| Total Phosphorus | 5 of 5 | Threatened |
| White River / Little White River Watershed | Little White River 1 | Fecal Coliform Bacteria | 3 of 5 | Threatened |
| E-coli Bacteria | 4 of 5 | Threatened |
| Total Phosphorus | 5 of 5 | Threatened |
| Total Suspended Solids | 1 of 5 | Threatened |
| Little White River 2 | Fecal Coliform Bacteria | 3 of 5 | Threatened |
| E-coli Bacteria | 5 of 5 | Threatened |
| Total Phosphorus | 5 of 5 | Threatened |
| Little White River 3 | Fecal Coliform Bacteria | 2 of 5 | Threatened |
| E-coli Bacteria | 3 of 5 | Threatened |
| Total Phosphorus | 5 of 5 | Threatened |
| Little White River 4 | Fecal Coliform Bacteria | 2 of 5 | Threatened |
| E-coli Bacteria | 5 of 5 | Threatened |
| Total Phosphorus | 5 of 5 | Threatened |
| Total Suspended Solids | 3 of 5 | Threatened |
| Cheyenne River Watershed | Cheyenne River 1 | E-coli Bacteria | 4 of 11 | Impaired |
| Total Suspended Solids | 4 of 11 | Impaired |
| Cheyenne River 2 | Fecal Coliform Bacteria | 7 of 11 | Impaired |
| E-coli Bacteria | 5 of 11 | Impaired |
| Total Suspended Solids | 3 of 11 | Impaired |

*\*\* South Dakota Surface Water Quality Standards (74:51:01) Appendix A Total Ammonia Criteria, (Equation 2):*

### 4.1.1 Upper White River Watershed Results

The Upper White River watershed has six stations: WHR1, WCC1, WOL1, WCC2, WCC3, WHR2. White River 1 (WHR1) is located near the Nebraska state line. White Clay Creek 1 (WCC1) is located near the Nebraska state line and upstream of the community of Pine Ridge. Wolf Creek 1 (WOL1) is located near the Nebraska state line. White Clay Creek 2 (WCC2) is located downstream of the community of Pine Ridge and below the confluence with Wolf Creek. White Clay Creek 3 (WCC3) is located downstream of the community of Oglala. White River 2 (WHR2) is the furthest downstream station is located below the confluence with White Clay Creek.

Water quality for the Upper White River in 2009 generally improved upstream to downstream for Upper White River stations in 2009 and 2011. However, the water quality declined from 38% fecal coliform exceedances in 2009 to 47% exceedances in 2011 and 55% E-coli exceedances in 2009 to 64% exceedances in 2011. Fecal coliform count for WHR1 exceeded water quality standards 33% (5 of 5) in 2011. E-coli bacteria count for WHR1 exceeded water quality standards 100% (6 of 6) in 2011. Fecal coliform count for WCC1 exceeded water quality standards 60% (3 of 5) in 2009 and 33% (2 of 6) in 2011. E-coli bacteria count for WCC1 exceeded water quality standards 80% (4 of 5) in 2009 and 83% (5 of 6) in 2011. Nitrate concentration for WCC1 exceeded proposed EPA water quality standards 60% (3 of 5) and 100% (6 of 6) in 2011. Fecal coliform count for WOL1 exceeded water quality standards 20% (1 of 5) in 2009 and 0% (zero of 6) in 2011. E-coli bacteria count for WOL1 exceeded water quality standards 20% (1 of 5) in 2009 and 17% (1 of 6) in 2011. Fecal coliform count for WCC2 exceeded water quality standards 40% (2 of 5) in 2009 and 66% (4 of 6) in 2011. E-coli bacteria count for WCC2 exceeded water quality standards 20% (1 of 5) in 2009 and 66% (4 of 6) in 2011. Nitrate concentration for WCC2 exceeded proposed EPA water quality 17% (1 of 6) in 2011. Total suspended solids concentration for WCC2 exceeded water quality standards 20% (1 of 5) in 2008 and 17% (1 of 6) in 2011.

Fecal coliform count for WCC3 exceeded water quality standards 33% (1 of 3) in 2009 and 33% (2 of 6) in 2011. E-coli bacteria count for WCC3 exceeded water quality standards 33% (1 of 3) in 2009 and 33% (2 of 6) in 2011. Fecal coliform count for WHR2 exceeded water quality standards and 66% (4 of 6) in 2011. E-coli bacteria count for WHR2 exceeded water quality standards 83% (4 of 6) in 2011. Nitrate concentration for WHR2 exceeded proposed EPA water quality 17% (1 of 6) in 2011. Total phosphorus concentration for all stations exceeded water quality standards 100% (5 of 5 respectively) in 2009 and 100% (6 of 6) 2011.

The majority of microbiological samples at the WHR1 and WHR2 stations exceeded regulatory limits during periods of both high flow and low flow. All WHR1 and WHR2 phosphorus samples exceeded EPA suggested guidelines for nutrients. Exceedances of fecal coliform and E-coli at the Nebraska State line (WHR1) and below the confluence with White Clay Creek (WHR2) indicate that water quality impairments exist in both high and low flow periods. Non-exceedances for WHR1 and WHR2 stations occurred only during the October sampling period.

### 4.1.2 White River / Wounded Knee Creek Subwatershed Results

The White River/Wounded Knee watershed has 6 stations: WOK1, WOK2, WOK3, WOK4, POR1, POR2 and POR3. Wounded Knee Creek, which has a length of about 50 miles, is in the west central portion of the Pine Ridge Reservation. The southern extent of the watersheds headwaters begins south of Highway 18 in the Sandhills ecoregion and flows northwest to the White River crossing the Northern Great Plains and White River Badlands ecoregions. Wounded Knee Creek 1 in the Sandhills ecoregion is located upstream of Denby Dam on the south side of US Highway 18. Wounded Knee Creek 2 in the Northwest Great Plains ecoregion is located downstream of WOK1 upstream of in the Wounded Knee community along BIA-27. Wounded Knee 3 in the Northwest Great Plains ecoregion and is located downstream of Manderson in Kisa Park west off of BIA-26. Wounded Knee Creek 4 in the White River Badlands ecoregion is located above the confluence with the White River. Porcupine Creek headwaters are south of US Highway 18 flowing north through the town of Porcupine and continuing along BIA-27 to the White River near Rockyford. Porcupine Creek 1 in the Northwest Great Plains ecoregion is located upstream of the Porcupine community near BIA-23. Porcupine Creek 2 in the Northwest Great Plains ecoregion and is located east of BIA-27, approximately two miles upstream of the community of Sharps Corner. Porcupine Creek 3 in the White River Badlands ecoregion is located two miles north of Rockyford and approximately one mile east of the ranger station near the confluence with the White River. The nearest White River station (WHR3) also includes stream flow from the Medicine Root watershed.

The degree of impairment increased from upstream to downstream in Wounded Knee Creek in 2008 and generally stayed steady upstream to downstream in 2011. The overall bacterial water quality exceedances for Wounded Knee Creek decreased from 20% fecal coliform exceedances in 2008 samples to 21% fecal coliform exceedance in 2011 and 33% E-coli exceedances in 2008 samples to 21% E-coli exceedances in 2011. Fecal coliform count for WOK1 exceeded water quality standards 0% (zero of 4) in 2008 and 33% (2 of 6) in 2011. E-coli bacteria count for WOK1 exceeded water quality standards 25% (1 of 4) in 2008 and 50% (3 of 6) in 2011. Nitrate concentration for WOK1 exceeded water quality standards 0% (zero of 4) and 50% (3 of 6) in 2011. Total phosphorus concentration for WOK1 exceeded water quality standards 100% (2 of 2) in 2008 and 100% (6 of 6) 2011. Fecal coliform count for WOK2 exceeded water quality standards 0% (zero of 2) in 2008 and 17% (1 of 6) in 2011. E-coli bacteria count for WOK2 exceeded water quality standards 0% (1 of 3) in 2008 and 17% (1 of 6) in 2011. Total phosphorus concentration for WOK2 exceeded water quality standards 100% (1 of 1) in 2008 and 100% (6 of 6) 2011. Fecal coliform count for WOK3 exceeded water quality standards were 33% (1 of 3) in 2008 and 17% (1 of 6) in 2011. E-coli bacteria count for WOK3 exceeded water quality standards 60% (3 of 5) in 2008 and 33% (2 of 6) in 2011. Total suspended solids concentration for WOK3 exceeded water quality standards 0% (zero of 5) in 2008 and 17% (1 of 6) in 2011. Fecal coliform count for WOK4 exceeded water quality standards were 50% (1 of 2) in 2008 and 17% (1 of 6) in 2011. E-coli count for WOK4 exceeded water quality standards 100% (4 of 4) in 2008 and 60% (3 of 5) in 2011. Total phosphorus concentration for WOK4 exceeded water quality standards 100% (1 of 1) in 2008 and 100% (6 of 6) 2011. Total phosphorus samples at WOK4 exceeded water quality standards 100% in 2008 (1 of 1) and 2011 (6 of 6). Total suspended solids concentration for WOK4 exceeded water quality standards 25% (1 of 4) in 2008 and 50% (3 of 6) in 2011.

The degree of impairment tended to remain steady upstream to downstream in Porcupine Creek in 2008 and increase upstream to downstream in 2011. The overall bacterial water quality exceedances for Porcupine Creek decreased from 36% (4 of 11) fecal coliform exceedances in 2008 samples to 22% (4 of 18) fecal coliform exceedance in 2011 and 36% (5 of 14) E-coli exceedances in 2008 samples to 24% (4 of 17) E-coli exceedances in 2011. All 2011 bacterial water quality exceedances were at Porcupine Creek 3. Fecal coliform count for POR1 exceeded water quality standards 0% (0 of 3) in 2008 and 0% (zero of 6) in 2011. E-coli bacteria count for POR1 exceeded water quality standards 20% (1 of 5) in 2008 and 0% (0 of 6) in 2011. Total phosphorus concentration for POR1 exceeded water quality standards 100% (2 of 2) in 2008 and 100% (6 of 6) in 2011. Fecal coliform count for POR2 exceeded water quality standards 60% (3 of 5) in 2008 and 0% (0 of 6) in 2011. E-coli bacteria count for POR2 exceeded water quality standards 20% (1 of 5) in 2008 and 0% (0 of 6) in 2011. Total phosphorus concentration for POR2 exceeded water quality standards 100% (3 of 3) in 2008 and 100% (6 of 6) 2011. Fecal coliform count for POR3 exceeded water quality standards 33% (1 of 3) in 2008 and 66% (4 of 6) in 2011. E-coli bacteria count for POR3 exceeded water quality standards 75% (3 of 4) in 2008 and 80% (4 of 5) in 2011. Total suspended solids concentration for POR3 exceeded water quality standards 0% (0 of 4) in 2008 and 17% (1 of 6) in 2011. Total phosphorus concentration for POR3 exceeded water quality standards 100% (3 of 3) in 2008 and 100% (6 of 6) in 2011.

### 4.1.3 White River / Medicine Root Creek Subwatershed Results

The White River / Medicine Root Subwatershed has 6 stations: MER1, MER3, MER4, NFL1, AMH1, and RED1. American Horse Creek (AMH1) is located directly south of Kyle, Medicine Root 1 (MER1) is located south and slightly east of Kyle in the High Plains ecoregion. No Flesh Creek (NFL1) is also located southeast of Kyle in the High Plains. Three creeks, which are classified as being in the Great Plains ecoregion flow into Kyle Dam. Medicine Root 3 (MER3) is downstream and northwest of Kyle Medicine Root 3 is in the transition zone between the Great Plains and the White River ecoregions. Medicine Root 4 is in the White River ecoregion downstream of MER3. The nearest White River station (WHR3) station located between Medicine Root Creek and Red Water Creek (RWC1), a White River tributary that lies northeast of Kyle in the Great Plains ecoregion. WHR3 includes flow from both the White River / Wounded Knee and White River / Medicine Root subwatersheds.

The degree of impairment remains relatively steady upstream to downstream in the Medicine Root Watershed in 2010. The overall bacterial water quality exceedances for the Medicine Root subwatershed are 23% (5 of 22) fecal coliform exceedances and 32% (7 of 22) E-coli exceedances in 2010 samples. Fecal coliform count for AMH1 exceeded water quality standards 50% (2 of 4) in 2010. E-coli bacteria count for AMH1 exceeded water quality standards 50% (2 of 4) in 2010. The bacterial exceedances occurred during the months of June and July. Total phosphorus concentration for AMH1 exceeded water quality standards 100% (4 of 4) in 2010. Fecal coliform count for MER1 exceeded water quality standards 0% (0 of 4) in 2010. E-coli bacteria count for MER1 exceeded water quality standards 25% (1 of 4) in 2010. The bacterial exceedances occurred during the month of July. Total phosphorus concentration for MER1 exceeded water quality standards 75% (3 of 4) in 2010. Fecal coliform count for NFL1 exceeded water quality standards 0% (0 of 4) in 2010. E-coli bacteria count for MER1 exceeded water quality standards 0% (0 of 4) in 2010. Total phosphorus concentration for POR1 exceeded water quality standards 100% (4 of 4) in 2010. Fecal coliform count for MER3 exceeded water quality standards 20% (1 of 5) in 2010. E-coli bacteria count for MER3 exceeded water quality standards 20% (1 of 5) in 2010. The bacterial exceedance occurred during the months of June and July. Total phosphorus concentration for MER3 exceeded water quality standards 100% (4 of 4) in 2010. Fecal coliform count for MER4 exceeded water quality standards 20% (1 of 5) in 2010. E-coli bacteria count for MER4 exceeded water quality standards 60% (3 of 5) in 2010. Bacterial exceedances occurred during the months of April, June and September. Total phosphorus concentration for MER4 exceeded water quality standards 100% (5 of 5) in 2010. Fecal coliform count for WHR3 exceeded water quality standards 75% (3 of 4) in 2010. E-coli bacteria count for MER4 exceeded water quality standards 100% (4 of 4) in 2010. Bacterial exceedances occurred during the months of April, June, July and September. Total phosphorus concentration for WHR3 exceeded water quality standards 25% (1 of 4) in September 2010. Total phosphorus concentration for MER4 exceeded water quality standards 100% (5 of 5) in 2010. Fecal coliform count for RED1 exceeded water quality standards 60% (3 of 5) in 2010. E-coli bacteria count for MER4 exceeded water quality standards 80% (4 of 5) in 2010. Bacterial exceedances occurred during the months of May, June, July and September. Total phosphorus concentration for MER4 exceeded water quality standards 100% (5 of 5) in 2010. Water samples were not collected for the Medicine Root Creek watershed in August 2010.

### 4.1.4 White River / Bear in the Lodge Creek Subwatershed Results

The White River / Bear in the Lodge subwatershed, which includes: Potato Creek, Lost Dog Creek, Bear Creek, Corn Creek, Bear in the Lodge Creek, Eagle Nest Creek watersheds, has 11 stations: POT1, LOD1, BEA1, BEA2, BEA3, COR1, BLC1, BLC2, EAN1, EAN2. Potato Creek and Lost Dog Creek are White River tributaries in the Great Plains ecoregion. The Bear in the Lodge Creek watershed includes headwater stations on Bear Creek east of Allen (BEA1) and (BEA2) in the High Plains ecoregion and Corn Creek (COR1) in the Northern Great Plains ecoregion, mid-order stations, a mid-order station north of Hisle (BEA3) in the Northern Great Plains ecoregion, and downstream stations on Bear in the Lodge Creek below the confluence with Bear Creek in the Northern Great Plains ecoregion (BEL1) and near the confluence with the White River in the White River Badlands ecoregion (BEL2). Eagle Nest watershed, located east of the Bear in the Lodge watershed, has an upstream station (EAN1) in the Great Plains ecoregion and a downstream station (EAN2) in the Badlands ecoregion near the confluence with the White River. The nearest White River station (WHR5) includes flow from the White River / Medicine Root Subwatershed, as well as Potato Creek (POT1), Lost Dog Creek (LOD1).

The degree of impairment generally increases upstream to downstream in the Bear in the Lodge subwatershed in 2008. The overall bacterial water quality exceedances for the Bear in the Lodge subwatershed are 58% (18 of 31) fecal coliform exceedances and 66% (25 of 38) E-coli exceedances in 2008 samples. Fecal coliform count for POT1 exceeded water quality standards 33% (1 of 3) in 2008. E-coli bacteria count for POT1 exceeded water quality standards 66% (3 of 5) in 2008. The bacterial exceedances occurred during the months of June, July and August. Total suspended solids concentration for POT1 exceeded water quality standards 25% (1 of 4) in 2008. Total phosphorus concentration for POT1 exceeded water quality standards 100% (4 of 4) in 2008. Fecal coliform count for LOD1 exceeded water quality standards 0% (0 of 3) in 2008. E-coli bacteria count for LOD1 exceeded water quality standards 25% (1 of 4) in 2008. The bacterial exceedance occurred during the month of July. Total phosphorus concentration for LOD1 exceeded water quality standards 100% (3 of 3) in 2008. Fecal coliform count for BEA1 exceeded water quality standards 50% (2 of 4) in 2008. E-coli bacteria count for LOD1 exceeded water quality standards 25% (1 of 4) in 2008. The bacterial exceedance occurred during the months of July and August. Total phosphorus concentration for LOD1 exceeded water quality standards 100% (3 of 3) in 2008. Fecal coliform count for BEA2 exceeded water quality standards 100% (4 of 4) in 2008. E-coli bacteria count for BEA2 exceeded water quality standards 100% (4 of 4) in 2008. The bacterial exceedance occurred during the months of June, July, August, September, and October. Total phosphorus concentration for BEA2 exceeded water quality standards 100% (3 of 3) in 2008. Fecal coliform count for BEA3 exceeded water quality standards 100% (4 of 4) in 2008. E-coli bacteria count for BEA3 exceeded water quality standards 100% (4 of 4) in 2008. The bacterial exceedance occurred during the months of June, July, August, September, and October. Total phosphorus concentration for BEA2 exceeded water quality standards 100% (3 of 3) in 2008. Fecal coliform count for BEL1 exceeded water quality standards 50% (2 of 4) in 2008. E-coli bacteria count for BEL1 exceeded water quality standards 50% (2 of 4) in 2008. The bacterial exceedance occurred during the months of June, July, August. Total phosphorus concentration for BEL1 exceeded water quality standards 100% (3 of 3) in 2008. Fecal coliform count for BEL2 exceeded water quality standards 100% (3 of 3) in 2008. E-coli bacteria count for BEL2 exceeded water quality standards 100% (5 of 5) in 2008. The bacterial exceedance occurred during the months of June, July, August, September, October. Total phosphorus concentration for BEL1 exceeded water quality standards 100% (3 of 3) in 2008. Fecal coliform count for EAN1 exceeded water quality standards 0% (0 of 3) in 2008. E-coli bacteria count for BEL2 exceeded water quality standards 0% (4 of 4) in 2008. Total phosphorus concentration for BEL1 exceeded water quality standards 100% (2 of 2) in 2008. Fecal coliform count for EAN2 exceeded water quality standards 100% (1 of 1) in 2008. E-coli bacteria count for EAN2 exceeded water quality standards 100% (1 of 1) in 2008. The bacterial exceedance occurred during the month of June. Total phosphorus concentration for BEL1 exceeded water quality standards 100% (1 of 1) in 2008. EAN2 was dry by July 16 sampling and remained dry in August. Fecal coliform count for WHR5 exceeded water quality standards 50% (1 of 2) in 2010. E-coli bacteria count for WHR5 exceeded water quality standards 75% (3 of 4) in 2010. Bacterial exceedances occurred during the months of June, July and August. Total phosphorus concentration for WHR5 exceeded water quality standards 100% (1 of 1). Fecal coliform count for LOD1 exceeded water quality standards 14% (1 of 7) in 2010. E-coli bacteria count for LOD1 exceeded water quality standards 13% (1 of 8) in 2010. Total phosphorus concentration for LOD1 exceeded water quality standards 100% (8 of 8). Fecal coliform count for POT1 exceeded water quality standards 38% (3 of 8) in 2010. E-coli bacteria count for POT1 exceeded water quality standards 60% (6 of 10) in 2010. Total phosphorus concentration for POT1 exceeded water quality standards 100% (9 of 9).

### 4.1.5 White River / Pass Creek Subwatershed Results

The White River / Bear in the Lodge subwatershed, which includes: Craven Creek, Long Creek, Pass Creek, and Black Pipe Creek watersheds, has 11 stations: CRA1, LON1, PAS1, PAS2, PAS3, BUZ1, and BLP1. Craven Creek, which is also known as Buckle Creek, and Long Creek are in the Great Plains ecoregion and have one station (CRA1) and (LON1), respectively. The Pass Creek watershed includes: headwater stations in the High Plains ecoregion on Pass Creek, PAS1, and in the Great Plains ecoregion on Buzzard Creek, BUZ1, a mid-order station, PAS2, in the High Plains ecoregion, and a station in the Badlands ecoregion near the confluence with the White River. Black Pipe Creek watershed has a station, BLP1, near the Pine Ridge reservation boundary.

The degree of impairment generally decreases upstream to downstream in the Pass Creek subwatershed in 2009. The overall bacterial water quality exceedances for the Pass Creek subwatershed are 51% (18 of 35) fecal coliform exceedances and 69% (24 of 35) E-coli exceedances in 2008-2009 samples. Fecal coliform count for PAS1 exceeded water quality standards 80% (4 of 5) in 2009. E-coli bacteria count for PAS1 exceeded water quality standards 100% (5 of 5) in 2009. The bacterial exceedances occurred during the months of May, June, July, August, and September. Total phosphorus concentration for PAS1 exceeded water quality standards 100% (5 of 5) in 2009. Fecal coliform count for PAS2 exceeded water quality standards 60% (3 of 5) in 2009. E-coli bacteria count for PAS2 exceeded water quality standards 100% (5 of 5) in 2009. The bacterial exceedances occurred during the months of May, June, July, August, and September. Total phosphorus concentration for PAS2 exceeded water quality standards 100% (5 of 5) in 2009. Fecal coliform count for PAS3 exceeded water quality standards 40% (2 of 5) in 2009. E-coli bacteria count for PAS3 exceeded water quality standards 60% (3 of 5) in 2009. The bacterial exceedances occurred during the months of June, July, and August. Total suspended solids concentration for PAS3 exceeded water quality standards 20% (1 of 5) in 2009. Total phosphorus concentration for PAS3 exceeded water quality standards 100% (5 of 5) in 2009. Fecal coliform count for CRA1 exceeded water quality standards 0% (0 of 5) in 2008. E-coli bacteria count for CRA1 exceeded water quality standards 0% (0 of 5) in 2008. Total phosphorus concentration for CRA1 exceeded water quality standards 100% (2 of 2) in 2008. Fecal coliform count for BUZ1 exceeded water quality standards 60% (3 of 5) in 2009. E-coli bacteria count for BUZ1 exceeded water quality standards 100% (5 of 5) in 2009. The bacterial exceedances occurred during the months of May, June, July, August, and September. Total phosphorus concentration for BUZ1 exceeded water quality standards 100% (5 of 5) in 2009. Fecal coliform count for BLP1 exceeded water quality standards 100% (5 of 5) in 2009. E-coli bacteria count for BLP1 exceeded water quality standards 100% (5 of 5) in 2009. The bacterial exceedances occurred during the months of May, June, July, August, and September. Total phosphorus concentration for BLP exceeded water quality standards 100% (5 of 5) in 2009. Fecal coliform count for LON1 exceeded water quality standards 0% (0 of 5) in 2009. E-coli bacteria count for LON1 exceeded water quality standards 20% (1 of 5) in 2008. The bacterial exceedances occurred during the month of July. Total phosphorus concentration for LON1 exceeded water quality standards 100% (2 of 2) in 2008. Fecal coliform count for WHR4 exceeded water quality standards 80% (4 of 5) in 2009. E-coli bacteria count for WHR4 exceeded water quality standards 80% (4 of 5) in 2009. The bacterial exceedances occurred during the months of May, June, July, and August. Total suspended solids concentration for WHR4 exceeded water quality standards 20% (1 of 5) in 2009. Total phosphorus concentration for WHR4 exceeded water quality standards 100% (5 of 5) in 2009.

## 4.2 Nutrient Specific Results

The State of South Dakota has not yet developed numeric water criteria for nutrients to prevent nuisance algal blooms and corresponding nighttime low dissolved oxygen. However, the US-EPA has provided guidelines for the establishment of numeric nutrient concentration goals based on the 25th percentile of samples collected throughout the region. “Excessive amounts nutrients cause eutrophication or hypereutrophication, which results in overgrowth of plant life and decline of the biological community. Excessive nutrients can also result in human health risks, such as the growth of harmful algal blooms, most recently manifested in the Pfiesteria outbreaks on the Gulf and East Coasts. Chronic nutrient overenrichment of a waterbody can lead to the following consequences: algal blooms, low dissolved oxygen, fish kills, overabundance of macrophytes, likely increased sedimentation, and species shifts of both flora and fauna [EPA, 2001]”. The EPA recommends 0.55 mg/L as the water quality goal for nitrogen as nitrate and 0.025 mg/L as the water quality goal for total phosphorus in the Upper Midwest region (EPA 2001). The Oglala Sioux Tribe has also drafted a total phosphorus water quality standard of 0.037 mg/L. The draft water quality standards and goals are in line with researchers estimates of “excessive” phosphorus of between 0.015 and 0.02 mg/L (Masters and Ela 2007).

The water quality for streams on the Pine Ridge Reservation are not meeting the State of South Dakota’s narrative criteria for excess nutrients, as nuisance algal blooms are occurring at several monitoring stations (Tinant personal observation). Nitrate concentrations of 2008-2011 water quality samples exceed the EPA recommendation of 0.55 mg/L at 29% of stations (12 of 42 stations; N=298 samples). The mean and median nitrate concentration for 2008-2011 samples is 0.220 mg/L, and the 25th percentile is 0.025 mg/L. The nitrate goal exceedances of nitrate guidelines occur exclusively in the Pass Creek watershed and the Cheyenne and White Rivers. Total phosphorus (TP) concentrations of 2008-2011 water quality samples exceed the EPA recommendation of 0.025 mg/L at 100% (42 of 42 stations; N=250 samples, mean = 0.403 mg/L, 50th-percentile = 0.110 mg/L, 25th-percentile = 0.090 mg/L).

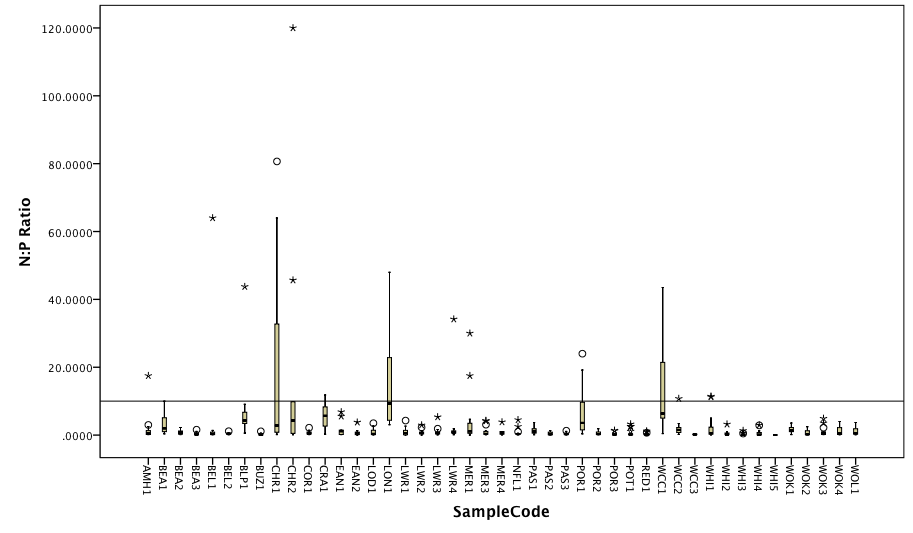
Eutrophication describes an increase in algal or aquatic macrophyte density (e.g. “nuisance algal blooms) as a response to nutrient enrichment. The degree to which eutrophication occurs as a response to nutrient enrichment depends on light availability, as well as the availability of the most limiting nutrient, usually nitrogen or phosphorus. Strumm and Morgan (1981) define algal growth by the following equation:

106 CO2 + 16 NO3- + HPO42- + 122 H2O + 18H+ -> C106H263O110N16P + 138 O2

A stoichiometric analysis of the algal growth equation provides a first-approximation of a mass ratio of nitrogen to phosphorus (N/P ratio) of 7 to 10 as defining whether a stream is nitrogen limited or phosphorus limited (Master and Ela 2007). The median ratio for all Pine Ridge reservation streams sampled between 1993-2011 was 0.59 indicating streams are nitrogen limited. However, a small percentage of samples (6% or 41 of 671 samples) in which nitrate and phosphorus were analyzed exhibited N/P ratios greater than 10 indicating a potential phosphorus limitation. These exceedances include: Cheyenne River stations (winters from 1993 – 2004), Craven Creek (winters 1997 – 2008), Long Creek (2008), Medicine Root Creek 1 (1996), Porcupine Creek 1 (winters 1993, 1997, 2003, 2004), White Clay Creek 1 (1995 – 1997, 2003, 2004, winter 1993), White River 1 (2000, 2004). High nitrate concentrations was in most cases the reason for N/P ratios greater than 10 with 34% (14 of 41 samples) exceedances at 200% of the EPA goal of 0.55 mg/L and 63% of exceedances at 150% of the EPA goal. Phosphorus levels of less than 0.02 mg/L were the cause for exceedances of the N/P ratio for only 2% (1 of 41 samples). For the reporting period of 2008-2010, Black Pipe Creek, Long Creek and Craven Creek exhibited N/P ratios greater than 10. Nitrogen as nitrate concentrations for these stations ranged from 1.3 to 2.7 mg/L (N=4 samples).

***\*74:51:01:09. Nuisance aquatic life.*** *Materials which produce nuisance aquatic life may not be discharged or caused to be discharged into surface waters of the state in concentrations that impair an existing or designated beneficial use or create a human health problem.*

***74:51:01:12. Biological integrity of waters.*** *All waters of the state must be free from substances, whether attributable to human-induced point source discharges or nonpoint source activities, in concentrations or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities.*

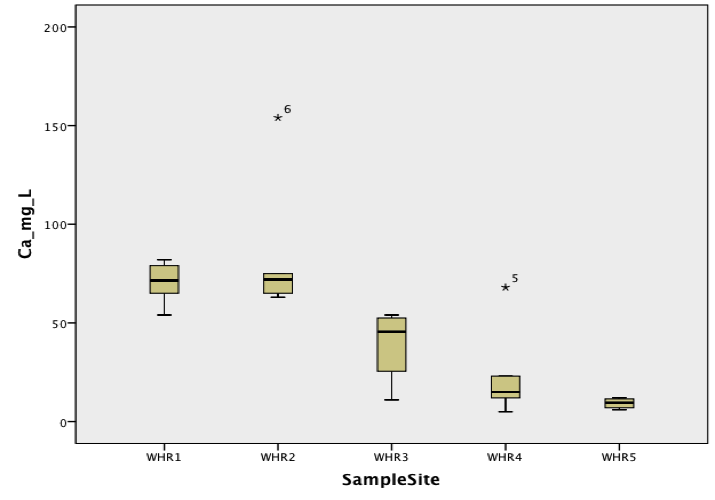


## 4.3 Geochemical Modeling

Tetra-tech (2005) recommended that the OST-EPP add common inorganics: calcium, magnesium, and sodium to the sampling program in order to leverage heavy metals concentration data collected in the 1990s. Using these additional parameters, I attempted to model the geochemistry of surface waters in 2010 using Geochemist’s Workbench software. However, I was unable to achieve a charge balance with available water quality parameters. Furthermore, model outputs indicated surface waters were supersaturated with total phosphorus. I recommended that the OST-EPP sample for potassium and soluble reactive phosphorus in 2011 in order to better constrain model parameters. Soluble reactive phosphorus (SRP) concentrations of 2008-2011 water quality samples exceed the EPA recommendation of 0.55 mg/L at 100% (42 of 42 stations; N=90 samples, mean = 0.124 mg/L, 50th-percentile = 0.110 mg/L, 25th-percentile = 0.050 mg/L).

I used the PHREEQC geochemical model to investigate total phosphorus and common inorganics in the White River in 2011. Geochemical modeling involves two steps: 1) estimation of input parameters and 2) estimation of probable net reactions. I used SPSS (IBM Corporation 2012) to estimate input parameters for the PHREEQC model (Parkhurst and Appelo 2013). Water quality and physical parameters from 1993-2012 for White River monitoring stations were input into SPSS. I estimated concentrations for non-detects at 50% of the detection limit. I used the *Explore* command to create histograms, normality plots, and box-plots. I removed parameters with highly non-normal distributions that resulted from large numbers of non- detects and extreme outliers from subsequent analyses. I conducted independent t-tests for differences in concentration and location after first using Levene’s Test for equality of variance. I calculated molar concentration and saturation indices for aggregated upstream and downstream water qualities in the summer and fall using the PHREEQC geochemical model with mean mass concentrations and mean temperatures as model parameters. I ran the model again after removing parameters other than phosphorus with upstream-downstream differences of less than five log-orders. I estimated probable net reactions from changes in molar concentration and saturation indices.

The first step in the geochemical analysis was to determine model inputs. Mass concentrations of calcium, magnesium, potassium, and sodium, alkalinity, chloride, fluoride, sulfate, total phosphorus, arsenic, barium, chromium, cadmium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and zinc, along with temperature and pH were input into SPSS. Year by year comparisons of White River water quality were not possible because not all parameters were sampled on every year. The trace metals chromium, cadmium, copper, lead, mercury, nickel, selenium, silver, and zinc, which had strongly non-normal distributions because of the high number of non-detections, were removed from subsequent analysis. Upstream to downstream calcium concentration differences indicated a possibly significant difference in concentration between stations WHR2 and WHR3 (Figure 19).

I conducted an independent-samples t-test was to compare calcium concentrations at upstream (WHR1 and WHR2) and downstream stations (WHR3, WHR4, and WHR5). There was a significant difference in the calcium concentrations between the upstream and downstream stations (M=56.7, SE=6.4; t(15.93)=7.126, p<0.001) A visual analysis of monthly and temperatures during periods of high flow (March to August) and low flow (September to December) indicated a great enough difference in temperatures to split the model inputs into spring-summer and fall-winter groups (Figure 20).

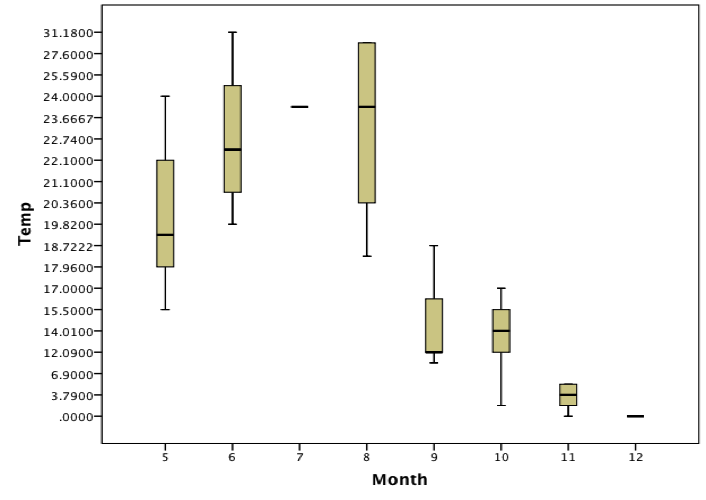


Figure : Monthly Temperature Differences for White River Stations

Figure : Box Plots of Calcium Concentration by White River Station

The second step in the geochemical analysis was to run the geochemical model and evaluate model outputs to estimate major geochemical reactions. Initial PHREEQC results indicated the molar concentrations of barium, fluoride, and manganese were very small (> 3 log orders difference) relative to changes in calcium and magnesium concentrations and were removed from further analysis. Potassium was removed from further analysis because it was only sampled in 2012 at one location and did not vary between upstream and downstream stations or by season. Concentrations and differences by season and location are shown in Tables 16 and 17. Charge balances and percent error for the geochemical modeling shown in Table 18 indicate the approximations of the groups are reasonable and few major ions are missing from the analysis. Saturation indices and the differences in the indices by location and season are given in Table 16. The apparent seasonal difference in downstream sodium concentrations (Table 19), which is not statistically significant (M=-6.05, SE=17.5; t(13)=-.345, p<0.735), is likely caused by the relatively small number of sodium samples taken. The seasonal difference in downstream alkalinity concentrations (Table 17) is not statistically significant (M=-30.3, SE=29.6; t(12)=-1.02, p<0.327). The upstream – downstream difference in SO4 concentration (Table 2) is not statistically significant (M=24.27, SE=29.27; t(56.57)=.873, p<0.386).

Table 16. Cation Concentrations and Differences by Location and Season



Table 17. Anion Concentrations and Differences by Location and Season



Table 18. Charge Balances for the Upper and Lower White River



Table 19. Selected Saturation Indices for the Upper and Lower White River by Location and Season. Values greater than zero indicate supersaturation.

## 

# 5.0 Stream Health Results

The Pine Ridge Reservation stream health results for 2008-2011 are shown in Table 20. The general trend for impairments follows the water quality results with 10% (4 of 40) stations scoring less than 29% of the best station in the region being designated severely impaired and 43% (17 of 40) stations scoring less than 79% of the best station in the region being designated moderately impaired. The general trend over time is a decrease in stream health over time with 5% (2 of 37) stations scoring less than 29% of the maximum score for the station designated as being severely degraded and 51% (19 of 37) stations scoring less than 79% of the maximum score for the station designated as being moderately degraded. Major changes in stream health since the 1990s result from increases in abundance of tolerant taxa as designated by the Family Biotic Index and increases in abundance of taxa designated as collector gatherers. Notable exceptions to the general trend are No Flesh Creek and Wolf Creek, which have improved markedly since the 1990s.

Table 20: Generalized Stream Health Results for Pine Ridge Reservation Streams 2008 – 2011 with Highlighted Stations Representing the Reference Stream for the Ecoregion.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Ecoregion** | **Station** | **Impairment Status** | **Status** |
| 2008 | Badlands | Medicine Root 3 | 25%; 6/24  33%; 6/18 | Moderately Impaired /  Moderate Degradation |
| Medicine Root 4 | 100%; 24/24  No data | Non-impaired / No Data |
| White River 3 | 38%; 9/24  No data | Moderately Impaired / No Data |
| Great Plains | American Horse Creek | 38%; 9/24  30%; 9/30 | Moderately Impaired / Moderate Degradation |
| No Flesh Creek | 100%; 24/24  100%; 24/24 | Non-impaired /  Moderate Improvement |
| Red Water | 75%; 18/24  86%; 18/21 | Moderately Impaired /  No Change |
| High Plains | Medicine Root 1 | 25%; 6/24\*  25%; 6/24 | Moderately Impaired\* /  Moderate Degradation |
| 2010 | Badlands | Pass Creek 3 | 100%; 30/30  100%; 30/30 | Non-impaired / No Change |
| Porcupine Creek 3 | 60%; 18/30  67%; 18/27 | Moderately Impaired / Moderate Degradation |
| Wounded Knee Creek 4 | 80%; 24/30  73%; 24/33 | Non-impaired / Moderate Degradation |
| Great Plains | Buzzard Creek | 18%; 6/33  40%; 6/15 | Severely Impaired /  Moderate Degradation |
| Black Pipe Creek | 91%; 30/33  91%; 30/33 | Non-impaired / No Change |
| Pass Creek 2 | 100%; 33/33  100%; 33/33 | Non-impaired / No Change |
| Porcupine Creek 1 | 73%; 24/33  100%; 24/24 | Moderately Impaired / No Change |
| Porcupine Creek 2 | 36%; 12/33  36%; 12/33 | Moderately Impaired /  Moderate Degradation |
| Wounded Knee Creek 2 | 64%; 21/33  88%; 21/24 | Moderately Impaired /  No Change |
| Wounded Knee Creek 3 | 64%; 21/33  88%; 21/27 | Moderately Impaired / Moderate Degradation |
| High Plains | Pass Creek 1 | 100%; 33/33\*  100%; 33/33 | Non-impaired / No Change |
| Sand Hills | Little White River 1 | 18%; 6/33  29%; 6/21 | Severely Impaired /  Moderate Degradation |
| Little White River 3 | 100%; 33/33  91%; 30/33 | Non-impaired / No Change |
| Little White River 4 | 82%; 27/33  82%; 27/33 | Non-impaired / No Change |
| Wounded Knee Creek 1 | 100%; 33/33  100%; 33/33 | Non-impaired / No Change |
| 2011 | Badlands | Porcupine Creek 3 | 89%; 24/27  89%; 24/27 | Non-impaired / Moderate Improvement |
| White River 1 | 100%; 27/27  82%; 27/33 | Non-impaired / No Change |
| White River 2 | 56%; 15/27  50%; 15/30 | Moderately Impaired / Moderate Degradation |
| Wounded Knee Creek 4 | 44%; 12/27  36%; 12/33 | Moderately Impaired / Moderate Degradation |
| Cheyenne River | Cheyenne River 1 | 92%; 36/39  82%; 36/36 | Non-impaired / No Change |
| Cheyenne River 2 | 100%; 39/39  No data | Non-impaired / No data |
| Great Plains | Porcupine Creek 1 | 25%; 6/24  25%; 6/24 | Moderately Impaired / Moderate Degradation |
| Porcupine Creek 2 | 38%; 9/24  27%; 9/33 | Moderately Impaired / Moderate Degradation |
| White Clay Creek 1 | 25%; 6/24  33%; 6/18 | Moderately Impaired / Moderate Degradation |
| White Clay Creek 2 | 38%; 9/24  38%; 9/24 | Moderately Impaired / Moderate Degradation |
| White Clay Creek 3 | 25%; 6/24  50%; 6/12 | Moderately Impaired / Moderate Degradation |
| Wounded Knee Creek 2 | 100%; 24/24  100%; 24/24 | Non-Impaired / No Change |
| Wounded Knee Creek 3 | 75%; 18/24  66%; 18/27 | Moderately Impaired / Moderate Degradation |
| Sand Hills | Little White River 1 | 32%; 10.5/33  50%; 10.5/21 | Moderately Impaired / Moderate Degradation |
| Little White River 2 | 100%; 33/33  100%; 33/33 | Non-Impaired / No Change |
| Little White River 3 | 73%; 24/33  73%; 24/33 | Moderately Impaired / Moderate Degradation |
| Wolf Creek | 55%; 18/33  100%; 18/18 | Moderately Impaired / No Change |
| Wounded Knee Creek 1 | 64%; 21/33  64%; 21/33 | Moderately Impaired / Moderate Degradation |
|  |  |  |  |  |

*\* 2008 and 2010 High Plains watersheds were assessed against the 2008 and Great Plains watershed with the greatest stream health score.*

## 5.1 Upper White River Subwatershed Results

The Upper White River Subwatershed was sampled in 2011. All White Clay Creek stations (WCC1) declined significantly when comparing 1990s to 2000s stream health metrics (1990s mean = 19, st. dev = 4.9, n = 6; 2000s mean = 7, st. dev. = 1.7, n = 3). Stream health in Wolf Creek (WOL1) improved when comparing 1990s to 2000s stream health metrics. The White River above the confluence with White Clay Creek (WHR1) did not change from the 1990s to the 2000s. However, the White River below the confluence with White Clay Creek (WHR2) declined from an average score of 26 in the 1990s to a score of 15 in 2011. The upstream to downstream changes along White Clay Creek in 2010 indicate water quality impairments throughout the stream with the most common declines in EPT Index, %EPT, FBI, and % Dipterans and Non-Insects. Several macroinvertebrate stream health metrics declined from WHR1 to WHR2 including taxa richness, EPT Index, %EPT, FBI, % Dominant Family and % Dipterans and Non-insects.

The percentage of collector gatherer waters increased causing a decline in the % collector-gatherer quality parameter as the dominant family shifted from the Ephemeropteran Baetidae collector-gatherer family dominated from at WHR1 to the Dipteran Simuliidae filterer-gatherer family dominated at WHR2.

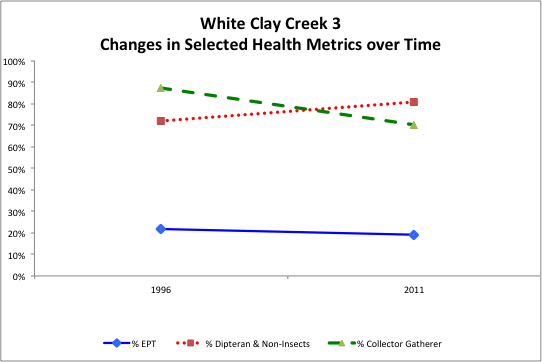
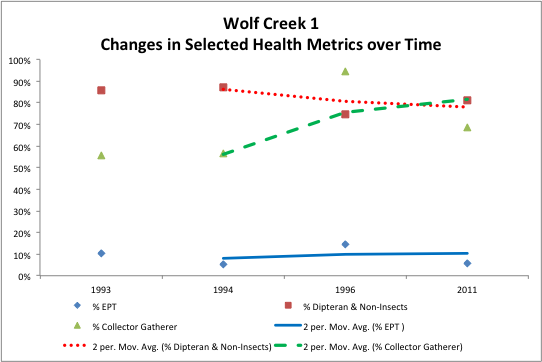
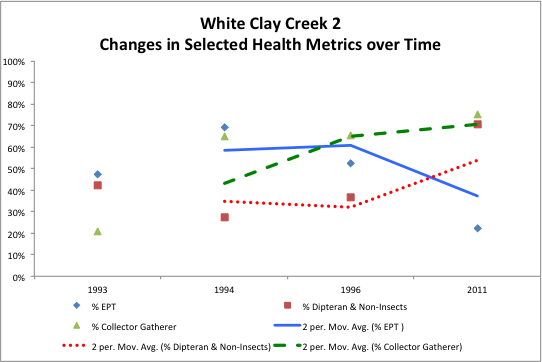
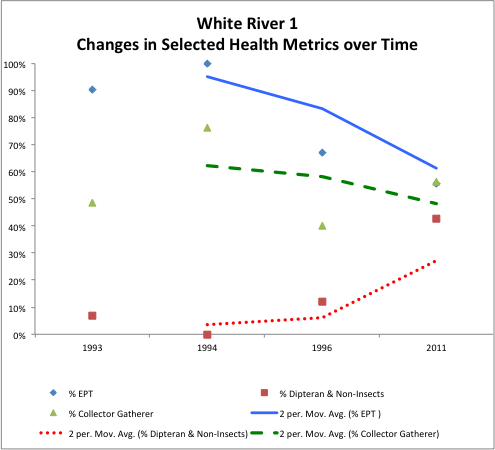
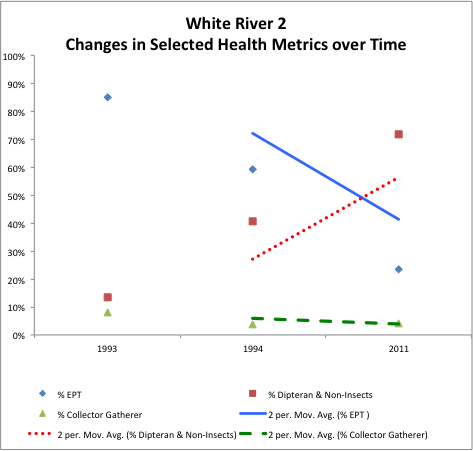


Figure : Changes in Upstream White River Subwatershed Health Metrics over Time

Stream health of upper White River (WHR1) is designated non-impaired relative to other Badlands streams sampled in 2011 (100%, 27 of 27). WHR1 stream health declined from 1996 to 2011 from a total score of 27 to a total score 33, with a corresponding change from Hydroptilidae dominated to Baetidae dominated. The long-term average health of WHR1 is 28.5. Taxa richness increased from 12 to 13, with a long-term average of 10.0.The EPT Index declined from 7 to 3 taxa. The %EPT declined from 67% to 56% with a long-term average of 78%, Family Biotic Index increased from 4.2 to 5.2 with a long term average of 4.4, %Dominant Family decreased from 32% to 25% with a long term average of 41%, %Dipterans and Non-insects increased from 12% to 43% with a long-term average of 15% and %Collector Gatherers increased from 40% to 57% with a long-term average of 55%.

Stream health of upper White Clay Creek (WCC1) is designated moderately impaired relative to other Great Plains streams sampled in 2011 (25%, 6 of 24). WCC1 stream health declined from 1996 to 2011 from a total score of 18 to a total score 6, with a corresponding change from Brachecentridae dominated to Oligochaeta dominated. The long-term average health of WCC1 is 13.0. The EPT Index declined from 4 to 3 taxa. The %EPT declined from 48% to 6% with a long-term average of 23%, Family Biotic Index increased from 5.0 to 8.3 with a long term average of 6.2, %Dominant Family increased from 40% to 48% with a long term average of 51%, %Dipterans and Non-insects increased from 49% to 94% with a long-term average of 74% and %Collector Gatherers increased from 54% to 66% with a long-term average of 46%. However, taxa richness increased from 8 to 9, with a long term average of 9.0.

Stream health of Wolf Creek (WOL1) is designated moderately impaired relative to other Sandhills streams sampled in 2011 (55%, 18 of 33). WOL1 stream health improved from 1996 to 2011 from a total score of 9 to a total score 18, with a corresponding change from Gammaridae dominated to Chironomidae dominated. The long-term average health of WCC1 is 11.3. Taxa richness increased from 10 to 7, with a long-term average of 11.8. The EPT Index increased from 2 to 6 taxa. The %EPT declined from 15% to 6% with a long-term average of 21%, Family Biotic Index increased from 5.4 to 6.4 with a long term average of 6.4, %Dominant Family increased from 55% to 60% with a long term average of 45%, %Dipterans and Non-insects increased from 75% to 94% with a long-term average of 77%. Percent Collector Gatherers decreased from 84% to 68% with a long-term average of 72%, due to the emergence of dipteran Simuladae and bivalve Sphaeriidae taxa.

Stream health of middle White Clay Creek (WCC2) is designated moderately impaired relative to other Great Plains streams sampled in 2011 (38%, 9 of 24). WCC2 stream health declined from 1996 to 2011 from a total score of 24 to a total score 9, with a corresponding change from Hydropsychidae dominated to Chironomidae dominated. The long-term average health of WCC1 is 19.5. Taxa richness decreased from 12 to 7, with a long-term average of 8.5. The EPT Index declined from 6 to 1 taxa. The %EPT declined from 52% to 22% with a long-term average of 48%, Family Biotic Index increased from 5.3 to 6.0 with a long term average of 5.3, %Dominant Family increased from 29% to 49% with a long term average of 37%, %Dipterans and Non-insects increased from 37% to 71% with a long-term average of 47% and %Collector Gatherers increased from 66% to 75% with a long-term average of 57%.

Stream health of middle White Clay Creek (WCC3) is designated moderately impaired relative to other Great Plains streams sampled in 2011 (25%, 6 of 24). WCC3 stream health declined from 1994 to 2011 from a total score of 12 to a total score 6, with a corresponding change from Chironomidae dominated to Oligochaeta dominated. The long-term average health of WCC1 is 9.0. Taxa richness decreased from 9 to 5, with a long-term average of 7. The EPT Index declined from 3 to 1 taxa. The %EPT declined from 22% to 19% with a long-term average of 21%, Family Biotic Index increased from 6.3 to 7.2 with a long term average of 6.7, %Dominant Family decreased from 47% to 40% with a long term average of 44%, %Dipterans and Non-insects increased from 72% to 81% with a long-term average of 77%. Percent Collector Gatherers decreased from 66% to 75% with a long-term average of 57%, due to the emergence of dipteran Simuladae taxa.

Stream health of the White River below the White Clay Creek confluence (WHR2) is designated moderately impaired relative to other Badlands streams sampled in 2011 (56%, 15 of 27). WHR2 stream health declined from 1994 to 2011 from a total score of 21 to a total score 15, with a corresponding change from Heptageniidae dominated to Simuliidae dominated. The long-term average health of WHR2 is 28.5. Taxa richness increased from 6 to 9, with a long-term average of 7.7. The EPT Index remained at 4 taxa. The %EPT declined from 59% to 23% with a long-term average of 56%, Family Biotic Index increased from 4.9 to 5.5 with a long term average of 4.5, %Dominant Family increased from 41% to 70% with a long term average of 57%, %Dipterans and Non-insects increased from 41% to 72% with a long-term average of 42% and %Collector Gatherers remained at 4%, with a long-term average of 5%.

## 5.2 White River / Wounded Knee Creek Subwatershed Results

Wounded Knee Creek was sampled in 2010 and 2011. Wounded Knee Creek headwaters (WOK1) improved significantly in 1990s to 2000s samples (Figure 22). However, stream health declined from 2010 to 2011 (Table 20). Mid-order Wounded Knee Creek stations in the Great Plains ecoregion (WOK2 and WOK3) are designated moderately impaired in 2010. Wounded Knee Creek 2 (WOK2) improved slightly in 2011 and was designated as non-impaired. However, several health metrics declined in 2011 and WOK3 remained moderately impaired. Wounded Knee Creek 4 (WOK4) was designated moderately impaired in both 2010 and 2011.

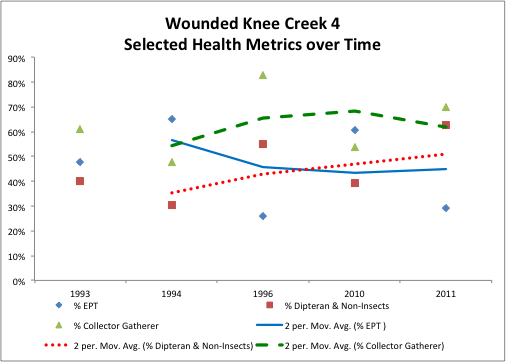
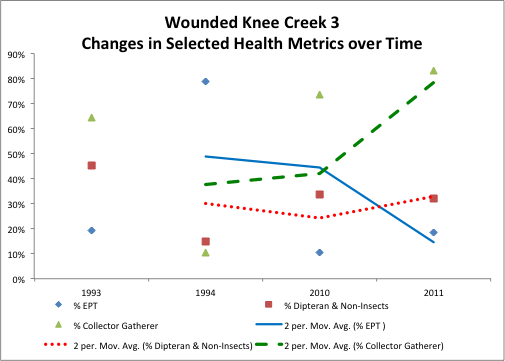
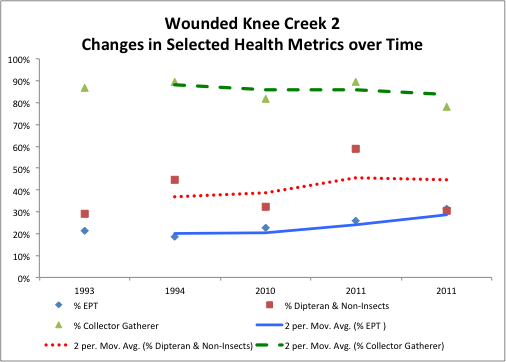


Figure : Changes in Wounded Knee Creek Health Metrics over Time

Stream health of upper Wounded Knee Creek (WOK1) is designated moderately impaired relative to other Sandhills streams sampled in 2011 (64%, 21 of 33). WOK1 stream health declined from 2010 to 2011 from a total score of 33 to a total score 21, with a corresponding change from Brachecentridae dominated to Baetidae dominated. The long-term average health of WOK1 is 18.75. The %EPT declined from 93% to 64% with a long-term average of 51%, Family Biotic Index increased from 1.4 to 4.1 with a long term average of 4.7, %Dipterans and Non-insects increased from 39% to 63% with a long-term average of 62% and %Collector Gatherers increased from 54% to 70% with a long-term average. However, taxa richness increased from 11 to 13, and %Dominant Family decreased from 89% to 36%.

Stream health of middle Wounded Knee Creek (WOK2) is designated non-impaired relative to other Great Plains streams sampled in 2011 (24 of 24, 100%). WOK2 stream health improved slightly from 2010 to 2011 from a total score of 21 to a total score of 24, with Elmidae and Chironomidae as co-dominant. The long-term average health of WOK2 is 21.6. The %EPT increased slightly from 23% to 26% with a long-term average of 20%, Family Biotic Index decreased slightly from 4.7 to 4.6 with a long-term average of 4.8. Taxa richness remained at 13 in 2008 and 2011, with a long-term average of 13.3. However, Dipterans and Non-insects increased from 32% to 59% with a long-term average of 40% and %Collector Gatherers increased slightly from 82% to 90%, with a 90% long-term average, and %Dominant Family increased from 44% to 50%.

Stream health of middle Wounded Knee Creek (WOK3) is designated moderately impaired relative to other Great Plains stations sampled in 2011 (75%, 18 of 24). Stream health at WOK3 was stable from 2010 to 2011 with total score of 18 for both years and continues to be Elmidae dominated. The long-term average health of WOK3 is 21.0. Taxa Richness declined from 12 to 8 in 2010 and 2011, respectively, with a long-term average of 9 families. EPT Index increased from 3 in 2010 to 5 in 2011. The %EPT increased slightly from 11% to 19% in 2010 and 2011, respectively, with a long-term average of 30%. Family Biotic Index decreased slightly from 4.7 to 4.3 in 2010 to 2011, respectively, with a long-term average of 3.7. The %Dominant Family decreased from 55% to 49% in 2010 to 2011, respectively. %Dipterans and Non-insects decreased from 34% to 32% in 2010 to 2011, respectively, with a long-term average of 30%. The %Collector Gatherers increased from 74% to 83% in 2010 to 2011, respectively, with a long-term average of 60%.

Stream health of lower Wounded Knee Creek (WOK4) is designated moderately impaired relative to other Badlands stations (44%, 12 of 27). Stream health at Wounded Knee 4 declined from 2010 to 2011 from a total score of 21 to a total score of 12 with a corresponding change from Brachycentridae dominated to Chironomidae dominated. The long-term average stream health for WOK4 is 22.2. The %EPT decreased from 61% to 29% with a long-term average of 50%, FBI increased from 4.12 to 7.67 with a long-term average of 5.5. Dipterans and non-insects increased slightly from 39% to 63% with a long-term average of 50% and %collector gatherers increased from 54% to 70% with a long term average of 60%. Taxa richness increased from 8 to 11 with a long-term average of 10.6 and %dominant family increased from 34% to 41% with a long-term average of 30%.

The Porcupine Creek watershed was sampled in 2010 and 2011. Porcupine Creek headwaters in the Great Plains ecoregon (POR1) significantly declined in 1990s to 2000s samples (Figure 23). The mid-order Porcupine Creek station in the Great Plains ecoregion (POR2) moderately declined in 1990s to 2000s samples. The lower Porcupine Creek 3 (POR3) was designated moderately impaired in 2010 and improved in 2011.

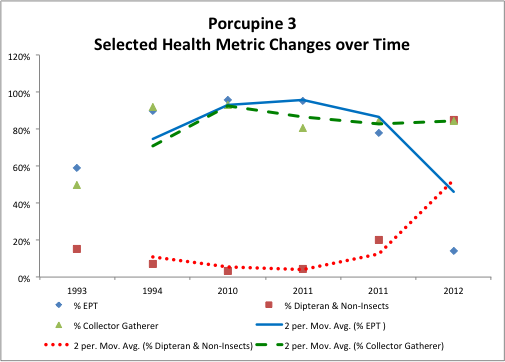
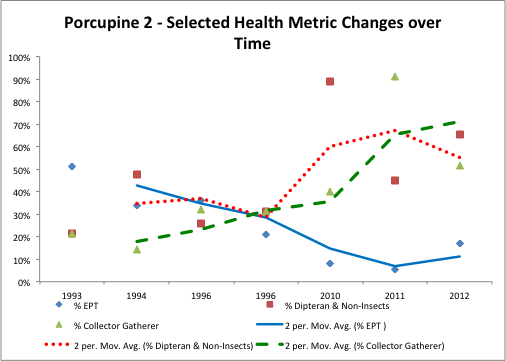
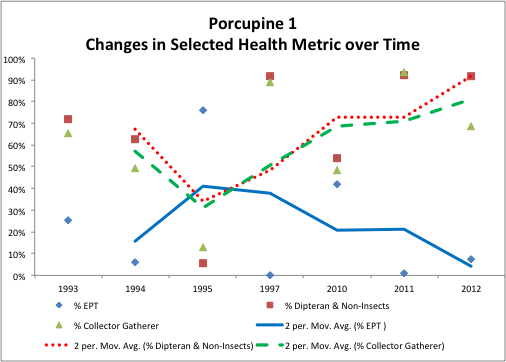


Figure : Porcupine Creek watershed changes in %EPT, %Diperan and Non-Insect, and %Collector Gatherer metrics over time

Stream health of upper Porcupine Creek (POR1) is designated moderately impaired relative to other Great Plains streams sampled in 2010 (73%, 24 of 33) and 2011 (25%, 6 of 24). POR1 stream health declined from 2010 to 2011 from a total score of 24 to a total score of 6. The macroinvertebrate community changes rapidly between 1993 to 2011 from Brachycentridae dominated in years with high stream health to Taltridae, Gammaridae, or Chironomidae dominated in years with low stream health. The long-term average health of POR1 is 15.9. Taxa richness increased from 9 to 10, with a long-term average of 11.4. The %EPT declined from 44% to 1% with a long-term average of 23%, Family Biotic Index increased from 4.4 to 6.1 with a long term average of 5.3, %Dominant Family increased from 34% to 83% with a long-term average of 52%, %Dipterans and Non-insects increased from 53% to 92% with a long-term average of 67%, and %Collector Gatherers increased from 51% to 94% with a long-term average of 62%.

Stream health of middle Porcupine Creek (POR2) is designated moderately impaired relative to other Great Plains streams sampled in 2010 (36%, 12 of 33) and 2011 (38%, 9 of 24). POR2 stream health remained steady from 2010 to 2011 from a total score of 12 for both years. However, POR2 stream health average score is degraded compared to 1990’s samples (n = 4) with an average score of 30, and a long-term average sore of 21.4. The macroinvertebrate community changes from 1993 to 2011 from Perlidae dominated to coleopteran dominated (Hydraenidae and Elmidae) and dipteran dominated (Simulidae). From 2010 to 2011, taxa richness increased from 6 to 9, with a long-term average of 10.0. the EPT index increased from 1 to 2, with a long-term average of 2.4, the %EPT declined from 8% to 6% with a long-term average of 17%, Family Biotic Index increased from 6.3 to 5.2 with a long term average of 5.3, %Dominant Family increased from 50% to 39% with a long-term average of 23%, %Dipterans and Non-insects decreased from 89% to 45% with a long-term average of 46%, and %Collector Gatherers increased from 41% to 91% with a long-term average of 41%.

Stream health of lower Porcupine Creek (POR3) is designated moderately impaired relative to other Badland streams sampled in 2010 (60%, 24 of 30) and non-impaired in 2011 (89%, 24 of 27). POR3 stream health increased from 2010 to 2011 from a total score of 18 to a total score of 24, and a long-term average score of 20.5. The macroinvertebrate community was Tricorythidae dominated in 1993 and Baetidae dominated from 1994 to 2011. From 2010 to 2011, taxa richness increased from 5 to 8, with a long-term average of 7.8, the EPT index increased from 2 to 3.5, with a long-term average of 3.2, the %EPT declined from 95% to 78% with a long-term average of 72%, Family Biotic Index increased from 4.1 to 4.3 with a long term average of 4.6, %Dominant Family decreased from 91% to 76% with a long-term average of 73%, %Dipterans and Non-insects increased from 3% to 13% with a long-term average of 23%, and %Collector Gatherers decreased from 91% to 82% with a long-term average of 80%.

## 5.6 White River / Medicine Root Crek Subwatershed Results

The Medicine Root Creek Subwatershed was sampled in 2008. Medicine Root Creek headwaters (MER1 in the High Plains ecoregion and AMH1 and NFL1 in the Great Plains ecoregion) are at different states (Table 20) with MER1 and AMH1 designated as moderately impaired and NFL1 designated as non-impaired. The mid-order Medicine Creek station in the transition from Great Plains ecoregion to Badlands ecoregion (MER3) is designated severely impaired. The lower Medicine Root Creek station (MER4) is designated non-impaired. The White River station and its tributary, Red Water Creek are designated moderately impaired.

Stream health of American Horse Creek (AMH1) is designated moderately impaired relative to other Great Plains streams sampled in 2008 (38%, 9 of 24). AMH1 stream health decreased from 1996 to 2008 from a total score of 30 to a total score of 9, and a long-term average score of 22.5. The macroinvertebrate community changed from Hydropsychidae dominated in 1996 and Chironomidae dominated in 2008. From 1996 to 2008, taxa richness increased from 8 to 10, with a long-term average of 9.3, the EPT index decreased from 3 to 1, with a long-term average of 2.8, the %EPT declined from 61% to 1% with a long-term average of 45%, Family Biotic Index increased from 4.7 to 6.7 with a long term average of 5.0, %Dominant Family remained steady at 46% with a long-term average of 45%, %Dipterans and Non-insects increased from 10% to 95% with a long-term average of 37%, and %Collector Gatherers increased from 48% to 92% with a long-term average of 66%.

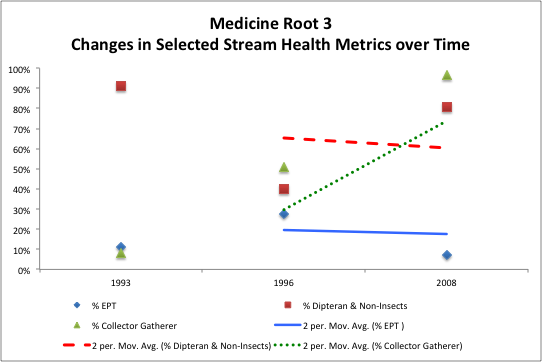
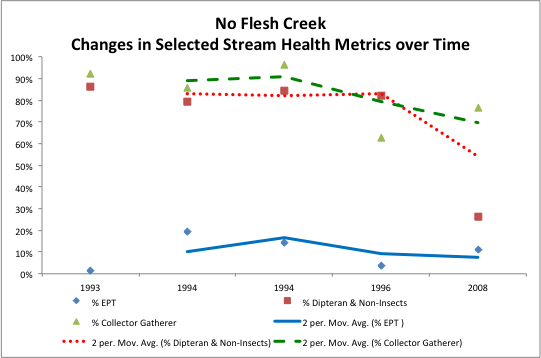
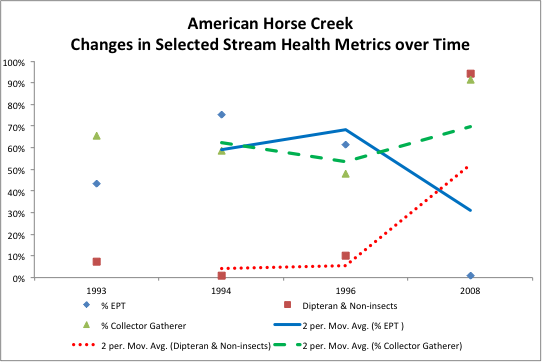
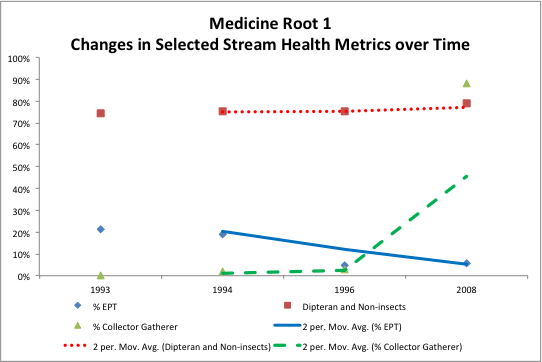


Figure : Medicine Root Creek Subwatershed changes in %EPT, %Diperan and Non-Insect, and %Collector Gatherer metrics over time

Stream health of the Medicine Root Creek headwaters (MER1) is designated moderately impaired relative to other Great Plains streams sampled in 2008 (25%, 6 of 24). MER1 stream health decreased from 1996 to 2008 from a total score of 21 to a total score of 6, and a long-term average score of 16.5. The macroinvertebrate community changed from Athericidae dominated in 1996 to Oligichaeta dominated in 2008. From 1996 to 2008, taxa richness decreased from 17 to 10, with a long-term average of 11.5, the EPT index remained steady at 2, with a long-term average of 2.3, the %EPT increased from 5% to 6% with a long-term average of 13%, Family Biotic Index increased from 3.6 to 7.7 with a long term average of 5.0, %Dominant Family decreased from 59% to 52% with a long-term average of 49%, %Dipterans and Non-insects increased from 75% to 79% with a long-term average of 76%, and %Collector Gatherers increased from 3% to 88% with a long-term average of 23%.

Stream health of No Flesh Creek (NFL1) is designated non-impaired relative to other Great Plains streams sampled in 2008 (100%, 24 of 24). NFL1 stream health increased from 1996 to 2008 from a total score of 15 to a total score of 24, and a long-term average score of 10.8. The macroinvertebrate community changed from Gammaridae dominated in 1996 to Elmidae dominated in 2008. From 1996 to 2008, taxa richness increased from 11 to 19, with a long-term average of 10.6, the EPT index increased from 3 to 7, with a long-term average of 3.4, the %EPT increased from 3.8% to 11.3% with a long-term average of 10%, Family Biotic Index decreased from 6.7 to 4.5 with a long term average of 6.6, %Dominant Family increased from 45% to 62% with a long-term average of 59%, %Dipterans and Non-insects decreased from 82% to 26% with a long-term average of 72%, and %Collector Gatherers increased from 63% to 77% with a long-term average of 83%.

Stream health of middle Medicine Root Creek (MER3) is designated moderately impaired relative to other Badlands streams sampled in 2008 (25%, 6 of 24). MER3 stream health decreased from 1996 to 2008 from a total score of 18 to a total score of 6, and a long-term average score of 13.0. The macroinvertebrate community remained Chironomidae dominated from 1996 to 2008. From 1996 to 2008, taxa richness decreased from 14 to 8, with a long-term average of 8.7, the EPT index remained steady at 2, with a long-term average of 2.0, the %EPT decreased from 28% to 7% with a long-term average of 15%, Family Biotic Index increased from 5.4 to 6.2 with a long term average of 5.9, %Dominant Family increased from 58% to 63% with a long-term average of 58%, %Dipterans and Non-insects increased from 40% to 81% with a long-term average of 71%, and %Collector Gatherers increased from 51% to 96% with a long-term average of 52%.

Stream health of lower Medicine Root Creek (MER4) is designated moderately impaired relative to other Badlands streams sampled in 2008 (100%, 24 of 24). Medicine Root 4 was first monitored in 2008. The macroinvertebrate community of Medicine Root 4 in 2008 is hydrophychidae dominated.

Stream health of Red Water Creek (RED1) is designated moderately impaired relative to other Great Plains streams sampled in 2008 (75%, 18 of 24). RED1 stream health increased from 1996 to 2008 from a total score of 15 to a total score of 18, and a long-term average score of 15.8. The macroinvertebrate community changed from Gammaridae dominated in 1996 to Simulidae dominated in 2008. From 1996 to 2008, taxa richness increased from 14 to 20, with a long-term average of 15.8, the EPT index increased from 2 to 3, with a long-term average of 2.5, the %EPT decreased from 19% to 12% with a long-term average of 10%, Family Biotic Index decreased from 6.4 to 5.6 with a long term average of 6.4, %Dominant Family increased from 33% to 37% with a long-term average of 39%, %Dipterans and Non-insects increased from 54% to 75% with a long-term average of 66%, and %Collector Gatherers decreased from 68% to 46% with a long-term average of 58%.

Stream health of White River near the Medicine Root Creek confluence (WHR3) is designated moderately impaired relative to other Badlands streams sampled in 2008 (100%, 24 of 24). WHR3 was first monitored in 2008. The macroinvertebrate community of WHR3 in 2008 is almost (99%) Simulidae dominated.

## 5.6 White River / Pass Creek Subwatershed Results

The main stem of the Pass Creek subwatershed was sampled in 2010. Pass Creek headwaters (PAS1 in the High Plains ecoregion and BUZ1 in the Great Plains ecoregion) are at different states (Table 20) with PAS1 designated as non-impaired and BUZ1 designated as severely impaired. The mid-order Pass Creek station (PAS2 in the High Plains ecoregion) is designated non-impaired. The lower Pass Creek station (PAS3 in the Badlands) is designated non-impaired. The Black Pipe tributary of the White River is designated non-impaired.

Stream health of the Pass Creek headwaters (PAS1) is designated non-impaired relative to Great Plains streams sampled in 2010 (100%, 33 of 33). PAS1 stream health decreased from 1996 to 2010 from a total score of 36 to a total score of 33, and a long-term average score of 31. The macroinvertebrate community changed from Brachycentridae dominated in 1996 to Leptceridae dominated in 2010. From 1996 to 2010, taxa richness increased from 14 to 16, with a long-term average of 13.3, the EPT index increased from five families in 1996 to six families in 2010, with a long-term average of 5.0, the %EPT decreased from 66% to 58% with a long-term average of 59%, Family Biotic Index increased from 2.9 to 4.9 with a long term average of 4.0, %Dominant Family decreased from 52% to 25% with a long-term average of 41%, %Dipterans and Non-insects increased from 20% to 42% with a long-term average of 34%, and %Collector Gatherers increased from 30% to 53% with a long-term average of 44%.

Stream health of Buzzard Creek (BUZ1) is designated severely impaired relative to Great Plains streams sampled in 2010 (18%, 6 of 33). BUZ1 stream health decreased from 1996 to 2010 from a total score of 15 to a total score of 3, and a long-term average score of 9. The macroinvertebrate community changed from Hydropsychidae dominated in 1996 to Taltridae dominated in 2010. From 1996 to 2010, taxa richness decreased from 12 to 7, with a long-term average of 8.3, the EPT index increased from two families in 1996 to four families in 2010, with a long-term average of 2.3, the %EPT decreased from 38% to 15% with a long-term average of 19%, Family Biotic Index increased from 5.0 to 7.3 with a long term average of 6.2, %Dominant Family decreased from 38% to 65% with a long-term average of 48%, %Dipterans and Non-insects increased from 51% to 69% with a long-term average of 67%, and %Collector Gatherers increased from 29% to 71% with a long-term average of 63%.

Stream health of middle Pass Creek (PAS2) is designated non-impaired relative to other Great Plains streams sampled in 2010 (100%, 33 of 33). PAS2 stream health increased from 1996 to 2010 from a total score of 18 to a total score of 33, and a long-term average score of 28. The macroinvertebrate community changed from Cecidumyiidae dominated in 1996 to Hydropsychidae dominated in 2010. From 1996 to 2010, taxa richness decreased from 13 to 12, with a long-term average of 10.8, the EPT index increased from two families in 1996 to four families in 2010, with a long-term average of 3.5, the %EPT increased from 3% to 85% with a long-term average of 51%, Family Biotic Index decreased from 5.9 to 4.1 with a long term average of 3.8, %Dominant Family increased from 43% to 59% with a long-term average of 52%, %Dipterans and Non-insects decreased from 79% to 7% with a long-term average of 26%, and %Collector Gatherers increased from 17% to 26% with a long-term average of 15%.

Stream health of lower Pass Creek (PAS3) is designated non-impaired relative to other Great Plains streams sampled in 2010 (100%, 30 of 30). PAS3 stream health increased from 1996 to 2010 from a total score of 18 to a total score of 30, and a long-term average score of 15.8. The macroinvertebrate community changed from Leptophlebiidae dominated in 1996 to Baetidae dominated in 2010. From 1996 to 2010, taxa richness increased from six to nine, with a long-term average of 6.0, the EPT index increased from two families in 1996 to five families in 2010, with a long-term average of 2.3, the %EPT decreased from 81% to 62% with a long-term average of 55%, Family Biotic Index decreased from 4.9 to 4.6 with a long term average of 5.2, %Dominant Family decreased from 75% to 27% with a long-term average of 60%, %Dipterans and Non-insects increased from 14% to 36% with a long-term average of 31%, and %Collector Gatherers increased from 80% to 41% with a long-term average of 65%.

Stream health of lower Black Pipe Creek (BLP1) is designated non-impaired relative to other Great Plains streams sampled in 2010 (91%, 30 of 33). BLP1 stream health remained steady from 1996 to 2010 with a total score of 30, and a long-term average score of 29.3. The macroinvertebrate community remained Brachycentridae dominated between 1996 and 2010. From 1996 to 2010, taxa richness increased from 8 to 11, with a long-term average of 9.5, the EPT index increased from three families in 1996 to five families in 2010, with a long-term average of 3.3, the %EPT decreased from 81% to 70% with a long-term average of 71%, Family Biotic Index increased from 1.7 to 3.0 with a long term average of 2.5, %Dominant Family decreased from 79% to 61% with a long-term average of 67%, %Dipterans and Non-insects increased from 4% to 24% with a long-term average of 18%, and %Collector Gatherers increased from 10% to 29% with a long-term average of 18%.

## 5.6 White River / Little White River Subwatershed Results

Stream health at upper Little White River (LWR1) is designated severely impaired relative to other Sandhills streams sampled in 2010 (18%, 6 of 33) and moderately impaired relative to other Sandhills streams sampled in 2011 (32%, 10.5 of 33). LWR1 stream health declined from 1996 to 2010 and 2011 from a total score of 21 to a total score of 6 in 2010, and a total score of 10.5 in 2011 and a long-term average score of 12.0. The macroinvertebrate community changed from Hydropsychidae dominant in 1996 and to Culcidae dominant in 2010 and Taltridae-Chironomidae co-dominant in 2011. From 1996 to 2010 and 2011, taxa richness decreased from 14 families in 1996 to 11 families in 2010 and an average of 10 families in 2011, with a long-term average of 9.3, the EPT Index declined from 4 families in 1996 to 1 family in 2010 and 2 families in 2011 with a long-term average of 1.5, the %EPT declined from 57% in 1996 to 10% in 2010 and 11.5% in 2011, with a long-term average of 15%, Family Biotic Index increased from 5.2 in 1996 to 7.4 in 2010 and an average of 6.4 in 2011, with a long-term average of 6.3, %Dominant Family decreased from 50% in 1996 to 64% in 2010 and an average of 37.5% in 2011, with a long-term average of 48%, %Dipteran & Non-insects increased from 39% in 1996 to 89% in 2010 and an average of 79% in 2011, with a long-term average of 80%, the %Collector Gatherer increased from 39% in 1996 to 80% in 2010 and 76% in 2011, with a long-term average of 47%.

Stream health at Little White River at Martin (LWR2) is designated non-impaired relative to other Sandhills streams sampled in 2011 (100%, 33 of 33). LWR2 stream health improved from 1996 to 2011 from a total score of 30 to a total score of 33 in 2011, with a long-term average score of 31.0. The LWR2 macroinvertebrate community changed from Siphlonuridae dominated to Caenidae dominated in 2011. From 1996 to 2010, taxa richness increased from 15 families in 1996 to 16 families in 2011, with a long-term average of 12.7, EPT Index increased from 8 families in 1996 to 10 families in 2011, with a long-term average of 7.3, the %EPT was steady from 1996 to 2011 at 78%, with a long-term average of 72%, Family Biotic Index decreased from 1996 to 2011 from 4.3 to 4.0, with a long-term average of 4.0. The %Dominant Family decreased from 1996 to 2011 from 33% to 24%, with a long-term average of 28%, %Dipteran & Non-insects decreased from 16% in 1996 to 13% in 2011, with a long-term average of 21%., the %Collector Gatherer increased from 1996 to 2011 from 55% to 62%, with a long-term average of 44%.

Stream health at Little White River at Tuthill (LWR3) is designated non-impaired relative to other Sandhills streams sampled in 2010 (100%, 33 of 33) and moderately impaired in 2011 (72%; 24/33). LWR3 stream health was steady between 1996 and 2010 (100%, 33 of 33) then moderately declined in 2011 (72%; 24 of 33), with a long-term average stream health score of 32. The LWR3 macroinvertebrate community was Oligoneuriidae dominated in 1996, changing to Polymitoreyidae dominated in 2010 and Caenidae dominated in 2011. From 1996 to 2011, Taxa Richness increased from 10 families in 1996 to and average of 12 families in 2010, then decreased to 10 families in 2011, with a long-term average of 11.2 families, EPT Index decreased from seven families in 1996 to an average of six families in 2010 and five families in 2011, with a long-term average of 5.8, the %EPT declined from 83% in 1996 to 81% in 2010 and 60% in 2011, with a long-term average of 81%, Family Biotic Index increased from 3.4 in 1996 to an average of 4.0 in 2010 and 6.0 in 2011, with a long-term average of 3.8, the %Dominant Family increased from 32% in 1996 to an average of 34.3% in 2010 and 39% in 2011, with a long-term average of 41%, the %Dipteran & Non-insects increased from 7% in 1996 to an average of 16.3% in 2010 and 21% in 2011, with a long-term average of 13%, the %Collector Gatherer increased from 29% in 1996 to an average of 66% in 2010 and 90% in 2011, with a long-term average of 54%.

Stream health at Little White River at Vetal (LWR4) is designated non-impaired relative to other Sandhills streams sampled in 2010 (82%; 27/33). LWR4 stream health between 1994 and 2010 was steady (100%; 27/27), with a long-term average stream health score of 29. The LWR4 macroinvertebrate community was Caenidae dominated in 1994 changing to Simuliidae dominated in 2010. From 1994 to 2010, Taxa Richness increased from 12 families in 1994 to 15 families in 2010, with a long-term average of 12, EPT Index decreased from seven families in 1994 to eight families in 2010, with a long-term average of 6.7 families. The %EPT declined from 88% in 1994 to 59% in 2011, with a long-term average of 72%. Family Biotic Index decreased from 5.4 in 1994 to 5.2 in 2010, with a long-term average of 4.6. The %Dominant Family decreased from 51% in 1994 to 29% in 2010, with a long-term average of 45%, the %Dipteran & Non-insects increased from 8% in 1994 to 36% in 2010, with a long-term average of 15%. The %Collector Gatherer decreased from 75% in 1994 to 63% in 2010, with a long-term average of 49%.

## 5.6 Cheyenne River Subwatershed Results

Stream health at the upstream Cheyenne River station (CHR1) is designated non-impaired in 2011 (92%, 36 of 39) relative to the downstream Cheyenne River station, with a long-term average health of 33.0. CHR1 health scores improved slightly relative to its maximum health in the 1990s (110%; 36 vs. 33). The CHR1 macroinvertebrate community changed from Helicopsychidae dominated in 1994 to Hydroptilidae dominated in 1996 and Heptageniidae dominated in 2011. From 1994 to 2010, Taxa Richness increased from 10 families in 1996 to 11 families in 2011, with a long-term average of 9.7, the EPT Index increased from 4 families in 1996 to 7 families in 2011, with a long-term average of 5.7, the %EPT increased from 80% in 1996 to 89% in 2011, with a long-term average of 87%, Family Biotic Index decreased from 4.3 in 1996 to 3.9 in 2011, with a long-term average of 4.0, the %Dominant Family increased from 40% in 1996 to 45% in 2011, with a long-term average of 43%, %Dipteran & Non-insects increased from 3% in 1996 to 7% in 2011, with a long-term average of 4%, the %Collector Gatherer decreased from 46% in 1996 to 39% in 2011, with a long-term average of 40%.

Stream health at the downstream Cheyenne River station (CHR2) is designated non-impaired in 2011 (100%, 39 of 39) relative to the upstream Cheyenne River station. The Cheyenne River 2 station was first sampled in 2011. The CHR1 macroinvertebrate community is Hydropsychidae dominated in 2011.

## 5.7 Macroinvertebrate Metric Analysis Results

I conducted an analysis of the macroinvertebrate stream health metrics to determine: 1) how effective individual the stream health variables: taxa richness, EPT index, %EPT, FBI, %Dominant Family, Dipteran and Non-Insect, and Collector Gatherer were in predicting effects of land use intensity, 2) if differences exist between ecoregions, and 3) if changes in stream health are occurring over time. Because independent measurements of land use intensity were unavailable, I used the life history for the dominant family in a macroinvertebrate sample to estimate the land use such that EPT dominant samples were classified as low intensity, non-EPT and non-dipteran and non-insect dominant samples were classified as moderate intensity, and dipteran and non-insect dominant samples were classified as high intensity. I used a multivariate analysis of variance (MANOVA) test in SPSS version 20 (IBM Corporation 2012) to test for differences in stream health between land use intensities, ecoregions and decades (Appendix B). I found that the combined stream health variables (e.g. the total stream health score) could detect differences in land use intensity, and ecoregion, as well as an interaction between ecoregion and land use. However, the combined stream health variables did not identify differences between 1990s and 2000s stream health scores. Univariate ANOVA tests and Tukey’s post-hoc tests were conducted as follow up tests to the MANOVA test. The follow-up tests indicate: 1) the stream health metrics: EPT Index, %EPT, FBI, %Dipteran and Non-Insect, and %Collector Gatherer metrics distinguish between the different land use intensities, however, Taxa Richness, and %Dominance did not detect land use intensity differences, 2) significant increase in FBI scores and %Collector Gatherers occurred between the 1990’s and 2000’s samples, 3) %EPT and %Collector Gather scores are significantly different when combining land use and ecoregion indicating that the Badlands ecoregion has higher %EPT and %Collector Gatherer scores than the other ecoregions with the same land use intensity.

## 5.8 Stream Flow and Stream Health Results

Stream health is correlated with annual stream flow volume. Annual stream flow in Pine Ridge Reservation streams vary by a wide magnitude. The annual stream flow for years in which macroinvertebrate samples were taken is 95,000 cubic feet, with low flows of 8,740 cubic feet (2008), and 34,600 cubic feet (2011) and high flows of 189,000 cubic feet (1996) and 154,000 cubic feet (2010) for the White River near Interior. Stream health was regressed against annual stream flow (Figure 25). A semi-log model best fit the data, explaining 11% of the variance in stream health.

## 6.0 Combined Stream Health Results

Figure : Individual stream health vs. annual flow at the White River at Interior.

A crosswalk of stream health and impairment status indicates stream health is broadly correlated with the number of impairments (Table 21). The prioritization metric scores a ‘1’ for each unimpaired water quality metric, a ‘2’ for a threatened state, and a ‘3’ for an impaired state. The metrics are then averaged to provide a total chemical score. Biological condition is treated in the same fashion to provide a total biological score. The two scores are added together to provide a total ranking value. A pristine section of stream would score a ‘2’ by the metric and a totally impaired section of stream would score a ‘6’. These data are quantified in tables 22 to 26 using the watershed prioritization metric developed by Matrix (2010).

The overall change in stream health over the previous period was a 3% overall improvement in combined stream health over the previous period. The improvement was caused by a 22% improvement in the Little White River subwatershed, a 13% improvement in the Pass Creek subwatershed, and an 11% improvement in the Wounded Knee Creek subwatershed. The Upper White River subwatershed declined by 18% and the Cheyenne River subwatershed declined by 10%. The Medicine Root subwatershed combined stream health improved by 1%.

Table 21: Cross-walk of Water Quality and Stream Health Results for Pine Ridge Reservation Streams 2008 – 2011

|  |  |  |  |
| --- | --- | --- | --- |
| **Watershed Name** | **Station Name** | **Stream Health** | **Impairment Status and Percentage** |
| Upper White River | White Clay Creek 1 | Moderately Impaired (25%) in 2011 | Impaired in Fecal Coliform (45%) and E-Coli (82%) in 2009 and 2011 samples |
| Wolf Creek | Moderately Impaired (75%) in 2011 | Impaired in E-Coli (18%) in 2009 and 2011 samples |
| White Clay Creek 2 | Moderately Impaired (38%) in 2011 | Impaired in Fecal Coliform (55%) and E-Coli (45%) in 2009 and 2011 samples |
| White Clay Creek 3 | Moderately Impaired (25%) in 2011 | Threatened in Fecal Coliform (33%) and E-Coli (56%) in 2009 and 2011 samples |
| White River 1 | Non-impaired (100%) in 2011 | Threatened in Fecal Coliform (83%) and E-coli (100%) in 2009 and 2011 samples |
| White River 2 | Moderately Impaired (56%) in 2011 | Threatened in Fecal Coliform (66%) and E-coli (83%) in 2009 and 2011 samples |
| White River/ Wounded Knee Creek Sub Watershed | Wounded Knee Creek 1 | Non-impaired in 2010 (100%) Moderately Impaired in 2011 (64%) | Impaired in Fecal Coliform (30%) and E-coli (40%) in 2008 and 2011 samples |
| Wounded Knee Creek 2 | Non-impaired (100%) in 2010 and 2011 | Threatened in Fecal Coliform (22%) and E-coli (11%) in 2008 and 2011 samples |
| Wounded Knee Creek 3 | Moderately Impaired (75%) in 2010 and 2011 | Impaired in Fecal Coliform (55%) and E-coli (45%) in 2008 and 2011 samples |
| Wounded Knee Creek 4 | Moderately Impaired (44%) in 2010 and 2011 | Impaired in Fecal Coliform (90%) and Total Suspended Solids (40%) in 2008 and 2011 samples Threatened in E-coli (78%) in 2008 and 2011 samples |
| Porcupine Creek 1 | Non-impaired (100%) in 2010 and 2011 | Impaired in Fecal Coliform (18%) in 2008 and 2011 samples |
| Porcupine Creek 2 | Moderately Impaired (38%) in 2010 and 2011 | Impaired in Fecal Coliform (27%) in 2008 and 2011 samples |
| Porcupine Creek 3 | Moderately Impaired (78%) in 2010 and 2011 | Impaired in Fecal Coliform (60%) and Threatened in E-coli (78%) in 2008 and 2011 samples |
| White River / Medicine Root Sub Watershed | American Horse Creek | Moderately Impaired (38%) in 2008 | Threatened in Fecal Coliform (50%) and E-coli (50%) in 2010 samples |
| No Flesh Creek | Non-impaired (100%) in 2008 | Non-impaired in 2010 samples |
| Medicine Root Creek 1 | Severely Impaired (25%) in 2008 | Threatened in E-coli (25%) in 2010 samples |
| Medicine Root Creek 3 | Severely Impaired (25%) in 2008 | Threatened in Fecal Coliform (20%) and E-coli (20%) in 2010 samples |
| Medicine Root Creek 4 | Non-impaired (100%) in 2008 | Threatened in Fecal Coliform (20%), E-coli (60%), and TSS (60%) in 2010 samples |
| White River 3 | Moderately Impaired (28%) in 2008 | Threatened in Fecal Coliform (75%), E-coli (100%) and TSS (25%) in 2010 samples |
| Red Water Creek | Moderately Impaired (75%) in 2008 | Threatened in Fecal Coliform (60%) and E-coli (80%) in 2010 samples |
| White River / Bear in the Lodge Subwatershed | Bear Creek 1 | No data | Threatened in Fecal Coliform (40%) and E-coli (60%) in 2008 samples |
| Bear Creek 2 | No data | Threatened in Fecal Coliform (100%), E-coli (100%), and TSS (20%) in 2008 samples |
| Bear Creek 3 | No data | Threatened in Fecal Coliform (100%), E-coli (100%) and TSS (20%) in 2008 samples |
| Bear in the Lodge Creek 1 | No data | Threatened in Fecal Coliform (60%), E-coli (80%) and TSS (60%) in 2008 samples |
| Bear in the Lodge Creek 2 | No data | Threatened in Fecal Coliform (100%), E-Coli (100%) and TSS (20%) in 2008 samples |
|  | Eagle Nest Creek 1 | No data | Threatened in Fecal Coliform (20%) and E-coli (40%) in 2008 samples |
| Eagle Nest Creek 2 | No data | Threatened in Fecal Coliform (100%), E-coli (100%) and TSS (100%) in 2008 samples |
| White River 5 | No data | Threatened in Fecal Coliform (75%) and E-coli (75%) in 2008 samples |
| White River Pass Creek Watershed | Pass Creek 1 | Non-impaired (100%) in 2010 | Threatened in Fecal Coliform (75%) and E-coli (100%) in 2009 samples |
| Pass Creek 2 | Non-impaired (100%) in 2010 | Threatened in Fecal Coliform (60%) and E-coli (100%) in 2009 samples |
| Pass Creek 3 | Non-impaired (100%) in 2010 | Threatened in Fecal Coliform (20%), E-coli (60%), and TSS (60%) in 2009 samples |
| Buzzard Creek | Severely Impaired (9%) in 2010 | Threatened in Fecal Coliform (60%) and E-coli (100%) in 2009 samples |
| Long Creek | No data | Threatened in Fecal coliform (20%) and E-coli (40%) in 2008 samples |
| White River 4 | No data | Threatened in Fecal Coliform (100%), E-coli (80%) and TSS (80%) in 2009 samples |
| Black Pipe | Non-impaired (91%) in 2010 | Threatened in Fecal Coliform (100%) and E-Coli (100%) in 2009 samples |
| White River / Little White River Watershed | Little White River 1 | Severely Impaired (18%) in 2010 and 2011 | Threatened in Fecal Coliform (60%), E-coli (80%) and TSS (20%) in 2009 samples |
| Little White River 2 | Non-impaired (100%) in 2011 | Threatened in Fecal Coliform (60%) and E-coli (100%) in 2009 samples |
| Little White River 3 | Non-impaired (100%) in in 2010 and 2011 | Threatened in Fecal Coliform (40%) and E-coli (60%) in 2009 samples |
| Little White River 4 | Non-Impaired (82%) in 2010 | Threatened in Fecal Coliform (40%), E-coli (100%) and TSS (60%) in 2009 samples |
| Cheyenne River Watershed | Cheyenne River 1 | Non-impaired (92%) in 2011 | Impaired in E-coli (36%) and TSS (36%) |
| Cheyenne River 2 | Non-impaired (100%) in 2011 | Impaired in Fecal Coliform (64%), E-coli (45%), and TSS (27%) |
|  |  |  |  |

Table 22: Watershed Prioritization of the Cheyenne River Subwatershed based on Chemical and Biological Metrics for Streams Sampled from 2008 – 2011



Table 23: Watershed Prioritization of the White Clay Creek Subwatershed based on Chemical and Biological Metrics for Streams Sampled from 2008 – 2011



Table 24: Watershed Prioritization of the White Clay Creek Subwatershed based on Chemical and Biological Metrics for Streams Sampled from 2008 – 2011



Table 25: Watershed Prioritization of the Medicine Root Creek Subwatershed based on Chemical and Biological Metrics for Streams Sampled from 2008 – 2011

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Year** | **Fecal Coliform** | **E-Coli** | **TSS** | **TN** | **TP** | **Fecal Coliform** | **E-Coli** | **TSS** | **TN** | **TP** | **Total Chem** | **Bio Condition** | **Total Ranking Value** |
| **AMH1** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 1.8 | 1 | **2.80** |
| **AMH1** | **2010** | 50% | 50% | 0% | 0% | 100% | 2 | 2 | 1 | 1 | 3 | 1.80 | *2* | ***3.80*** |
| **MER1** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 1.5 | 1 | **2.50** |
| **MER1** | **2010** | 0% | 25% | 0% | 0% | 0% | 1 | 1 | 1 | 1 | 1 | 1.00 | *2* | ***3.00*** |
| **NFL1** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2.00 | 2 | **4.00** |
| **NFL1** | **2010** | 0% | 0% | 0% | 0% | 25% | 1 | 1 | 1 | 1 | 1 | 1.00 | *1* | ***2.00*** |
| **MER3** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2.40 | 2 | **4.40** |
| **MER3** | **2010** | 20% | 20% | 0% | 0% | 100% | 1 | 1 | 1 | 1 | 3 | 1.40 | 2 | ***3.40*** |
| **MER4** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | No Data | No Data |  |
| **MER4** | **2010** | 20% | 60% | 60% | 0% | 80% | 1 | 2 | 2 | 1 | 3 | 1.80 | 1 | **2.80** |
| **WHR3** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2 | 1 | **3.00** |
| **WHR3** | **2010** | 75% | 100% | 25% | 25% | 100% | 3 | 3 | 1 | 1 | 3 | 2.20 | 2 | ***4.20*** |
| **RED1** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2.25 | 2 | **4.25** |
| **RED1** | **2010** | 60% | 80% | 0% | 0% | 80% | 2 | 3 | 1 | 1 | 3 | 2.00 | 2 | ***4.00*** |

Table 26: Watershed Prioritization of the Bear Creek Subwatershed based on Chemical and Biological Metrics for Streams Sampled from 2008 – 2011

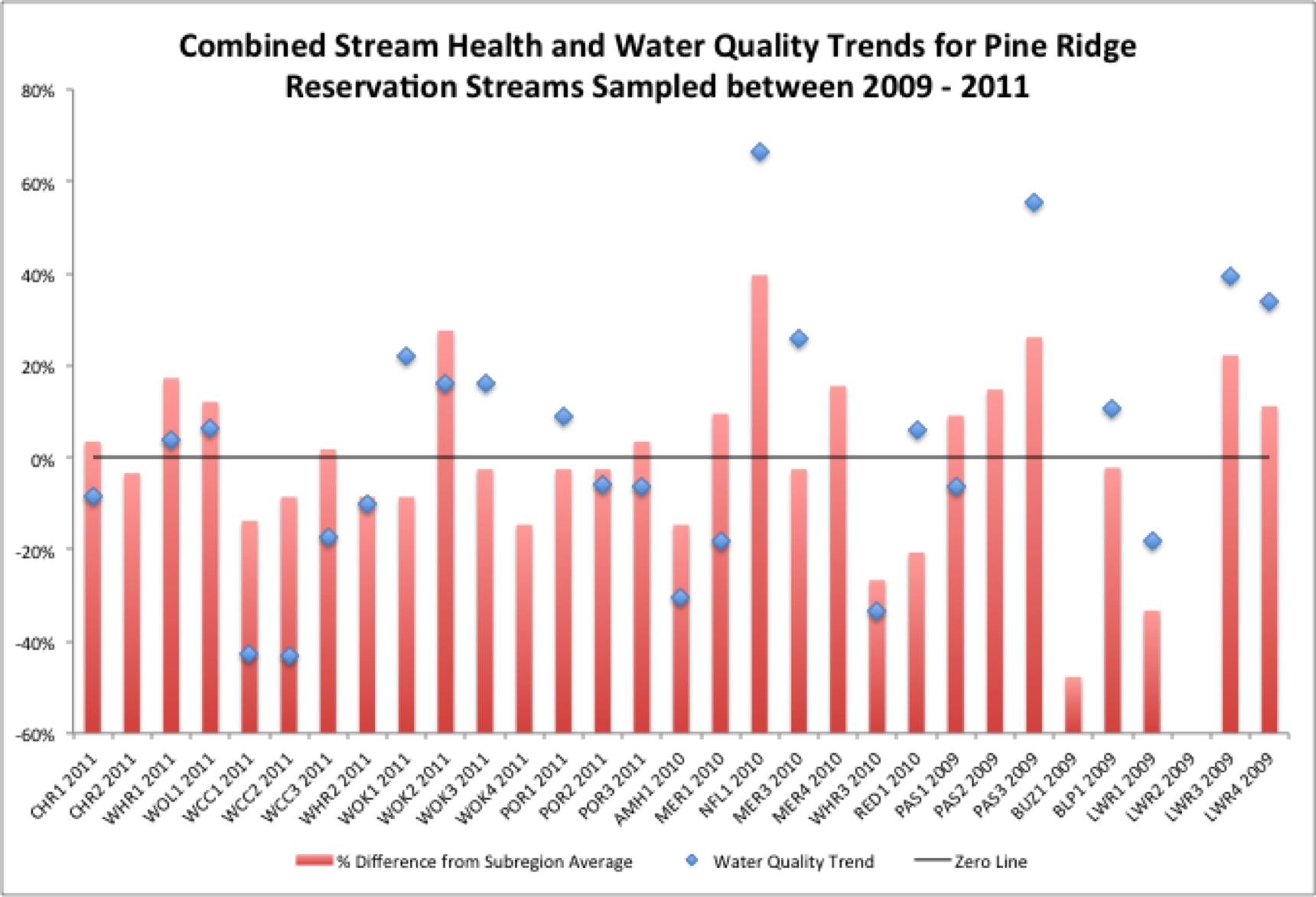
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Year** | **Fecal Coliform** | **E-Coli** | **TSS** | **TN** | **TP** | **Fecal Coliform** | **E-Coli** | **TSS** | **TN** | **TP** | **Total Chem** | **Bio Condition** | **Total Ranking Value** |
| **BEA1** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2 | 2 | ***4.00*** |
| **BEA1** | **2008** | 25% | 50% | 0% | 0% | 0% | 1 | 2 | 1 | 1 | 1 | 1.20 | No Data |  |
| **BEA2** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2.14 | 2 | ***4.14*** |
| **BEA2** | **2008** | 100% | 100% | 20% | 0% | 0% | 3 | 3 | 1 | 1 | 1 | 1.80 | No Data |  |
| **BEA3** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2.8 | 2 | ***4.80*** |
| **BEA3** | **2008** | 75% | 100% | 60% | 0% | 100% | 3 | 3 | 2 | 1 | 3 | 2.40 | No Data |  |
| **BLC1** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2.2 | 1 | ***3.20*** |
| **BLC1** | **2008** | 50% | 50% | 20% | 0% | 100% | 2 | 2 | 1 | 1 | 3 | 1.80 | No Data |  |
| **BLC2** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2.08 | 2 | ***4.08*** |
| **BLC2** | **2008** | 100% | 100% | 20% | 20% | 50% | 3 | 3 | 1 | 1 | 2 | 2.00 |  |  |
| **EAN1** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | No Data | No Data |  |
| **EAN1** | **2008** | 0% | 0% | 0% | 0% | 100% | 1 | 1 | 1 | 1 | 3 | 1.40 | No Data |  |
| **EAN2** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2.25 | 2 | ***4.25*** |
| **EAN2** | **2008** | 100% | 100% | 100% | 100% | No Data | 3 | 3 | 3 | 3 | 3 | 3.00 | No Data |  |
| **LOD1** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2.2 | 2 | ***4.20*** |
| **LOD1** | **2008** | 0% | 25% | 20% | 0% | 75% | 1 | 1 | 1 | 1 | 3 | 1.40 | No Data |  |
| **LOD1** | **2010** | 25% | 25% | 0% | 0% | 80% | 1 | 1 | 1 | 1 | 3 | 1.40 | No Data |  |
| **POT1** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 1.86 | 2 | ***3.86*** |
| **POT1** | **2008** | 33% | 60% | 20% | 0% | 33% | 2 | 2 | 1 | 1 | 2 | 1.60 | No Data |  |
| **POT1** | **2010** | 40% | 60% | 0% | 0% | 100% | 2 | 2 | 1 | 1 | 3 | 1.80 | No Data |  |
| **COR1** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2 | 2 | ***4.00*** |
| **COR1** | **2008** | 50% | 100% | 0% | 0% | 66% | 2 | 3 | 1 | 1 | 3 | 2.00 | No Data |  |
| **WHR5** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | No Data | No Data | ***No Data*** |
| **WHR5** | **2008** | 75% | 50% | 50% | 25% | 100% | 3 | 2 | 2 | 1 | 3 | 2.20 | No Data |  |

Table 27: Watershed Prioritization of the Pass Creek Subwatershed based on Chemical and Biological Metrics for Streams Sampled from 2008 – 2011

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **PAS1** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2 | 1 | ***3.00*** |
| **PAS1** | **2009** | 80% | 100% | 0% | 0% | 100% | 3 | 3 | 1 | 1 | 3 | 2.20 | 1 | ***3.20*** |
| **PAS2** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | No Data | No Data |  |
| **PAS2** | **2009** | 60% | 100% | 0% | 0% | 100% | 2 | 3 | 1 | 1 | 3 | 2.00 | 1 | ***3.00*** |
| **PAS3** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2.6 | 2 | ***4.60*** |
| **PAS3** | **2009** | 20% | 60% | 20% | 0% | 80% | 1 | 2 | 1 | 1 | 3 | 1.60 | 1 | ***2.60*** |
| **CRA1** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 1.63 | 2 | ***3.63*** |
| **CRA1** | **2008** | 0% | 0% | 0% | 100% | 100% | 1 | 1 | 1 | 3 | 3 | 1.80 | No Data | **No Data** |
| **BUZ1** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | No Data | No Data |  |
| **BUZ1** | **2009** | 75% | 100% | 0% | 0% | 100% | 3 | 3 | 1 | 1 | 3 | 2.20 | 3 | ***5.20*** |
| **BLP1** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2 | 2 | ***4.00*** |
| **BLP1** | **2009** | 100% | 100% | 0% | 100% | 80% | 3 | 3 | 1 | 3 | 3 | 2.60 | 1 | ***3.60*** |
| **LON1** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2 | 2 | ***4.00*** |
| **LON1** | **2008** | 0% | 25% | 0% | 100% | 0% | 1 | 1 | 1 | 3 | 1 | 1.40 | No Data | **No Data** |
| **WHR4** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2.5 | 1 | ***3.50*** |
| **WHR4** | **2009** | 80% | 80% | 80% | 40% | 100% | 3 | 3 | 3 | 2 | 3 | 2.80 |  |  |

Table 28: Watershed Prioritization of the Pass Creek Subwatershed based on Chemical and Biological Metrics for Streams Sampled from 2008 – 2011

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **LWR1** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2 | 2 | **4.00** |
| **LWR1** | **2009** | 60% | 80% | 20% | 0% | 60% | 2 | 3 | 1 | 1 | 2 | 1.80 | 3 | **4.80** |
| **LWR2** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2.2 | 2 | **4.20** |
| **LWR2** | **2009** | 60% | 100% | 0% | 0% | 100% | 2 | 3 | 1 | 1 | 3 | 2.00 | No Data | **No Data** |
| **LWR3** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2.17 | 2 | **4.17** |
| **LWR3** | **2009** | 40% | 60% | 0% | 0% | 100% | 2 | 2 | 1 | 1 | 3 | 1.80 | 1 | **2.80** |
| **LWR4** | **Prior Ranking** |  |  |  |  |  |  |  |  |  |  | 2.5 | 2 | **4.50** |
| **LWR4** | **2009** | 40% | 100% | 60% | 0% | 100% | 2 | 3 | 2 | 1 | 3 | 2.20 | 1 | **3.20** |



**Figure 25: Combined Stream Health and Water Quality Trends for Streams Sampled from 2008 – 2011**

# 7.0 Discussion

Water quality sampling efforts between 2008-2011 indicate widespread impairments of fecal coliform bacteria (86%; 36 of 42 stations), E-coli bacteria (88%; 37 of 42 stations), total phosphorus (100%; 42 of 42 stations), and total suspended sediments (40%; 17 of 42 stations). There were no exceedances of biochemical oxygen demand (BOD), ammonia (NH3), or nitrate (NO3) at the water quality standard of greater than 88 mg/L. Potential sources for water quality exceedances discussed in prior reports include:

**Agricultural runoff** - In March 2004, EPA determined there were approximately 20 cattle ranching operations across the reservation, with agricultural activities include cattle grazing, crop production, and winter feeding and calving areas (Matrix 2011). Crop agriculture, which consists primarily of dryland and irrigated faming for spring and winter wheat, is conducted primarily in the southeastern portion of the reservation.

**Septic Systems** - Approximately 50 percent of households on tribal land are served by individual septic systems (Tetra tech 2005).

**Storm water Runoff** - Most towns and villages across the reservation lack storm water collection systems. Pine Ridge and Martin have storm water collection systems, however, the Tribe is unaware of any BMPS being implemented to minimize pollutant loads (Tetra tech 2005) (Matrix 2011).

**Illegal dumping** - Improper disposal of domestic solid waste, household appliances and automobiles continue to contribute pollutants to surface waters (Tetra tech 2005) (Matrix 2011).

**Roads** - Many roads across the reservation are constructed of dirt and gravel, contributing significant sediment loads to surface waters (Tetra tech 2005) (Matrix 2011).

**Construction -** Silt fences and other BMPS do not appear to be used for smaller construction projects.BMPs could be used to minimize sediment loads from construction projects into surface waters (Tetra tech 2005) (Matrix 2011).

**Natural Sources** - Tetra Tech (2005a) concluded that many metals exceeding water quality standards in Pine Ridge reservation surface waters could originate from natural sources and proscribed best management practices aimed at reducing total suspended solids.

Agricultural runoff is the most likely primary source of fecal coliform and E. Coli exceedances in the Wounded Knee, Porcupine Creek, Medicine Root, Bear in the Lodge, Pass Creek, and Little White River subwatersheds, although septic systems may be contributing to some of the pathogen loading. Marnach (2013) found event E. coli and fecal coliform loadings at BEL2 and PAS3 were two log orders higher than base flow loadings during events indicating the primary pathogen transport pathway is by surface flow. Sampling upstream and downstream of sewage lagoons in Porcupine and Wounded Knee watersheds indicates these lagoons are not contributing to pathogen loading (EPP, unpublished data). However, high concentrations of pathogens in samples of effluent from the Pine Ridge sewage lagoon above WCC1 indicates a need to monitor White Clay Creek below the sewage lagoon (EPP, unpublished data).

Natural erosion and agricultural runoff are the most likely sources of TSS and total phosphorus exceedances in the White River watershed. The draft total phosphorus numeric criterion was exceeded at all stations sampled between 2008-2011. Phosphorus concentrations of samples taken from the Cheyenne River watershed, which is mostly composed of marine sediments, are lower than the phosphorus concentrations of samples taken from the White River watershed samples, which is composed of varying amounts of volcanically derived sediments (TP mean = 0.290 mg/L and SRP mean = 0.015 mg/L vs. TP mean = 0.414 mg/L and SRP mean = 0.141 mg/L, respectively). Marnach (2013) found event TP and TSS loadings at BEL2 and PAS3 during events were between 2 and 2.5 log orders higher than during base flow indicating the most likely source of phosphorus exceedances across in the Wounded Knee, Porcupine Creek, Medicine Root, Bear in the Lodge, and Pass Creek subwatersheds is from the erosion of natural sources. Several sites with TSS exceedances are in the sparsely vegetated Badlands ecoregion. Natural erosion is the most likely sources of TSS exceedances in the White River watershed. Natural erosion and agricultural runoff are both likely to contribute in the Sandhills ecoregion, which includes the Little White River watershed.

Geochemical modeling supports natural erosion of sediments as the main source of phosphorus exceedances in the Wounded Knee, Porcupine Creek, Medicine Root, Bear in the Lodge, and Pass Creek subwatersheds. Increasing concentrations of phosphorus, sodium, and iron concentrations in downstream White River samples are consistent with a shift in geology from Pierre Shale and Arikaree Group sediments to White River Group sediments. Saturation indices indicate the transport of sodium is as a dissolved ion, and iron and phosphorus sorbed to sediments that are transported to the stream as overland flow. Hydroxyapatite (the solid form of phosphorus) is stable in alkaline waters. The 45-degree slope of the plot of soluble reactive phosphorus (SRP) to total phosphorus (TP) in water quality samples from Pine Ridge Reservation streams (Figure 25) indicates an approximately 1:1 relationship between SRP and TP at lower concentrations until an upper-limit is reached. The standard method for TP analysis is to conduct an SRP test after heating the sample for one hour in an acid solution, which increases hydroxyapatite solubility. Thus, the knee in the plot at approximately 0.5 mg/L in Figure 25 may be a function of the maximum sediment surface area available for SRP.

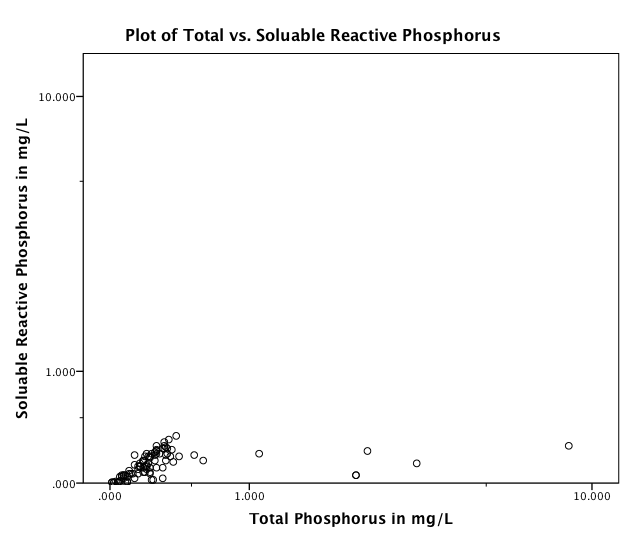


Figure : Total vs. Soluble Reactive Phosphorus

Geochemical modeling indicates seasonal and upstream - downstream differences in the transport, dissolution and precipitation of major anion and cations in the White River. Calcite and dolomite precipitation is the most likely cause for downstream calcium and magnesium ion reductions. Calcium and magnesium super-saturation in the upper White River is most likely a result of a significant fraction of the stream flow originating as ground water. Seasonal differences in downstream saturation indices for calcite and dolomite are likely a result of retrograde solubility, which means that calcite and dolomite are more soluble at low temperatures. Thus, the lower fall temperatures that cause the lower White River waters to shift from precipitating dolomite to dissolving dolomite. The non-significant seasonal differences in downstream alkalinity stations may indicate greater photosynthetic activity in the lower White River during the summer through algal uptake of bicarbonate alkalinity (Figure 26).

Upstream HCO3

CO2 inputs

Downstream HCO3

CaCO3 precipitation

Algal Uptake uptake

Figure : Conceptual model of alkalinity fluxes in the White River

The multivariate analysis of macroinvertebrate stream health metrics indicates the EPP strategy to define stream health by ecoregion is a helpful strategy in understanding stream health, and the total stream scores can detect differences in land use intensity. Five of the seven individual stream health indices: EPT Index, %EPT, FBI, %Dipteran and Non-Insect, and %Collector Gatherers detected differences in land use. However, the stream health indices: Taxa Richness and %Dominance did not detect differences in land use. A possible reason these indices did not detect differences in land use is that taxa richness may increase under low to moderate levels of nutrient enrichment and single taxon dominance may not occur until a stream is under high levels of nutrient enrichment.

The frequent flushing in Badlands streams may increase the resilience of Badlands macroinvertebrates communities to disturbance caused by nutrient loading, as well as promoting generalist feeding-strategies in Badlands macroinvertebrate populations. Two metrics for the Badlands ecoregion, %EPT and %Collector Gather, were statistically higher than for stations in other ecoregions with the same land use intensity. %EPT or percentage of *Ephemeroptera*, *Plecoptera*, and *Trichoptera* measures the relative abundance of sensitive organisms. %Collector Gathers is a measurement of trophic dynamics. Trophic measures are surrogates for complex processes such as trophic interaction, production, and food source availability (Barbour 1996). The higher relative abundance of sensitive and generalist species at Badlands ecoregion stations most likely results from a greater frequency of flood disturbance. Badlands watersheds are less vegetated and contain soils with very low infiltration rates. Thus, streams in the Badlands ecoregion are more likely to contain a greater volume of water immediately following a precipitation event than streams in other ecoregions. The greater volume of water most likely flushes organic material from Badlands streams more frequently than may occur in streams in other ecoregions, thereby increasing the nutrient assimilative capacity.

There is a widespread increase in stressed conditions when compairing two stream health metrics: Family Biotic Index (FBI) and %Collector Gatherers 2000s values to 1990s values.. Family Biotic index is a measure of the overall tolerance of a stream macroinvertebrate community to nutrient enrichment (Barbour 1996). %Collector Gathers is an indication of trophic dynamics. An increase in %Collector Gatherer indicates stressed conditions because specialized feeders, which are more sensitive to pollution, are declining relative to generalist feeders which have a broader range of acceptable food materials (Barbour 1996). The statistically significant declines are correlated with widespread fecal coliform and E-coli exceedances. Nutrient enrichment by agricultural runoff is the most likely explanation for the declines in health, as the declines in health are correlated with pathogen exceedances. Nutrient enrichment affects water quality because algal and aquatic macrophyte density increases as the bioavailable nitrogen and phosphorus concentration increases. Algae and aquatic macrophytes photosynthesize increasing the daytime dissolved oxygen concentration. However, as algae and aquatic macrophytes also respire at night when photosynthesis is not occurring, an abundance of algae and aquatic macrophytes can significantly reduce dissolved oxygen levels at night. Low nighttime dissolved oxygen concentrations affect macroinvertebrate families differently with populations of taxa sensitive to pollution including mayflies (*Ephemeroptera*), caddis flies *(Trichoptera*) and stone flies (*Plecoptera*) decreasing relative to pollution tolerant families including true flies *(Diptera*), freshwater shrimp (*Isopoda*) and worms *(Oligichaeta*).

# 8.0 Recommendations

## 8.1 Implementation of Previous Recommendations

Two previous watershed assessments and non-point source management plans were developed prior to this report. Previous recommendations by Tetra-tech (2005) for non-point source management include the following action items: 1) minimize NPS pollutants in runoff from agricultural areas with strategies on a) identification of priority areas, b) improved coordination with other agencies, 2) identify and quantify natural sources of nutrients and metals to better distinguish and address nonpoint sources of pollutants with strategies including a) identifying and analyzing existing data sources and b) refining the existing monitoring program to facilitate investigation of natural contributions to surface water pollution, 3) minimize illegal dumping of household waste across the reservation, 4) identify data gaps including: monitoring for pesticides, fecal coliform, and total suspended solids, and 5) integration of water quality and biological assessment data. Previous recommendations by Matrix Consulting (2011) for non-point source management include the following action items: 1) fecal coliform and E-coli should be analyzed at a higher dilution level, 2) total coliform should be analyzed at a higher dilution level, 3) sampling of two watersheds per year for a period of two years including a) establishment of at least one continuous flow monitoring station per watershed that incorporates both flow and automated sampling, b) conduct monthly sampling in addition to c) event sampling of four to six events per year, d) rotation of the automated sampling at two-year intervals, 4) evaluate land use practices within each watershed to specifically identify potential sources of pollution, 5) develop load calculations to evaluate load reductions, 6) prioritization of watersheds for monitoring.

The OST Environmental Protection Program has made progress in the following areas:

**Recommendation 1 (Tetra Tech):** The OST Environmental Protection Program coordinated meetings with the Bureau of Indian Affairs, OST Land Office, South Dakota School of Mines and Technology, and Oglala Lakota College in fall 2012 to coordinate agricultural Best Management Practice (BMP) implementation. The meetings led to an implementation proposal submitted in 2012 that narrowly missed being funded and a resubmission by Respec on behalf of the OST EPP in 2013.

**Recommendation 2 (Tetra-tech):** OST Environmental Protection Program contacted faculty at SDSMT (Dr. Scott Kenner) and Oglala Lakota Collect (Mr. Charles Jason Tinant) to quantify natural sources of nutrients and metals to better distinguish and address non-point sources of pollutants. The result of the faculty contacts include: a) an updated NPS management plan and the establishment of load duration curves for fecal coliform, E-coli, phosphorus, and total suspended solids by Mr. Nicholas Marnach as part of an MS thesis funded in part through an EPA Education Grant, and b) analysis of phosphorus sources by Mr. Tinant (this report).

**Recommendation 3 (Tetra-tech):** The OST EPP is concerned about the risk of solid waste migration into reservation waterways. The volume of solid waste in found in waterways indicates a need for more public education. Solid waste in waterways also indicates the need of a sustainable solid waste management plan for the Pine Ridge Indian Reservation.The most recent version of the solid waste management plan version was collaboratively developed by the IHS, BIA, USEPA, Rapid City Landfill Director, Chadron Landfill operators, and the OST EHTT and approved by the OST Tribal Council. The essence of the plan was to transition service towards individualized service. However, the plan has not been implemented. The solid waste plan is being revisited through the support of Oglala Lakota College. We are planning a comprehensive review of the current operations of the Solid Waste facilities and to review the suggested action in all previous plans as part of guided pre-engineering student projects in summer 2014.

**Recommendation 4 (Tetra-tech):** The OST EPP now routinely samples for fecal coliform, e-coli, and total suspended solids. The OST EPP does not routinely sample sampling for pesticides. However, the USGS did conduct a comprehensive study of shallow ground water for the Pine Ridge reservation (Heaken 2000) that did not detect pesticides in shallow ground water. The Natural Resources Regulatory Agency has a pesticide pollution prevention program monitors pesticide use on the reservation.

**Recommendation 5 (Tetra-tech):** The OST EPP asked Oglala Lakota College to help with stream bioassessment. In 2010, Mr. Charles Jason Tinant began an undergraduate student research program focusing on macroinvertebrate bioassessment. Results of the research program are included in this report.

**Recommendations 1 and 2 (Matrix):** The OST EPP is working with OLC, Energy Labs, and the EPA to improve the reliability of the pathogen sampling program. In 2013, the OST EPP revised the pathogen sampling program in order to improve the reliability of results and to maximize sampling program efficiency.

**Recommendation 3 (Matrix):** The OST EPP worked with SDSMT to sample Pass Creek and Bear in the Lodge Creek watersheds in 2012-2013. Continuous flow monitoring stations coupled with automated sampling were established at Pass Creek 3 and Bear in the Lodge Creek 2. Event sampling was conducted at both stations in 2012-2013. Continuous flow monitoring and automated sampling is planned for Medicine Root Creek. An additional six continuous flow monitoring stations were set up at WOK2, WOK4, POR2, POR3, MER3, and MER4 through a partnership with OLC. In addition to stream flow, the stations are monitoring pH, conductivity, dissolved oxygen, and temperature at 15-minute intervals.

**Recommendation 4 (Matrix):** Pollution sources within each watershed have not been specifically identified. However, Jason Tinant under the direction of Dr. Scott Kenner is planning a flow-duration based TMDL study that should identify specific pollution sources within the watershed.

**Recommendation 5 (Matrix):** Load calculations for Pass Creek III and Bear in the Lodge Creek II have been developed from event samples (see Marnach 2013). EPP staff have purchased stream flow monitoring equipment, received training to collect stream flow data and have developed a comprehensive stream-flow monitoring program, which is at early implementation.

**Recommendation 6 (Matrix):** The EPP has implemented the watershed prioritization schedule recommended by Matrix.

## 8.2 Recommendations Based on Recent Findings

### 8.2.1 Parameters of Concern and Monitoring Recommendations

The non-point source parameters of concern include both conventional and non-conventional pollutants including: pathogens, total suspended solids, and nutrients. However, the recent change in the sediment water quality standard for the White River has reduced the number of total suspended solids exceedances for Pine Ridge reservation streams. Physical parameter exceedances, which were not analyzed in this report, will be analyzed as part of an upcoming report analyzing water quality and biological .

The following parameters were sampled during 2008 – 2013 for water quality samples collected during three months with the highest annual precipitation, April, May and June, and four months with low precipitation, July, August, September, and October based on beneficial use criteria. Additional parameters were sampled to better understand phosphorus sources and to develop a more complete understanding of the distribution of common inorganic ions in order to evaluate historical metals data as part of Tetra-tech recommendation 1.

Physical Parameters (2008 – 2013):

* stream flow
* pH
* temperature
* conductivity
* dissolved oxygen
* turbidity

Conventional Pollutants (2008 – 2013):

* biochemical oxygen demand (BOD)
* total suspended solids (TSS)
* fecal coliform bacteria
* E-coli

Non-conventional pollutants (2008 – 2013):

* ammonia-nitrogen (NH3)
* nitrate-nitrogen (NO3)
* total phosphorus

Additional parameters sampled one or more years between 2008 and 2013:

* Total coliform bacteria
* soluble reactive phosphorus (SRP)
* hardness
* calcium
* magnesium
* sodium
* potassium
* chloride
* sulfate

Recommendations for physical parameters, conventional and non-conventional pollutants are discussed in detail below.

**Stream flow** is the most important physical parameter measured by EPP staff. Stream flow is necessary to calculate load from concentration data. Load calculations determine the reduction of pollutant load necessary to achieve water quality standards (See equations 1 - 3). Discussion with EPP staff have identified several challenges in collecting and verifying stream flow including: out of date or broken equipment, a lack of training opportunities for staff, inability to field verify stream flow measurements, lack of software to capture/calculate flow data, challenges in maintaining mechanical stream flow measuring equipment.

Equation 1 –Stream Flow Calculation

Equation 2 – Load Calculation

Equation 3 - Unit Conversion (kg/day)

**Recommendation 1a:** The purchase of and training with an acoustic doppler-type flow meter with integrated quality-control software (for example: Flow-tracker, which is used by the USGS, or a similar meter) will alleviate many challenges with maintaining equipment and capturing and calculating high quality flow data.

**Recommendation 1b:** Establishment of permanent staff gauges at flow monitoring stations will allow for the establishment of a stage – discharge relationship. The stage – discharge relationship will provide greater quality control of stream flow data and over time can be used to understand fluvial morphological changes in the stream near the monitored segment.

**pH** is a measurement of hydrogen ion concentration on a logarithmic scale. pH is related to pOH, which is a measurement of hydroxide ion concentration on a logarithmic scale. pH values for Pine Ridge reservation streams are typically about 8.1, which indicates that there is about 100 times as much hydroxide ion as hydrogen ion in stream waters. Thus, pH has implications on the amount of metals in streams, with streams having high pH tending to have low concentrations of most metals with arsenic being a notable exception. pH is often measured along with alkalinity. Alkalinity provides buffering capacity for pH values from about 6.5 to about 8.5. Pine Ridge reservation streams tend to have high alkalinities, thus pH measurements which are either very low (below about 7.5) or very high (above about 8.7) may be indicative of equipment failure, calibration solution contamination, or the need to recalibrate instruments at a higher frequency. pH measurement is a requirement under South Dakota water quality standards (Appendix 1).

**Recommendation 2a:** Calibration logs for pH, conductivity, turbidity and dissolved oxygen should be maintained as part of a Quality Assurance Protection Plan. Anomalous measurements can be checked against the calibration logs in order to identify equipment failures from changes in loadings into stream segments.

**Recommendation 2b:** Alkalinity should be added to the list of parameters to be analyzed in future years. Alkalinity is a Fish and Wildlife Propagation, Recreation, and Stock Watering Waters Criteria. Furthermore, measurement of alkalinity for will provide an early indication of changes to acidic or basic loadings into stream segments.

**Temperature** is a measurement of the amount of heat in a quantity of water. Temperatures tend to be highest during low flows and in unshaded segments of streams. Temperature measurement is a requirement under South Dakota water quality standards (Appendix 1).

**Conductivity** is a measurement of the amount of dissolved solids in a quantity of water. Temperature measurement is a requirement under South Dakota water quality standards (Appendix 1).

**Dissolved oxygen** is a measurement of the amount of oxygen is available for fish or other aquatic life. Thus, dissolved oxygen is a criteria parameter for fish life propagation. Low dissolved oxygen in streams can occur in two ways: 1) BOD loading from the watershed or a point source and 2) stream eutrophication from nutrient loading. Low dissolved oxygen and high BOD concentrations are consistent with streams receiving point source discharges from wastewater treatment plants. Streams experiencing high nutrient loadings (e.g. soluble phosphorus and soluble inorganic nitrogen loadings (e.g. NH3, NO2, NO3)) will typically have high daytime and low nighttime dissolved oxygen concentrations because algal and photosynthesis converts alkalinity to algal biomass and dissolved oxygen. In stream dissolved oxygen concentration decreases during the night as the algal population continues to respire. Streams segments monitored from 2008 to 2011 typically had low BOD concentrations, and high phosphorus and nitrogen loadings. Daytime dissolved oxygen concentrations measured between 2008-2011 were typically above 100% saturation (Tinant unpublished data). Dissolved oxygen measurements for selected Wounded Knee Creek subwatershed stations in the measured in summer 2012 shifted up to 6 mg/L over 24-hours (Tinant unpublished data). The large shifts in dissolved oxygen over 24-hours are correlated with overall macroinvertebrate community trends in the Wounded Knee Creek watershed. Dissolved oxygen measurement is a requirement under South Dakota water quality standards (Appendix 1).

**Recommendation 3:** Twenty-four hour measurement of dissolved oxygen should be implemented as part of a future monitoring strategy. Existing EPP water quality instrumentation has the capacity to collect continuous (e.g. 15-minute interval) dissolved oxygen data. The instrument can be secured using water quality probe shroud, which can be fashioned by a machine shop.

**Turbidity** is a measurement of water clarity. Water becomes cloudy as a result of the suspension of clay-sized particles or as a result of phytoplankton growth. Turbidity measurement is not currently a requirement under South Dakota water quality standards.

**Biochemical oxygen demand (BOD)** is a measurement of labile dissolved carbon compounds. The BOD tests measure labile carbon consumption by bacteria over a five-day interval by measuring the change in dissolved oxygen over the five-day interval. BOD measurement is a requirement under South Dakota water quality standards (Appendix 1).

**Total suspended solids (TSS)** is a measurement of the amount of sediment and organic compounds entrained in the water column. TSS measurement is conducted by filtering a quantity of a water sample and weighing the residue left on the filter conduct the measurement. TSS measurement is a requirement under South Dakota water quality standards (Appendix 1). A recent change in the South Dakota water quality standards increased the water quality standard for White River stations from 158 mg/L to 4525 mg/L. The majority of White River Badlands stations (4 of 6) were designated as threatened or impaired in TSS. However a TMDL may indicate that natural sources may be large component of TSS loading given that the natural erosion from White River group sediments have been identified as the major source of suspended sediments in the White River below Rockyford.

**Recommendation 4:** Identify partners and funding sources for Total Suspended Solids TMDL development for White River Badlands ecoregion stations (see below).

**Fecal coliform bacteria** and **E-coli bacteria** are counts of coliform bacteria commonly occurring in the intestines of mammals and birds. “E-coli bacteria is the major species in the fecal coliform group. Of the five general groups of bacteria that comprise the total coliforms, only E. coli is generally not found growing and reproducing in the environment. Consequently, E. coli is considered to be the species of coliform bacteria that is the best indicator of fecal pollution and the possible presence of pathogens.” (NY Dept. of Health 2013). Increased levels of fecal coliform bacteria and E-coli bacteria are an indication of either the failure of a water treatment system or the presence of livestock using streams as a watering source. Fecal coliform bacteria in water in most cases are not harmful to humans. However, the presence of fecal coliform and E-coli bacteria indicates a higher risk of pathogens in water such as: hepatitis A, hepatitis C, dysentery, typhoid fever, and gastroenteritis, and cholera. Fecal coliform bacteria and E-coli bacteria measurement are requirements under South Dakota water quality standards (Appendix 1). Fecal coliform and E-coli are the major sources of impairment in Pine Ridge reservation waters between 2008-2011.

**Recommendation 5:** Continue the strategy outlined by Matrix for continuous flow monitoring and automated sampling for at least one station per watershed that incorporates both flow and automated sampling. Monthly sampling should be conducted in addition to automated sampling of four to six events for a minimum of a one-year period with two years recommended to fully evaluate the watershed. Two watersheds should be sampled each year for a period of two years (and only those watersheds) and rotated every two years. Event samples should be evaluated for fecal coliform and E-coli, as well as TSS, and nutrients.

**Ammonia-nitrogen** is a measure of total ammonia (NH3 + NH4) concentration. Ammonia is toxic to fish and shellfish life. Ammonia concentration depends on temperature and pH. Ammonia is converted to nitrate (NO3) by bacteria in oxygenated streams. Sampling between 2008-2011 indicated that ammonia is not a significant concern. Ammonia measurement is required under South Dakota water quality standards (Appendix 1).

**Recommendation 6:** Best Management Practice (BMP) implementation over the short-term should focus primarily on fecal coliform, E-coli, and TSS reductions through agricultural best management practice implementation.

**Nitrate-nitrogen (NO3)** monitoring is required under South Dakota water quality standards for fish and wildlife propagation, recreation, and stock watering waters (Appendix 1). However the daily maximum of 88 mg/L and the 30-day average of 50 mg/L are 16,000% and 9,000%, respectively, of the EPA recommendation of 0.56 mg/L for total nitrogen (NDOM + NH3 + NO2 + NO3). Stoichiometric and geochemical analysis of nitrate and phosphorus indicates nitrogen is the limiting nutrient for algal blooms for reservation streams. Stream monitoring in 2011 – 2013 indicates a qualitative increase in algal biomass in the Wounded Knee Creek subwatershed. However, it is not clear from available data if the rapid bioassessment protocols used by the Environmental Protection Program to assess are detecting a quantitative increase in algal biomass.

**Recommendation 7b:** Rapid Bioassessment Protocol Physical Results should be analyzed with chemical data in order to detect changes in algal biomass over time and for Best Management Practice evaluation. Furthermore, riparian cover should be measured at each station in order to better forecast the effects of eutrophication at a site level.

The EPA has provided guidance for the developing nutrient criteria for States and Tribes that reflect local conditions and specific designated uses (EPA 2001). The guidance recommends the following prioritization for the development of nutrient criteria for nitrogen: 1) total nitrogen (TN) reported values in cases where there are a large number of streams in the sample, 2) the calculated median lowest 25th percentile values for subecoregions when there development of nutrient criteria where data are missing or very low, 3) the lowest aggregated values when a similar subecoregion can not be determined. The Pine Ridge reservation contains two subecoregions: subecoregion 43 – northwestern Great Plains and subecoregion 44 – Nebraska Sandhills. Reported median TN values are 0.65 mg/L (n=12) for subecoregion 43 – northwestern Great Plains and 0.80 mg/L (n=17) for subecoregion 44 – Nebraska Sandhills. Calculated median TN values are 0.38 mg/L (n range = 75 - 100) for subecoregion 43 – northwestern Great Plains and 0.35 mg/L (n range = 11 - 19) for subecoregion 44 – Nebraska Sandhills. The aggregate median reported TN values for ecoregion VI streams, which includes regions in South Dakota, Montana, North Dakota, Wyoming, Nebraska, Colorado, Kansas, New Mexico, Oklahoma, and Texas, are 56 mg/L (n = 65) and 61 mg/L (n range = 212 – 299). The aggregate value of 0.56 mg/L was chosen for this report because 1) it represents a compromise between the lower calculated subecoregion values and the higher reported values for subecoregions 43 and 44, and represents the median aggregate value with the highest sample size.

**Recommendation 7a:** The Environmental Protection Program should adopt a water quality goal of 0.56 mg/L for Total Nitrogen in order to limit eutrophication and degradation of stream health in Pine Ridge reservation streams.

**Total Phosphorus (TP)** monitoring is not currently required under South Dakota numeric water quality standards (Appendix 1). However, total phosphorus monitoring is required by most States and is generally discussed as part of South Dakota law:

*\*74:51:01:09. Nuisance aquatic life. Materials which produce nuisance aquatic life may not be discharged or caused to be discharged into surface waters of the state in concentrations that impair an existing or designated beneficial use or create a human health problem.*

*\*74:51:01:12. Biological integrity of waters. All waters of the state must be free from substances, whether attributable to human-induced point source discharges or nonpoint source activities, in concentrations or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities.*

While stoichiometric and geochemical analysis of nitrate and phosphorus indicates nitrogen is the limiting nutrient for algal blooms for reservation streams, continued phosphorus monitoring is important in order to detect changes in land use by shifts in the ratio of nitrogen to phosphorus. A numeric goal for total phosphorus or soluble reactive phosphorus (see below) should be adopted by the OST Environmental Protection Program in preparation for the adoption of water quality standards for Oglala Sioux Tribal Waters.

The EPA has provided guidance for the developing nutrient criteria for States and Tribes that reflect local conditions and specific designated uses (EPA 2001). The guidance recommends developing an initial standard and then refining the standard based on weight of evidence including: 1) literature sources, 2) historical data and trends, 3) reference condition, 4) models, 5) expert view and consensus, and downstream effects. Along this framework, the OST Tribe has adopted a draft TP standard of 37 ug/L that is consistent with reported median TP values of 28 ug/L (n = 111, range = 2 - 1,514 ug/L) for subecoregion 43 – northwestern Great Plains and reported aggregate median TP values of 23 ug/L (n = 341, range = 0 - 2,070 ug/L) and below the reported median TP value of 157 ug/L (n = 23 range = 104 - 598) for subecoregion 44 – Nebraska Sandhills. A historical trend for Pine Ridge reservation streams has not been established. However, analysis of historical data (this report) indicates that the 37 ug/L standard is unobtainable. One way to establish a general reference condition is by aggregating all of the stations and using the 25th percentile (EPA 2001). By this method, the TP standard for OST Tribal Waters should be set at 90 ug/L. The 90 ug/L standard should be evaluated at an ecoregion level as the most likely source for total phosphorus is by natural erosion (Tetra tech 2005, Matrix 2011, this report).

**Recommendation 8:** The Environmental Protection Program should adopt a water quality goal of 90 ug/L for Total Phosphorus to limit the potential for eutrophication and degradation of stream health in Pine Ridge reservation streams, with possibly higher limits for particular ecoregions or subwatersheds to account for the high background phosphorus concentrations.

**Total coliform bacteria** is the count of coliform bacteria occurring in soils, contaminated water, and the intestines of mammals and birds. Because total coliform bacteria includes bacteria growing in soils, it is not a good indicator of pathogens. **Total coliform bacteria sampling may be dropped from the monitoring program.**

**Soluble reactive phosphorus (SRP)** is the concentration of bioavailable phosphorus. The advantages to soluble reactive phosphorus measurements are 1) it is not correlated with chlorophyll in the water column as is total phosphorus (Biggs 2000) or with total suspended solids as is the likely case in Pine Ridge Reservation streams (see discussion), 2) analysis does not requires a digestion step as does total phosphorus, 3) because it is less temporarily variable than total phosphorus, which requires weekly monitoring for good estimates of mean concentration (Biggs 2000), good estimates can be obtained by monthly sampling. The main disadvantages are 1) phosphorus bound in organic matter (Biggs 2000) or in sediment (this report) *might*become available to algae and aquatic plants and would not be accounted for in a soluble reactive phosphorus test and 2) results might not be directly transferrable with TP results from other streams in Nebraska and South Dakota.

**Recommendation 10:** The Environmental Protection Program should ask for guidance for macroinvertebrate health metrics from EPA Region 8 staff based on the finding that Taxa Richness and %Dominance did not detect differences in land use, thus other metrics might be more reliable indicators of changes from oligotrophic to mesotrophic conditions in Pine Ridge reservation streams.

**Hardness** is a measurement of divalent ion concentration, which is mostly calcium and magnesium. The Environmental Protection Program measured hardness in order to calibrate geochemical models following the Tetra-tech report. Later, other major ions including: **calcium, magnesium, sodium, potassium, chloride, and sulfate** were added in order to better characterize streams for geochemical models as historical trace metals data was available, however major ion data was not available. Our modeling (this report) indicates there is now enough major ion data to address exploratory geochemical modeling questions. Thus, **hardness, calcium, magnesium, sodium, potassium, chloride, and sulfate can be dropped from the current monitoring program.**

**Macroinvertebrate assessment** is a key element of understanding trends in stream ecosystem structure and function, and ecosystem integrity in Pine Ridge reservation streams. Macroinvertebrate health metrics incorporate taxa richness, dominance of taxa that are sensitive or insensitive to pollution, and balance of functional feeding groups. Five of the seven individual stream health indices: EPT Index, %EPT, FBI, %Dipteran and Non-Insect, and %Collector Gatherers detected differences in land use. However, the macroinvertebrate health metrics: Taxa Richness and %Dominance did not detect land use differences. A possible reason these indices did not detect differences in land use is that taxa richness increases under moderate levels of nutrient enrichment and single taxon dominance may not occur until a stream is under high levels of nutrient enrichment.

## 8.3 Best Management Practices (BMPs)

An evaluation of land management practices needs to be completed to identify specific BMPs for implementation within each watershed. In order to accomplish this, Tinant and Kenner have planned a flow-duration-curve based TMDL for smaller reservation streams that will be conducted as part of Tinant’s proposed PhD dissertation.

This report addresses some changes in approaches to best management practice implementation from previous reports. Best management priorities should be updated to reflect a major finding of the White River Phase II TMDL that the high sediment concentration in streams is from natural sources from White River Group sediments. The finding resulted in an increase in the sediment water quality limit from 148 mg/L to 4525 mg/L for White River streams. At present 14 stream segments are exceeding water quality standards, of which 50% (7 of 14) are in White River Group sediments indicating that both natural sources and human impacts are likely contributing to the sediment exceedances in different watersheds. The highest priorities for best management practice implementation should be for bacteria, followed by nutrients and sediment (see Table .

BMP priorities established in previous NPS management plan are still relevant. However, more recent findings indicate that agricultural BMPs associated with livestock production are the most efficient BMPs in terms of implementation. Furthermore, with the recent changes in allowable sediment levels for White River stream, sediment from natural sources should not be listed for BMP implementation. Table 29 provides a list of BMPs with priorities for implementation listed in BOLD. Suggestions for BMP implementation from Matrix (2011) are still relevant.

Table 29 Priority NPS Pollutants

|  |  |
| --- | --- |
| **Pollutant** | **Contributing NPS Categories** |
| Bacteria | * **Agriculture – Livestock production** * Septic systems |
| Nutrients | * **Agriculture – Livestock production** * Agriculture – Crop production * Septic systems * Urban runoff from towns and villages |
| Sediment | * **Agriculture – Livestock production** * Agriculture – Crop production * Urban runoff from towns and villages |

**Livestock Production**

1. **Work with NRCS, BIA, and Tribal Land Office on an ongoing basis to identify producers needing assistance to implement BMPs for grazing lands and calving and winter feeding areas.**
2. **Identify specific projects and funding sources for target producers.**
3. **Secure funding and implement projects for target producers.**
4. **Conduct monitoring to assess BMP effectiveness in reducing NPS pollutant contributions.**

**Crop Production**

1. Identify specific BMPs and funding sources for target producers.
2. Secure funding and implement projects for target producers.
3. Conduct monitoring to assess BMP effectiveness in reducing NPS pollutant contributions.
   1. Establish monitoring strategies for priority projects.

**Urban runoff from roads**

1. Track proposed road construction and ongoing maintenance activities within reservation boundaries.
2. Ensure implementation of BMPs to control erosion on road construction and maintenance projects.

**Construction**

1. Track of proposed construction activities within reservations boundaries.
2. Ensure implementation of BMPs to be implemented on construction sites.

**Septic systems**

1. Improve information sharing and coordination with Indian Health Service to share or leverage resources to improve septic services across the reservation.
2. Rehabilitate failing septic systems and relocate poorly sited systems.
3. Ensure proper siting and environmental review for new septic system installation.
4. Address jurisdictional uncertainty for non-tribal lands within the reservation boundaries.

**Urban runoff from towns and villages**

1. Identify significant urban runoff drainages.
   1. Perform a field inspection to identify storm water flow paths and discharge points.
   2. Categorize the urban runoff sources on the basis of the volume of runoff discharged to surface waters.
2. Conduct targeted outreach on BMPs to improve the quality of storm water runoff in significant urban runoff drainages.
3. Implement programs to encourage businesses and homeowners to implement BMPs.

## 8.4 Next Steps

The following items are identified as next steps for the OST Water Pollution Control Program:

* Evaluation of land management practices within each watershed
  + - Implement BMPs with a focus on livestock production
* Complete next Watershed Assessment
* Prepare EPA Grant Applications for BMP Implementation

# 9.0 Public Participation and Education

## 9.1 Education

Education of Tribal members and other reservation residents is critical in the reduction of NPS pollution and in BMP implementation. The educational activities, their frequencies, and funding requirements discussed by Matrix (2011) and listed in Table 30 remain important milestones for public participation and education.

Table 30 Environmental Education Activities

|  |  |
| --- | --- |
| **Activity** | **Frequency** |
| Work with owners and land managers of livestock areas and cropland to encourage the use of BMPs. | 2 to 3 times per year |
| Solicit feedback from reservation residents and distribute educational materials to deter illegal dumping | 2 to 3 times during 2005– 2006, with follow-up as needed |
| Distribute educational materials on septic systems to reservation residents. | Once every 5 years, with follow-up as needed |
| Distribute storm water educational materials to business owners and homeowners in the towns of Martin, Oglala, Pine Ridge, and Kyle, and in other towns as needed. | 2 times per year during public meetings |
| Work with Shannon, Jackson, and Bennett counties to discuss NPS pollution issues and BMP implementation. Both Shannon and Bennett counties have developed Hydrologic Unit Plans and have ranked priorities for their watersheds (i.e. soil erosion, weed control, grazing management, Prairie Dog control). | 2 times per year |

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# APPENDIX

# Appendix A Tables Surface Water Quality Standards

Table 20 Criteria for Coldwater Marginal Fish Life Propagation Waters

|  |  |  |  |
| --- | --- | --- | --- |
| 74:51:01:46. Criteria for coldwater marginal fish life propagation waters. | | | |
| Parameter | Criteria | Unit of Measure | Special Conditions |
| Total ammonia nitrogen as N | Equal to or less than the result from Equation 3 in Appendix A | mg/L | 30-day average |
| Equal to or less than the result from Equation 1 in Appendix A | Daily maximum |
| Dissolved oxygen as measured anywhere in the water column of a non-stratified water body, or in the epilimnion and metalimnion of a stratified water body | ≥ 5.0 | mg/L | Daily minimum |
| Undisassociated hydrogen sulfide | ≤ 0.002 | mg/L | Daily maximum |
| pH | ≥ 6.5 - ≤ 9.0 | Units | See § 74:51:01:07 |
| Total Suspended Solids | ≤ 90 | mg/L | 30-day average |
| ≤ 158 | Daily maximum |
| Temperature | ≤ 75 | ͦF | See § 74:51:01:31 |

Table 21 Criteria for Warmwater Permanent Fish Life Propagation Waters

|  |  |  |  |
| --- | --- | --- | --- |
| 74:51:01:47. Criteria for warmwater permanent fish life propagation waters. | | | |
| Parameter | Criteria | Unit of Measure | Special Conditions |
| Total ammonia nitrogen as N | Equal to or less than the result from Equation 3 in Appendix A | mg/L | 30-day average March 1 – October 31 |
| Equal to or less than the result from Equation 4 in Appendix A | 30 day average November 1 – February 29 |
| Equal to or less than the result from Equation 2 in Appendix A | Daily maximum |
| Dissolved oxygen as measured anywhere in the water column of a non-stratified water body, or in the epilimnion and metalimnion of a stratified water body | ≥ 5.0 | mg/L | Daily minimum |
| ≥6.0 | In Big Stone Lake and Lake Traverse during April and May |
| Undisassociated hydrogen sulfide | ≤ 0.002 | mg/L | Daily maximum |
| pH | ≥ 6.5 - ≤ 9.0 | Units | See § 74:51:01:07 |
| Total Suspended Solids | ≤ 90 | mg/L | 30-day average |
| ≤ 158 | Daily maximum |
| Temperature | ≤ 80 | ͦF | See § 74:51:01:31 |

Table 22 Criteria for Warmwater Semipermanent Fish Life Propagation Waters

|  |  |  |  |
| --- | --- | --- | --- |
| 74:51:01:48. Criteria for warmwater semipermanent fish life propagation waters. | | | |
| Parameter | Criteria | Unit of Measure | Special Conditions |
| Total ammonia nitrogen as N | Equal to or less than the result from Equation 3 in Appendix A | mg/L | 30-day average  March 1 – October 31 |
| Equal to or less than the result from Equation 4 in Appendix A | 30-day average November 1 – February 29 |
| Equal to or less than the result from Equation 2 in Appendix A | Daily maximum |
| Dissolved oxygen as measured anywhere in the water column of a non-stratified water body, or in the epilimnion and metalimnion of a stratified water body | ≥ 5.0 | mg/L | Daily minimum |
| Undisassociated hydrogen sulfide | ≤ 0.002 | mg/L | Daily maximum |
| pH | ≥ 6.5 - ≤ 9.0 | Units | See § 74:51:01:07 |
| Total Suspended Solids | ≤ 90 | mg/L | 30-day average |
| ≤ 158 | Daily maximum |
| Temperature | ≤ 90 | ͦF | See § 74:51:01:31 |

Table 23 Criteria for Immersion Recreation Waters

|  |  |  |  |
| --- | --- | --- | --- |
| 74:51:01:50. Criteria for immersion recreation waters. | | | |
| Parameter | Criteria | Unit of Measure | Special Conditions |
| Dissolved oxygen as measured anywhere in the water column of a non-stratified water body, or in the epilimnion and metalimnion of a stratified water body | ≥ 5.0 | mg/L | Daily minimum |
| Fecal coliform | ≤ 200 | /100mL | Geometric mean based on a minimum of 5 samples obtained during separate 24-hour periods for an 30-day period, and they may not exceed this value in more than 20% of the samples examined in this same 30-day period |
| ≤ 400 | In any one sample |
| Escherichia coli | ≤ 126 | /100mL | Geometric mean based on a minimum of 5 samples obtained during separate 24-hour periods for any 30-day period |
| ≤ 235 | In any one sample |

Table 24 Criteria for Fish and Wildlife Propagation, Recreation, and Stock Watering Waters

|  |  |  |  |
| --- | --- | --- | --- |
| 74:51:01:52. Criteria for fish and wildlife propagation, recreation, and stock watering waters. | | | |
| Parameter | Criteria | Unit of Measure | Special Conditions |
| Total alkalinity as calcium carbonate | ≤ 750 | mg/L | 30-day average |
| ≤ 1313 | Daily maximum |
| Total dissolved solids | ≤ 2,500 | mg/L | 30-day average |
| ≤ 4375 | Daily maximum |
| Conductivity at 25 ͦC | ≤ 4,000 | Micromhos/cm | 30-day average |
| ≤ 7,000 | Daily maximum |
| Nitrates as N | ≤ 50 | mg/L | 30-day average |
| ≤ 88 | Daily maximum |
| pH | ≥ 6.5 - ≤ 9.0 | Units | See § 74:51:01:07 |
| Total petroleum hydrocarbon | ≤ 10 | mg/L | See § 74:51:01:10 |
| Oil and grease | ≤ 10 | mg/L | See § 74:51:01:10 |

(Table information is from the website <http://legis.state.sd.us/rules/DisplayRule.aspx?Rule=74:51:01> SD Legislature – Administrative Rules – Chapter 74:51:01 Surface Water Quality Standards)

Table 27 Wounded Knee Creek Criteria Comparison

| **Site #** | **Parameter** | **NPS Assessment Criteria** | **SD DENR Criteria** |
| --- | --- | --- | --- |
| WKI | pH (upper limit) | ≤ 8.8 s.u. | ≤ 9.0 s.u. |
| Dissolved Oxygen | ≥ 5 mg/L | ≥ 5 mg/L |
| Phosphorus, total | ≤ 36.56 µg/L | \*See Narrative Criteria |
| Arsenic | ≤ 0.14 µg/L |  |
| Iron | ≤300 µg/L |  |
| Manganese | ≤ 100 µg/L |  |
| Mercury | ≤ 0.012 µg/L |  |
| Nitrate as N |  | ≤88 mg/L |
| Total Ammonia Nitrogen as N |  | \*\*Based on pH |
| Fecal coliform |  | ≤ 400 /100mL |
| Escherichia coli |  | ≤ 235 /100mL |
| TSS |  | ≤ 158 mg/L |
| Temperature |  | ≤ 75 ͦF\*  ≤ 80 ͦF |
| WKII | pH (upper limit) | ≤ 8.8 s.u. | ≤ 9.0 s.u. |
| Dissolved oxygen | ≥ 5 mg/L | ≥ 5 mg/L |
| Turbidity | ≤ 5.70 NTU |  |
| Phosphorus, total | ≤ 36.56 µg/L | \*See Narrative Criteria |
| Arsenic | ≤ 0.14 µg/L |  |
| Cadmium | ≤0.66 µg/L |  |
| Iron | ≤1,000 µg/L |  |
| Manganese | ≤ 100 µg/L |  |
| Mercury | ≤ 0.012 µg/L |  |
| Nitrate as N |  | ≤88 mg/L |
| Total Ammonia Nitrogen as N |  | \*\*Based on pH |
| Fecal coliform |  | ≤ 400 /100mL |
| Escherichia coli |  | ≤ 235 /100mL |
| TSS |  | ≤ 158 mg/L |
| Temperature |  | ≤ 75 ͦF\*  ≤ 80 ͦF |
| WKIII | pH (upper limit) | ≤ 8.8 s.u. | ≤ 9.0 s.u. |
| Dissolved oxygen | ≥ 5 mg/L | ≥ 5 mg/L |
| Turbidity | ≤ 5.70 NTU |  |
| Phosphorus, total | ≤ 36.56 µg/L | \*See Narrative Criteria |
| Arsenic | ≤ 0.14 µg/L |  |
| Cadmium | ≤0.66 µg/L |  |
| Iron | ≤1,000 µg/L  ≤300 µg/L |  |
| Manganese | ≤ 100 µg/L |  |
| Mercury | ≤ 0.012 µg/L |  |
| Nitrate as N |  | ≤88 mg/L |
| Total Ammonia Nitrogen as N |  | \*\*Based on pH |
| Fecal coliform |  | ≤ 400 /100mL |
| Escherichia coli |  | ≤ 235 /100mL |
| TSS |  | ≤ 158 mg/L |
| Temperature |  | ≤ 80 ͦF |
| WKIV | pH (upper limit) | ≤ 9.0 s.u. | ≤ 9.0 s.u. |
| Dissolved oxygen | ≥ 5 mg/L | ≥ 5 mg/L |
| Turbidity | ≤ 5.70 NTU |  |
| Phosphorus, total | ≤ 36.56 µg/L | \*See Narrative Criteria |
| Arsenic | ≤ 0.14 µg/L |  |
| Cadmium | ≤0.66 µg/L |  |
| Iron | ≤1,000 µg/L  ≤300 µg/L |  |
| Manganese | ≤ 100 µg/L |  |
| Mercury | ≤ 0.012 µg/L |  |
| Nitrate as N |  | ≤88 mg/L |
| Total Ammonia Nitrogen as N |  | \*\*Based on pH |
| Fecal coliform |  | ≤ 400 /100mL |
| Escherichia coli |  | ≤ 235 /100mL |
| TSS |  | ≤ 158 mg/L |
| Temperature |  | ≤ 80 ͦF |

# Appendix B MANOVA Analysis Results

A two-way MANOVA was conducted to determine the effect of time, ecoregion, and land use intensity on the stream health variables: taxa richness, EPT index, %EPT, FBI, %Dominant Family, Dipteran and Non-Insect, and Collector Gatherer. MANOVA results indicate that ecoregion (Pillai’s Trace = 0.765, F(28, 324) = 2.735, p<0.001, eta-squared = 0.191), land use (Pillai’s Trace =1.067, F(14,158) = 12.910, p<0.001, eta-squared = .534), and ecoregion x landuse (Pillai’s Trace =0.761, F(42,498) = 1.721, p=0.004, eta-squared = .127) significantly affect the combined stream health metrics. MANOVA results indicate that time (Pillai’s Trace =0.138, F(7,78) = 1.779, p=0.103, eta-squared = .138) was not significant in driving changes of the combined stream health metrics.

Univariate ANOVA and Tukey’s post-hoc tests were conducted as follow-up tests. ANOVA results indicate that %EPT, Dipteran and Non-Insect, and Collector Gatherer metrics significantly differ by ecoregion (F(4,84)=8.806, p=<0.001, eta-squared=0.295; F(4,84)=1.886, p=0.039, eta-squared=0.112; F(4,84)=3.347, p=0.014, eta-squared=0.137) ANOVA results indicate that EPT Index, %EPT, FBI, Dipteran and Non-Insect, and Collector Gatherer metrics significantly differ by land use (F(2,84)=5.717, p=0.005, eta-squared=0.120; F(2,84)=71.325, p<0.001, eta-squared=0.629; F(2,84)=25.517, p<0.001, eta-squared=0.378; F(2,84)=65.805, p=<0.001, eta-squared=0.610; F(2,84)=3.346, p=0.04, eta-squared=0.074). ANOVA results indicate that %EPT and Collector Gather metrics differ significantly by ecoregion x land use (F(6,84)=3.306, p=0.006, eta-squared=0.191; F(6,84)=2.699, p=0.019; eta-squared=0.162). Although time was not significant in determining changes in overall stream health, ANOVA results indicate that FBI and Collector Gather metrics significantly differ between 1990 and 2000 samples (F(6,84)=3.306, p=0.006, eta-squared=0.074; F(6,84)=2.699, p=0.019, eta-squared=0.102).

Tukey’s Honestly Significant Difference test indicates significant differences between the Badlands and Great Plains, the Badlands and High Plains, and Badlands and Sand Hills ecoregion %EPT scores (MD=0.314, p<0.000; MD=0.248, p=0.002; MD=0.173, p=0.006). Tukey’s Honestly Significant Difference test indicates significant differences between the Badlands and Great Plains, the Badlands and High Plains and Badlands, and Sand Hills ecoregion Dipteran and Non-insect scores (MD=-0.207, p<0.001; MD=-0.267, p=0.002; MD=-0.198, p=0.003). Tukey’s Honestly Significant Difference test indicates significant differences between the Badlands and High Plains and Badlands and River ecoregion Collector Gatherer scores (MD=0.361, p=0.005; MD=0.337, p=0.005). Tukey’s Honestly Significant Difference test indicates significant differences between high and low and high and moderate land use by EPT Index (MD=-1.38, p<0.001; MD=-1.67, p=0.004).

Tukey’s Honestly Significant Difference test indicates significant differences between high and low, high and moderate, and moderate and low land use by % EPT (MD=-0.560, p<0.001; MD=-0.173, p<0.001, MD=-0.387, p<0.001). Tukey’s Honestly Significant Difference test indicates significant differences between high and low, high and moderate, and moderate and low land use by FBI (MD=2.287, p<0.001; MD=1.264, p<0.001, MD=1.023, p=0.003). Tukey’s Honestly Significant Difference test indicates significant differences between high and low, and high and moderate land use by % Dipterans and Non-insects (MD=0.541, p<0.001; MD=0.466, p<0.001). Tukey’s Honestly Significant Difference test indicates significant differences between high and low, and moderate and low land use by % Collector Gatherer (MD=0.200, p<0.001; MD=0.209, p=0.008).