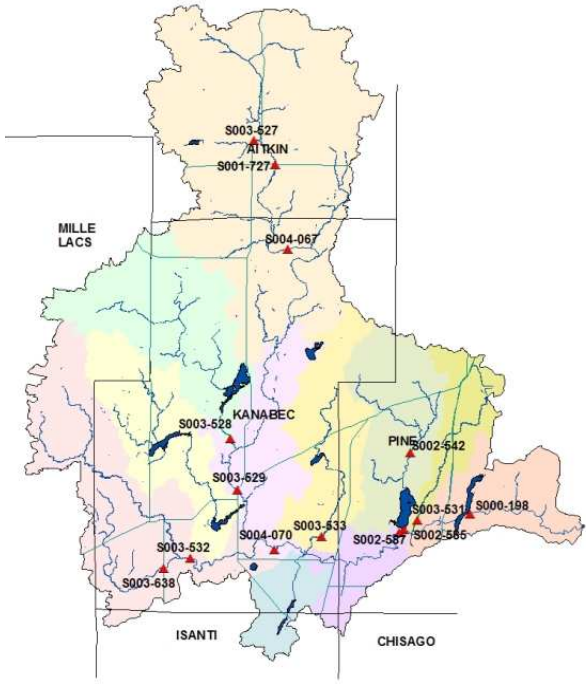
SNAKE RIVER WATERSHED

10 YEAR WATER QUALITY STREAM MONITORING REPORT (1998-2008)



September 25th, 2009

SNAKE RIVER WATERSHED MANAGEMENT BOARD
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INTRODUCTION

The Snake River Watershed is the third largest tributary watershed in the St. Croix River Basin. It spans 1,010 square miles with portions in Aitkin, Chisago, Isanti, Kanabec, Mille Lacs and Pine Counties. The Snake River originates in Aitkin County and flows for a total of 101.3 miles before entering the St. Croix River east of Pine City.

In recent years, reported nuisance levels of blue-green algae have become significant in many of the lakes and streams in the Snake River Watershed. High sediment and phosphorus loads have been identified during the growing season. Excessive fecal coliform bacteria concentrations are another major pollutant in the watershed predominantly during rainfall events.

In 2008, there were 26 stream sections and five lakes listed on the 303(d) impaired waters list. The Clean Water Act requires states to adopt water quality standards to protect the nation's waters. These standards define how much of a pollutant can be in surface water while still allowing it to meet its designated uses such as for drinking water, fishing, protection of aquatic life, recreation, irrigation or industry. Many Snake River waters do not meet the standards of their designated uses because of pollution problems from a combination of point sources, such as sewage treatment plants, industrial discharge and non-point sources. Some examples of non-point sources include pollutants carried by rainfall runoff from forests, agriculture land, and abandoned mine lands.

In 1998, the Snake River Watershed Management Board with the help of its partners, Minnesota Pollution Control Agency and Soil and Water Conservation Districts in the watershed began a ten year monitoring program. The goal of this program was to identify problem areas and provide a baseline of water quality information for future evaluation efforts.

This report is an analysis of the ten year stream monitoring water quality data collected for fourteen sites within the watershed from 1998-2008. Several tools were used to perform the analysis of data. The Seasonal Kendall test is a statistical test well suited for identifying trends in data over time. The Seasonal Kendall test was performed on five water quality parameters: Total Suspended Solids, Total Kjeldahl Nitrogen, Nitrate plus Nitrite Nitrogen, Total Phosphorus, Ortho Phosphorus. These parameters provided the minimum requirements (at least five years of data) to run the test.

In addition, monitoring data were compared with state water quality standards and minimallyly impacted streams' 25th and 75th percentiles for both North Central Hardwood Forest and Northern Lakes and Forest ecoregions. Sites in Aitkin County fall within the Northern Lakes and Forest ecoregion which has more restrictive benchmarks than the rest of the sites that fall within the North Central Hardwood Forest Ecoregion. Results of this analysis have helped define important characteristics of point and non- point sources pollution in the Snake River Watershed.

WATER QUALITY DATA

Water quality in the Snake River Watershed was monitored at fourteen locations during the period from 1998 to 2008. Of the fourteen sites twelve are still monitored. Below is the list of the stream sites included in this analysis (Figure 1). Monitoring at sites S002-587 (Snake River at CSAH-7 3.5 mi west of Pine City) and S003-527 (Bear Ck at CR-9 in McGrath) was discontinued in April 2006.

The water quality data was retrieved from STORET (Storage and Retrieval) which is the Environmental Protection Agency's Environmental Data System used to store water quality data. Data from 1998 to 2008 was downloaded for the following parameters:

- Total Suspended Solids (mg/L)
- Total Kjeldahl Nitrogen (mg/L)
- Nitrite plus Nitrate as Nitrogen (mg/L)
- Total Phosphorus (mg/L)
- Ortho-Phosphorus (mg/L)
- Chloride (mg/L)
- Fecal Coliform (# org/100 mL)
- Escherichia Coli (# org/100 mL)
- Transparency (cm)
- PH
- Specific Conductance (uS/cm)
- Dissolved Oxygen (mg/L)
- Temperature (C)

The ten year monitoring data showed inconsistency in the number of months and years of data collection for the fourteen sites. Most of the monitoring was done monthly during the summer, although there were some exceptions. There was only one month of data collected for 2003 and 2006 (April and June respectively) for most of the sites and water quality parameters. In 2000 there was no data collected for any of the sites. In addition, some monitoring data was collected for a few sites in 2007.

Data collected for field parameters (dissolved oxygen, specific conductance, temperature and PH) started in 2004 with the purchase of YSI meter by each Soil and Water Conservation District within the watershed which were in charge of the monitoring.
Sites S004-064 and S004-070 were incorporated in the monitoring program in 2006 so there was only two years of monitoring data for these sites. Sites S002-587 and S003-527 were discontinued in April 2006, so there were six complete years of data for these sites. See appendix A for a summary of the monitoring data for each site.

Stream Monitoring Sites:

- S001-727 Snake R at CSAH 18
- S004-067 Snake R at Olympic St
- S003-528 Knife R at CR-77 3
- S003-529 Snake R at MN-65
- S004-070 Snake R along 150th Ave
- S003-638 Groundhouse R at MN-47
- S003-532 Groundhouse R at CR-12
- S002-542 Pokegama Ck at CSAH 14
- S003-531 Mission Ck at CR-53
- S002-585 Pokegama Lk Outlet at CR-53
- S000-198 Cross Lk Outlet
- S002-587 Snake River at CSAH 7
- S003-527 Bear Ck at CR-9
- S003-533 Mud Ck at CSAH 5

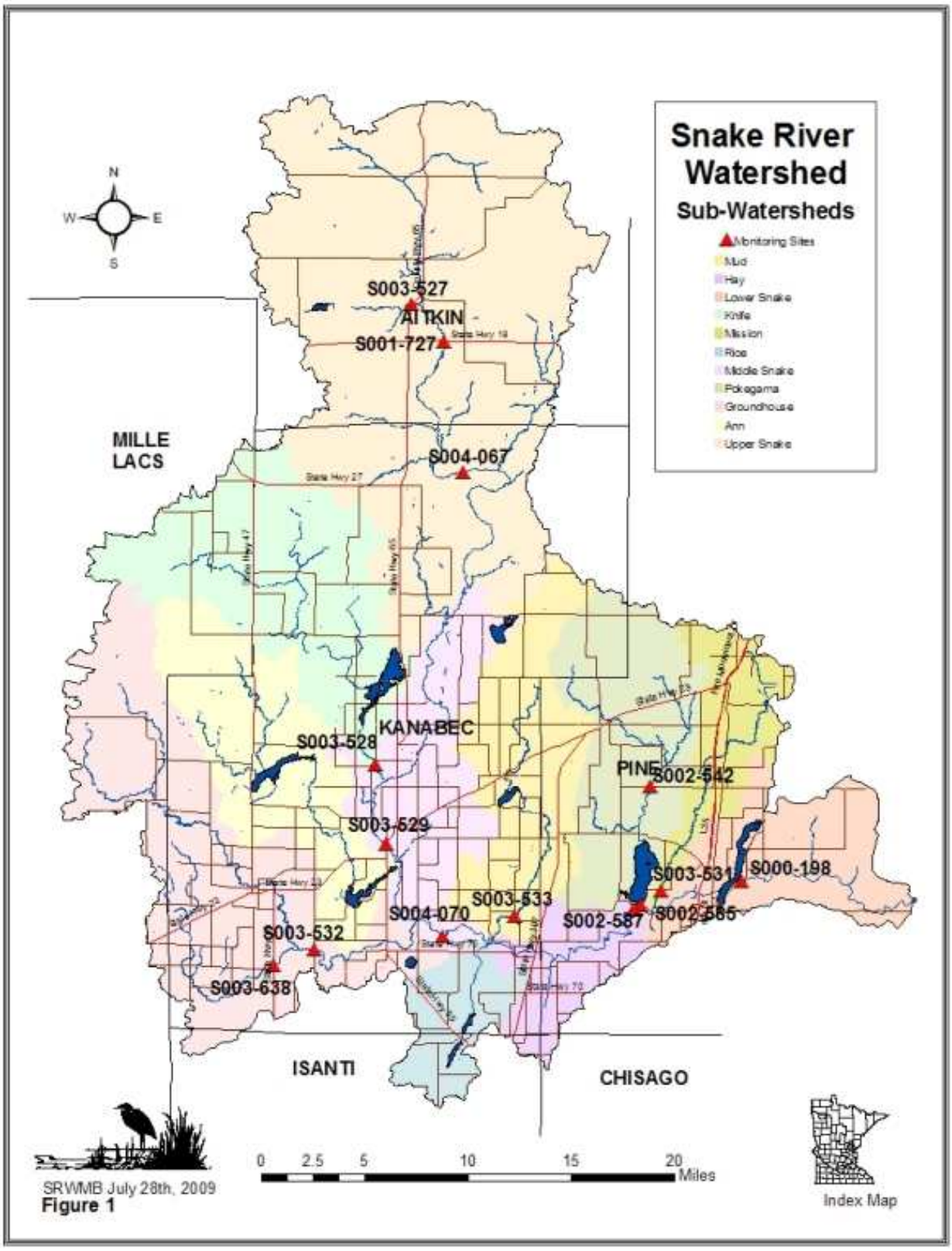

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Figure 1

WATER QUALITY ANALYSIS METHODS:

Trend analysis is an important step to determine if the water quality of the streams is improving or deteriorating. Since the data was not consistently monitored throughout the ten years of monitoring, it was not possible to perform a trend analysis for all parameters or sites. Therefore, two approaches were taken in the analysis of the data: The Seasonal Kendall statistical test trend analysis and a comparison of the statistics of the monitoring data against minimally impacted streams for the two ecoregions in the watershed and applying water quality standards.

Adjustments were made to the data prior to the analysis. Some data was reported in STORET as less than the detection limits and were set to one half of the detection limits for statistical analysis.

1. SEASONAL KENDALL

The Seasonal Kendall test is a statistical test well suited for identifying trends in data over time. It was developed by the U.S. Geological Survey and it is one of the most frequently used tests for trends in non-parametric data (data that is not normally distributed data) such as water quality data that varies seasonally. It does not require any assumptions as to statistical distribution of the data (e.g. normal, lognormal, etc) and it can be used with data sets that include irregular sampling intervals and missing data such as our case (Newell, 2007).

Some water quality parameters such as total suspended solids, nitrates and phosphorus are susceptible to flow levels in the streams, it is recommended but not necessary to transform data to flow-weighted values prior input into Kendall system. Since stream flow data was not available for the majority of the sites (MPCA is currently working on stream rating curves); therefore the analysis was performed on concentration values (mg/L).

The Seasonal Kendall test was performed for sites and water quality parameters' data sets with at least five years of monitoring data. There were only five parameters with a minimum of five years of data:

- Total Kjeldahl Nitrogen
- Nitrate plus Nitrite Nitrogen
- Total Phosphorus
- Ortho Phosphorus
- Total Suspended Solids

The Seasonal Kendall test compares water quality data at different time periods or seasons across years to determine the presence of a trend. Since the data was inconsistently monitored (no monthly data available for all years), data had to be grouped into seasons. Water quality data was divided into three and four seasons depending on the

frequency of the collection of data. Then, seasons were compared against each other across years to determine the presence of a trend. Due to gaps in data, there were some instances in which the test was performed for both seasons' groups in order to verify the significance of the trend results.

DISTRIBUTION OF THE DATA INTO SEASONS		
Seasons	**Four seasons group**	**Three seasons group**
season 1	October-December	October-January
season 2	January-March	February-May
season 3	April-June	June-September
season 4	July-September	NONE

Table 1

2. MINIMALLY IMPACTED STREAMS COMPARISON AND WATER QUALITY STANDARDS

2.1. WATER QUALITY STANDARDS

The water quality standards set the goals, pollution limits, and protection requirements for a waterbody. These standards are composed of designated (beneficial) uses, numeric and narrative criteria, and antidegradation policies and procedures (MPCA, 2009). They can be found in several Minnesota rules but the primary rule for statewide water quality standards is Minnesota Rules Chapter 7050.The following are the water quality standards applied for the Snake River watershed water quality data:

- **Dissolved Oxygen:** 5 mg/L as a daily minimum
- **pH:** Between 6.5 and 8.5
- **Chloride:** Chronic (four day average) = 230 mg/L, acute duration (one hour) = 860 mg/L
- **Escherichia Coli:** Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31.
- **Fecal Coliform:** Not to exceed 200 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31.

2.2. MINIMALLY IMPACTED STREAMS

The wide variety of geographic and environmental conditions in the state makes it hard to determine what "healthy" surface water is. Lakes and streams in the eastern and western part of the state have different chemical and physical characteristics than those in the northern and southern parts. In an effort to group these different ecosystems, the Environmental Protection Agency has divided the state of Minnesota into seven ecoregions. The Snake River watershed falls into two ecoregions (MPCA, 2006):

Northern Lakes and Forests (NLF):
This heavily forested ecoregion is made up of steep, rolling hills interspersed with pockets of wetlands, bogs, lakes and ponds. Agriculture is somewhat limited by the hilly terrain and lack of nutrients in the soil, though there are some beef and dairy cattle farms.

North Central Hardwood Forest (NCHF):
This ecoregion is an area of transition between the forested areas to the north and east and the agricultural areas to the south and west. The terrain varies from rolling hills to smaller plains. Upland areas are forested by hardwoods and conifers. Plains include livestock pastures, hay fields and row crops such as potatoes, beans, peas and corn.

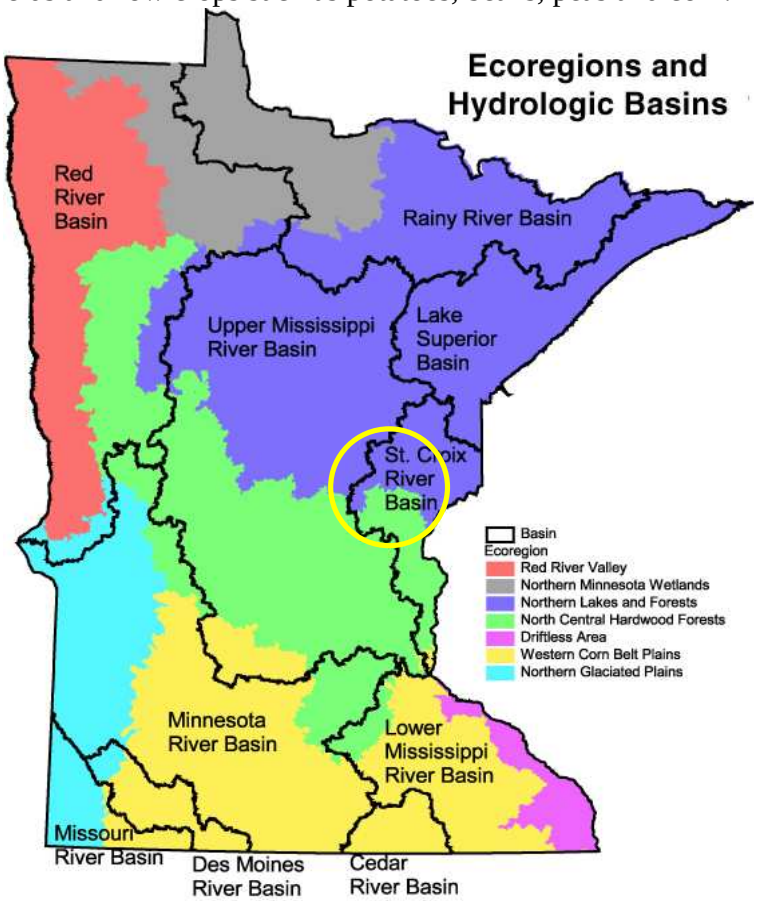

Figure 2

Data from minimallyly impacted streams in each ecoregion were used to estimate the attainable water quality in both ecoregions of the Snake River Watershed. The Snake River Watershed monitoring data-25th and 75th percentiles were compared against the 25th and 75th percentile annual results of the study done from 1986 to 1992 (Heiskary, 1993).

NORTH CENTRAL HARDWOOD FOREST
1986-1992 Annual

Parameter	N	Mean	SD	MAX	95%	75%	Median	25%	5%	MIN
Conductivity (uS/cm)	58	301	82.8	840	360	320	295	260	240	210
pH	58	8.2	0.28	8.9	8.7	8.4	8.1	8.0	7.8	7.6
TSS (mg/L)	58	9.1	6	29	20	13	7.7	4	2.2	1.4
NO2+NO3 (mg/L)	56	0.16	0.16	0.65	0.48	0.24	0.08	0.04	0.01	0.01
TP (mg/L)	57	0.08	0.06	0.43	0.13	0.09	0.07	0.05	0.02	0.01
Temperature (C)	57	14.2	9.9	28	26.5	23.5	15	5	0	0

Table 2.

NORTHERN LAKES AND FOREST
1986-1992 Annual

Parameter	N	Mean	SD	MAX	95%	75%	Median	25%	5%	MIN
Conductivity (uS/cm)	68	179	103	480	320	260	180	72.5	43	36
pH	68	7.7	526.4	8.3	8.2	8	7.8	7.5	7.3	6.9
TSS (mg/L)	68	3.0	2.2	9.8	7.2	4.0	2.0	1.5	0.8	0.5
NO2+NO3 (mg/L)	68	0.07	0.12	0.57	0.38	0.07	0.02	0.01	0.01	0.01
TP (mg/L)	68	0.03	0.05	0.43	0.06	0.04	0.03	0.01	0.01	0.01
Temperature (C)	67	10	8.5	26	25	18	10	1	0	0

Table 3.

RESULTS AND DISCUSSION

1. SEASONAL KENDALL

The results from the Seasonal Kendall Test were not surprising. Most of the results indicated no trend. There are two possible explanations for these results. There is "No Trend" because the water quality parameters' concentrations measured at a site are neither increasing nor decreasing. The specific water quality parameter is not getting better or worse. The second explanation is that the cause for "No Trend" is due to the gap in the data for years 2000, 2003, 2006 and 2007 which influenced the results.

The results from the Seasonal Kendall test are presented in tables 4 and 5. Table 4 shows a summary of the results from the test. Nitrite plus Nitrate as Nitrogen and Total Suspended Solid parameters showed increasing and decreasing trends. The Seaonal Kendall results for site S003-529 (Snake River in Mora) were highly significant (above 95% confidence), however the decreasing rates per year were quite small for Nitrates, Total Phosphorus, Ortho-Phosphorus and Total Suspended Solids parameters.
Table 5 shows the statistical results for sites where there was either an increasing or decreasing trend (Figure 2). Below is a description of the statistics of the test.

The Mann-Kendall Statistics (S): measures the trend in the data. Positive values indicate an increase in concentrations over time, whereas negative values indicate a decrease in concentrations over time. The strength of the trend is proportional to the magnitude of the Mann-Kendall Statistics (ie. large magnitudes indicate a strong trend).

Z statistics: It is the test statistic. It measures how far the data diverge from the null hypothesis (there is "No Trend" or change). A large value of the test statistic indicates that there is evidence against the null hypothesis, meaning that there exists a trend in the data (increasing large positive values or decreasing large negative values).

p-value: It is the probability computed assuming that the null hypothesis is true ("No Trend"). "Significant" means that is not likely to happen just by chance. The lower the p-value, the more significant, meaning there is a high likelihood of an increasing or decreasing trend in the concentrations. For our analysis, we decided that there was a trend only when the results were significant (p-values smaller than 0.10). Any p-value greater than 0.10 was indicative of "No trend" in the data.

Highly significant	p-value <= 0.01
Significant	0.01 < p-value < 0.05
Marginal significant	0.05 < p < = 0.10

Slope: The rate of concentration change per year. The rate at which the water quality parameters' concentrations are either increasing or decreasing over time.

Confidence/Probability: The confidence in trend is the statistical probability that the concentration of a water quality parameter is increasing (S>0) or decreasing (S<0). If the confidence is less than 90%, then there is “No Trend”. It is based on p-value.

SEASONAL KENDALL TEST TREND SUMMARY

Location	Site ID	No. of Years	TKN	NO2+NO3	TP	Ortho-P	TSS
			1998-2008				1999-2008
Snake R at CASH 18, 2.35 mi SE of McGrath	**S001-727**	8	No Trend	No Trend	No Trend	No Trend	No Trend
Mission Ck at CR-53, 2.3 mi W of Pine City	**S003-531**	8	No Trend	Increasing	No Trend	No Trend	No Trend
Pokegama Lk Outlet at CR-53, 3.5 mi W Pine City	**S002-585**	8	No Trend	Increasing	No Trend	No Trend	No Trend
Cross Lk Outlet at CSAH-9 2 mi NE of Pine City	**S000-198**	8	No Trend	No Trend	No Trend	No Trend	No Trend
			1999-2008				
Knife R at CR-77 3 mi N of Mora	**S003-528**	7	No Trend	No Trend	No Trend	No Trend	No Trend
Snake R at MN-65, 0.7 mi S of Mora	**S003-529**	7	No Trend	Decreasing	Decreasing	Decreasing	Decreasing
Groundhouse R at CR-12 (Harbor St), 3.6 mi W of Brunswick	**S003-532**	7	No Trend	No Trend	No Trend	No Trend	No Trend
Mud Ck at CASH 5, 1.6 mi NW Grasston.	**S003-533**	7	No Trend	No Trend	No Trend	No Trend	Probably Increasing
Pokegama Ck at CSAH 14, 3.6 mi W of Beroun.	**S002-542**	7	No Trend	Increasing	No Trend	No Trend	No Trend
				1998-2005			1999-2008
Snake River at CASH-7 3.5 mi west of Pine City	**S002-587**	6	None	No Trend	No Trend	No Trend	Decreasing
Bear Ck at CR-9 in McGrath	**S003-527**	6	None	Decreasing	No Trend	No Trend	No Trend

Table 4. No data for years: 2000, 2007 and only one month data for 2003 and 2006. No TKN trend calculated for S002-587 and S003-527 only four years of data

Increansing or Decresing Trend: 95% confidence that there is a trend
Probably Increasing or Probably Decreasing: between 90% and 94% confidence that there is a trend.

No Trend : <90% confidence that there is a trend

SEASONAL KENDALL TEST TREND STATISTICAL ANALYSIS RESULTS FOR SITES WHERE THERE IS A TREND

Location	Site ID	Parameter	Trend	S	Z	Slope (mg/L/year)	p-value	Probability
Mission Ck at CR-53, 2.3 mi W of Pine City	S003-531	NO2+NO3	Increasing	48	3.779	0.003635	0.0002	99.98%
Pokegama Lk Outlet at CR-53, 3.5 mi W Pine City	S002-585	NO2+NO3	Increasing	26	2.391	0.003417	0.0168	98.32%
Snake R at MN-65, 0.7 mi S of Mora	S003-529	NO2+NO3	Decreasing	-20	-2.17	-0.01171	0.03	97.00%
Snake R at MN-65, 0.7 mi S of Mora	S003-529	TP	Decreasing	-22	-2.079	-0.0024	0.0376	96.24%
Snake R at MN-65, 0.7 mi S of Mora	S003-529	ORTHO-P	Decreasing	-21	-2.01	-0.0015	0.0444	95.56%
Snake R at MN-65, 0.7 mi S of Mora	S003-529	TSS	Decreasing	-31	-2.441	-0.1667	0.0146	98.54%
Mud Ck at CASH 5, 1.6 mi NW Grasston.	S003-533	TSS	Prob.Increasing	15	1.654	0.333	0.09	91.00%
Pokegama Ck at CSAH 14, 3.6 mi W of Beroun.	S002-542	NO2+NO3	Increasing	18	1.893	0.0033	0.058	94.20%
Snake River at CASH 3.5 mi west of Pine City	S002-587	TSS	Decreasing	-33	-2.559	-0.4583	0.01	99.00%
Bear Ck at CR-9 in McGrath	S003-527	NO2+NO3	Decreasing	-17	-1.955	-0.00098	0.05	95.00%

Table 5.

Highly significant	p-value <= 0.01
Significant	0.01 < p-value < 0.05
Marginal significant	0.05 < p < = 0.10

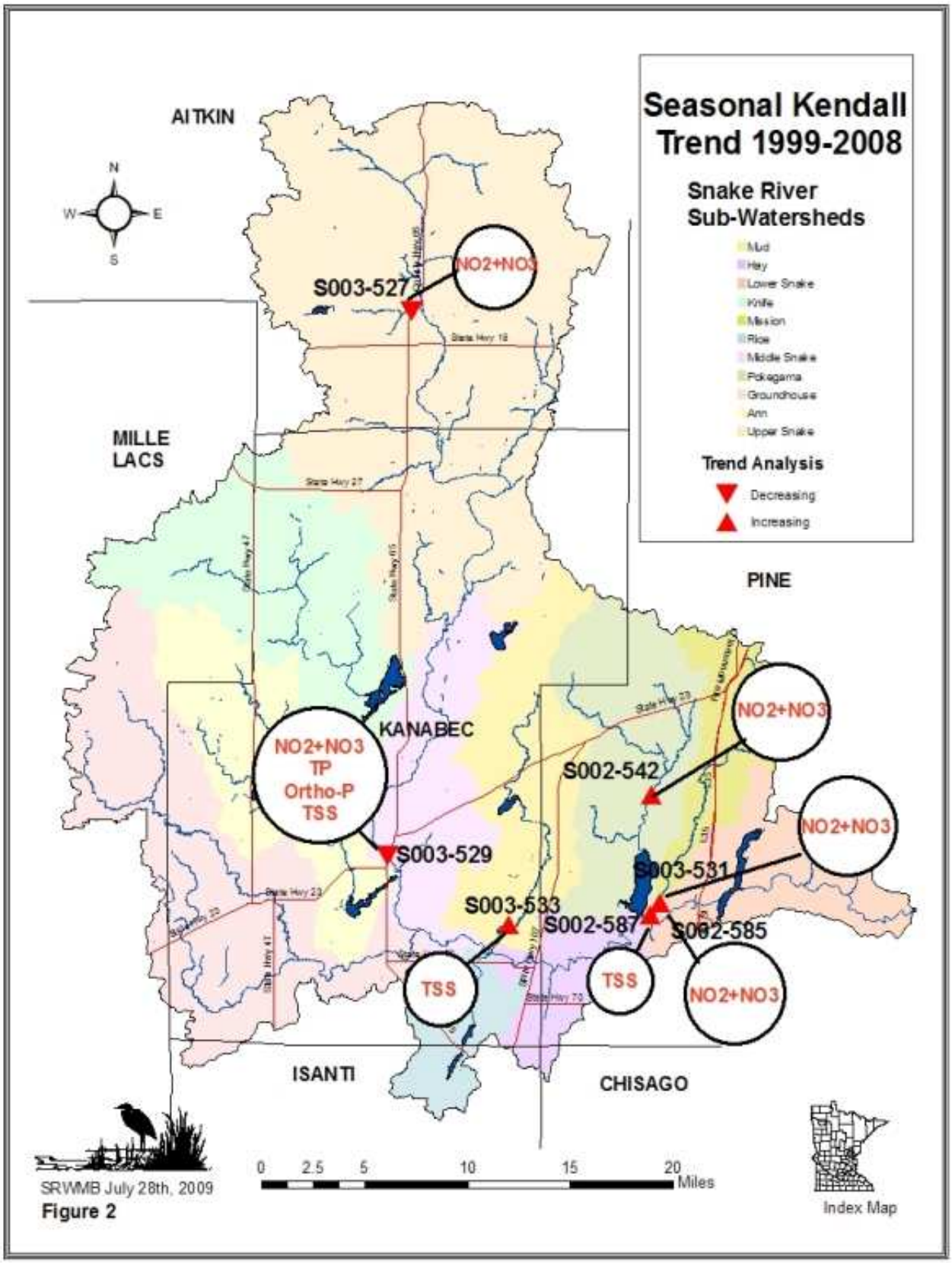

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Figure 2

2. MINIMALLY IMPACTED STREAM COMPARISON AND WATER QUALITY STANDARDS:

2.1. TOTAL KJELDAHL NITROGEN (TKN)

Total Kjeldahl Nitrogen is a measure the amount of the organic nitrogen and ammonia in the water column. It is largely organically bound nitrogen and much of the measured TKN is likely to be tied up in the algal cells. High levels of TKN typically result from sewage, fertilizer, erosion and manure discharge to water bodies (NHPES, 2008).

The benchmarks of 0.05 and 1.5 mg/L used in the comparison are not for minimallyly impacted streams and they do not correspond to the statistics 25th and 75th percentiles. They were used as a way to compare our monitoring data. These observed values are a result of a study by Minnesota Pollution Control Agency titled "Establishing Relationships Among In-Stream Nutrient Concentrations, Phytoplankton and Periphyton Abundance and Composition, Fish and Macroinvertebrate Indices, and Biochemical Oxygen Demand in Minnesota USA River" in the NCHF and NLF ecoregions (Heiskary, S., Markus, H., 2003).

The results of the comparison of these benchmarks against the monitoring data showed that most of the sites were within the specified ranges. From the distribution of the TKN concentration values we can only conclude that site S002-585 (Pokegama Creek) shows the highest 75th percentile levels of TKN in the watershed (Figure 5). This site had a maximum of 5.10 mg/L in August 2001. Similarly, site S003-529 (Middle Snake River) had the highest concentration levels 8 mg/L in April 2006. We can not establish other conclusions regarding the impairment of these sites because the benchmarks used are not 25th and 75th percentile statistics for minimally impacted streams in the watershed. See Appendix B-Table 6 for statistics results on this parameter.

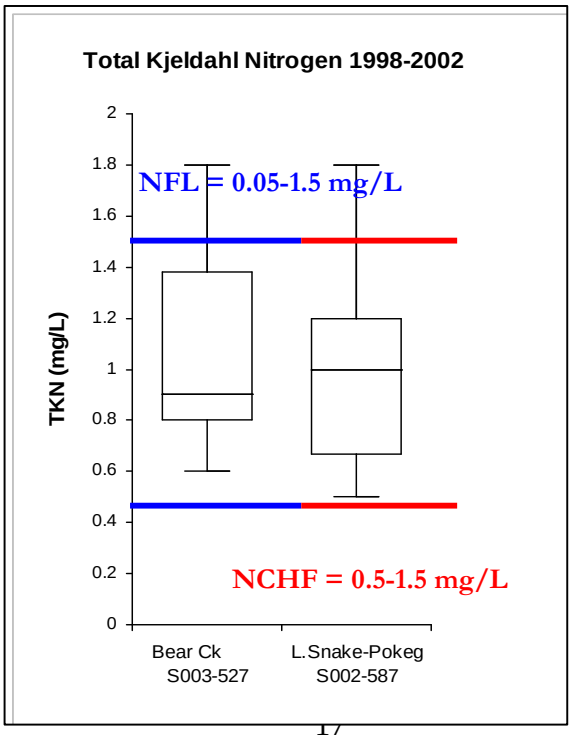

Figure 4

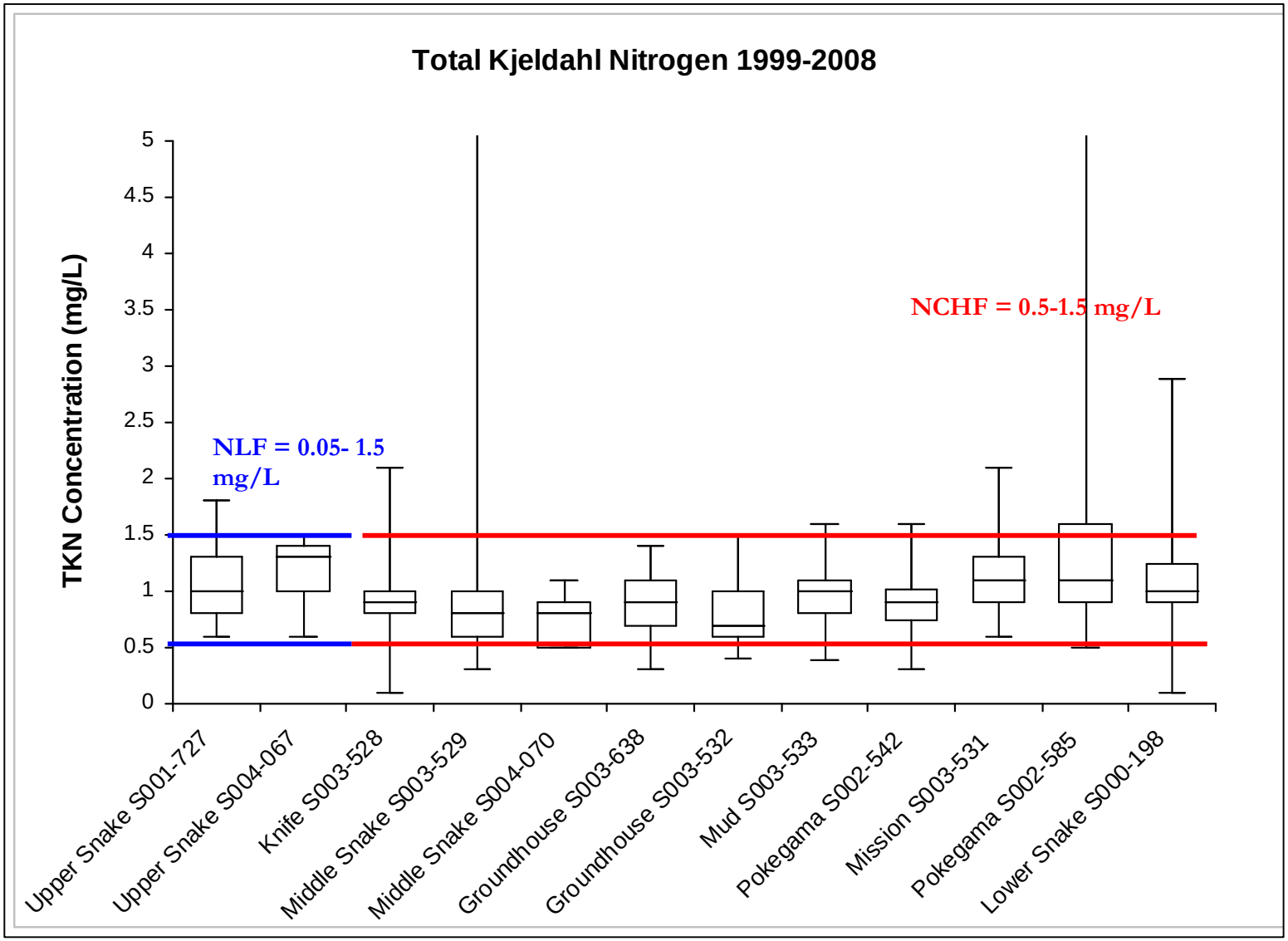
Total Kjeldahl Nitrogen 1999-2008
TKN Concentration (mg/L)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
NLF = 0.05- 1.5 mg/L
NCHF = 0.5-1.5 mg/L
Upper Snake S001-727
Upper Snake S004-067
Knife S003-528
Middle Snake S003-529
Middle Snake S004-070
Groundhouse S003-638
Groundhouse S003-532
Mud S003-533
Pokegama S002-542
Mission S003-531
Pokegama S002-585
Lower Snake S000-198

Figure 5

2.2. NITRITE PLUS NITRATE AS NITROGEN (NO2+NO3)

Nitrite (NO2) plus Nitrate (NO3) as nitrogen are often caused by over application of fertilizers in farmlands that leach into waterbodies, manure and failing septic systems. It measures the inorganic component of nitrogen in the water column.

Comparison of the data for the fourteen sampling sites with the minimally impacted stream data showed that the 75th percentiles values found in both of the Groundhouse River sites and S004-067 (Upper Snake) site are much higher than those found in the minimally impacted areas (Figures 7).

63 and 72 percent of the samples taken at S003-638 and S003-532 sites (Groundhouse River) exceeded the 0.24 mg/L (75th percentile) NCHF minimally impacted streams benchmark respectively (Figures 7, 9, 10). Also, 33 percent of the samples taken at site S004-067 (Upper Snake) exceeded the 0.07 mg/L (75th percentile) NLF minimally impacted benchmark (Figure 7, 8). See Appendix B-Table 7 for statistics results on this parameter.

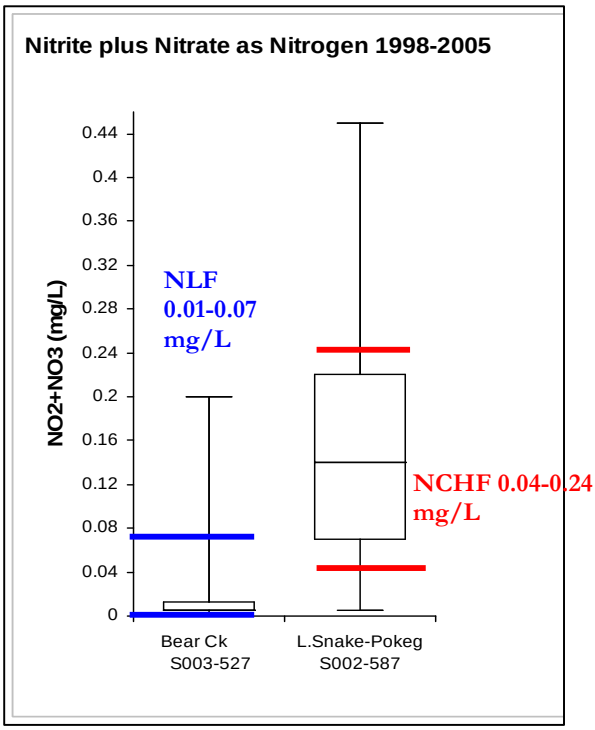

Figure 6

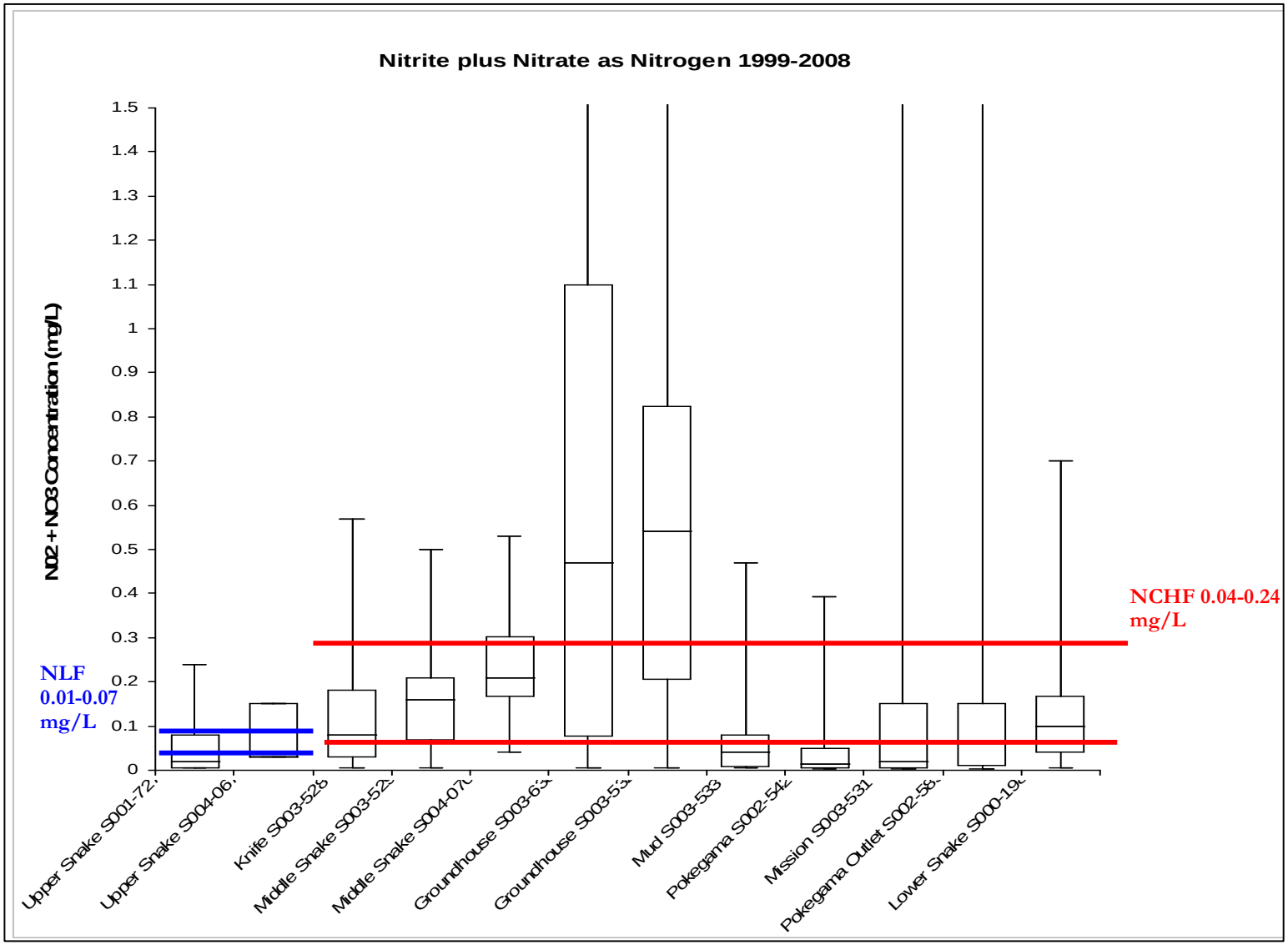
Nitrite plus Nitrate as Nitrogen 1999-2008
NO2 + NO3 Concentration (mg/L)
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
NLF
0.01-0.07
mg/L
NCHF 0.04-0.24
mg/L
Upper Snake S001-72
Upper Snake S004-06
Knife S003-528
Middle Snake S003-52
Middle Snake S004-07
Groundhouse S003-6
Groundhouse S003-5
Mud S003-533
Pokegama S002-54
Mission S003-531
Pokegama Outlet S002-58
Lower Snake S000-19

Figure 7

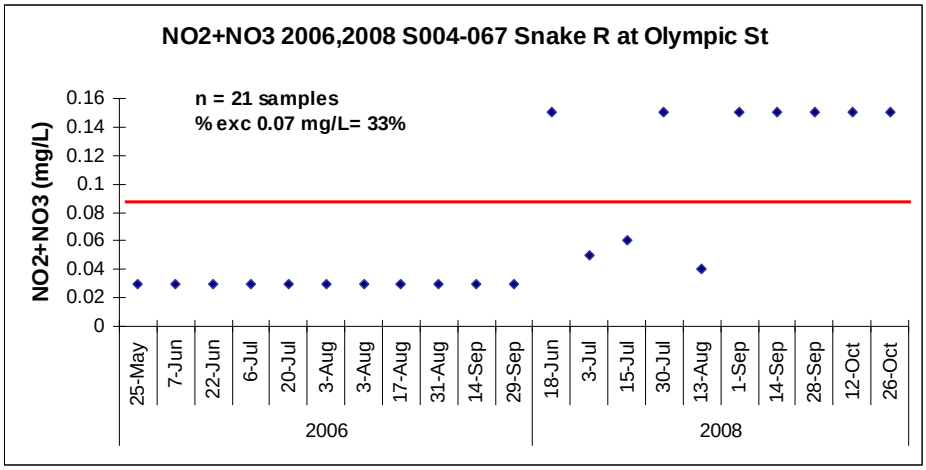

Figure 8

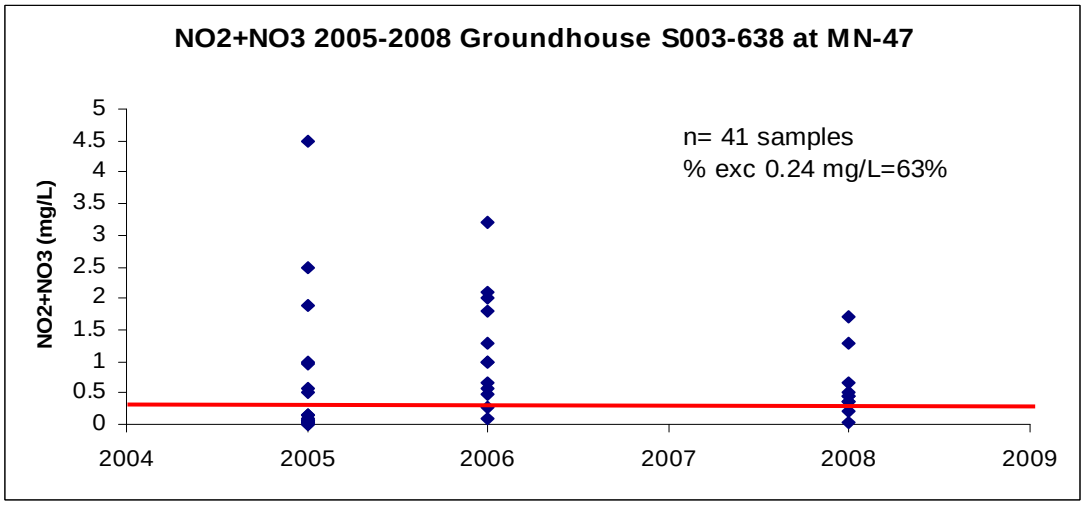

Figure 9

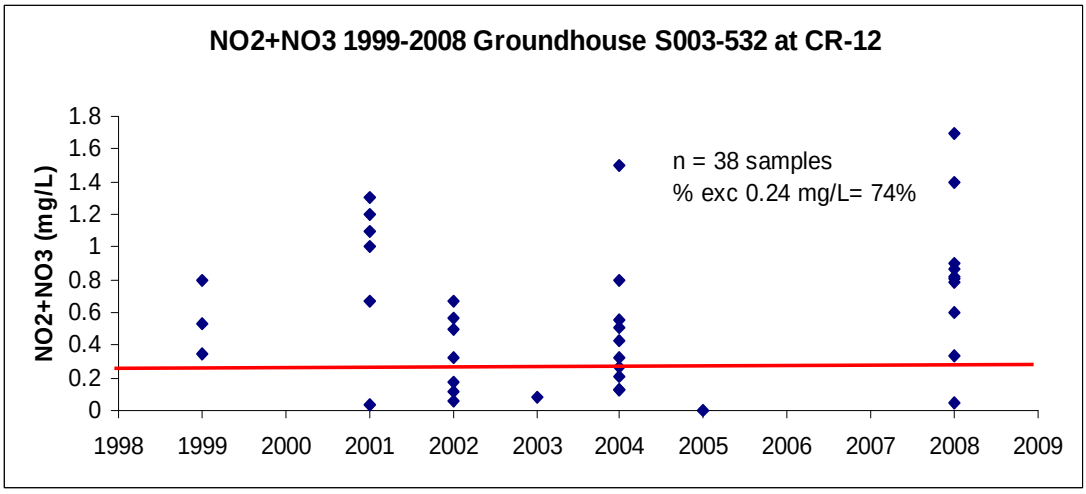

Figure 10

2.3. TOTAL PHOSPHORUS

Total phosphorus is a measure of all forms of phosphorus in the water column, including organic and inorganic forms. It is the nutrient essential for plant growth. Phosphorus is the limiting nutrient in freshwater streams; relative small amounts can cause large algae blooms. There are many sources of phosphorus in the watershed, both natural and human. It can indicate the presence of failing septic systems, animal manure, lawn fertilizer, road and construction erosion or natural wetland and atmospheric deposition.

Results from the comparison of the Snake River sites against the minimally impacted streams benchmarks showed eight sites being above the 75th percentile benchmarks. The 75th percentile total phosphorus values found in both of the Groundhouse River sites, Mission Creek and Mud Creek were the highest (Figure 16). See Appendix B-Table 8 for statistics results on this parameter.

Mission Creek had the highest number of samples (54% of samples) that exceeded the 0.05 mg/L (75th percentile) NCHF minimally impacted stream benchmark (Figure 12). In addition, 52% of samples taken at S003-638 (Groundhouse River), 47% of samples taken at Mud Creek and 38% of samples taken at S003-532 (Groundhouse River) sites exceeded the benchmark as well (Figures 13,14,15).

It is worth mentioning that these benchmarks might need to be adjusted in the near future due to the Lake St. Croix Nutrient Impairment TMDL that is currently underway. This TMDL requires reductions in phosphorus loading from the surrounding watersheds that discharge to Lake St. Croix. The current TMDL proposal suggests a reduction goal for total phosphorus for the lake of 0.04 mg/L which is a value that goes back to 1940's. The proposed TMDL for Lake St. Croix requires a total phosphorus reduction of 100 metric tons for the St. Croix River Watershed. The current phosphorus load from the St. Croix Watershed to the lake is 460 metric tons per year and the goal is 360 metric tons per year of phosphorus. The Snake River Watershed contributes approximately 51,000 kg/year of total phosphorus to the St. Croix Basin of which 25,000 kg/year comes from point and non-point sources. The other 26,000 kg/year phosphorus load is coming from natural sources. The proposed TMDL is looking for a total phosphorus reduction for the Snake River Watershed of about 9,500 kg/year (38% reduction of 25,000 kg/year) (Barr Engineering, 2009).

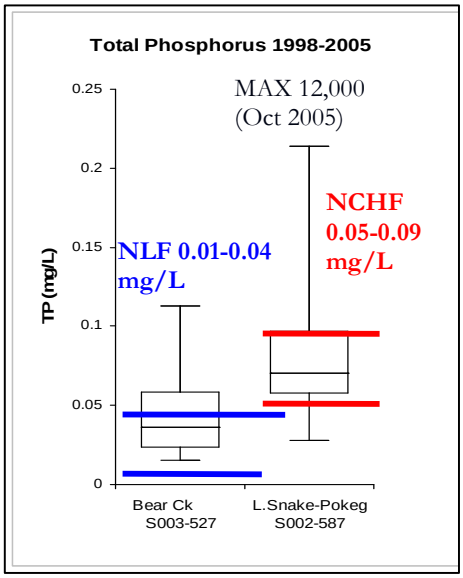

Figure 11

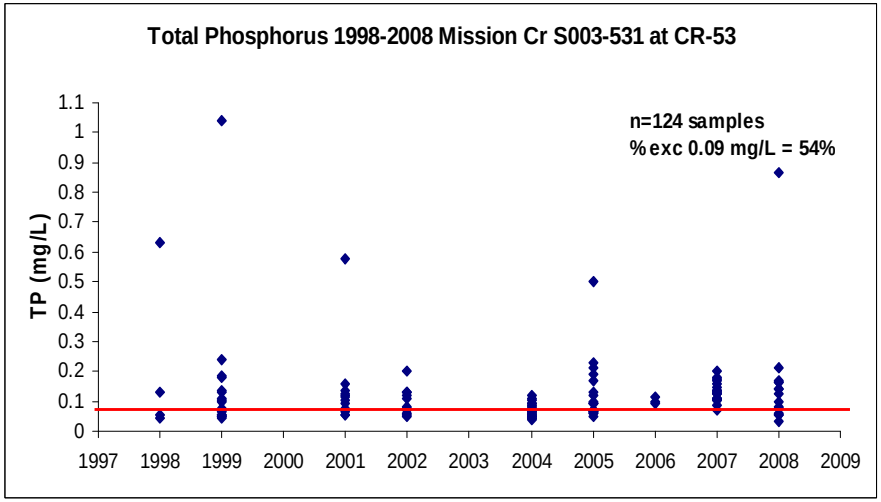

Figure 12

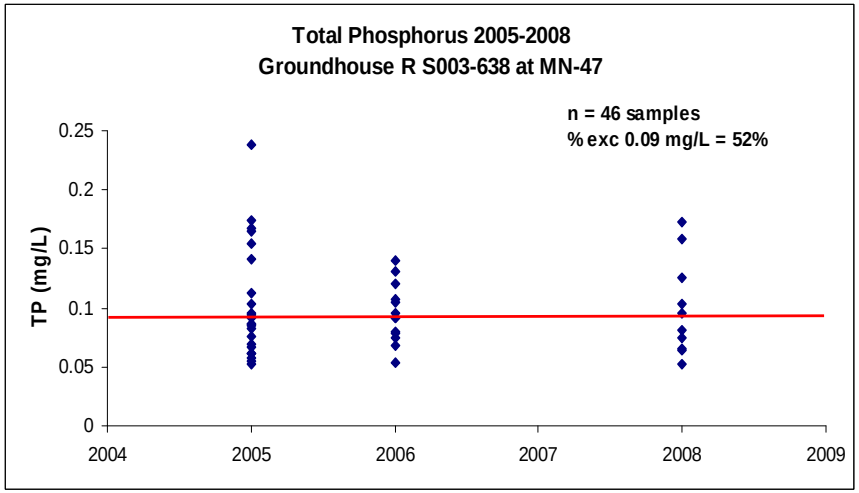

Figure 13

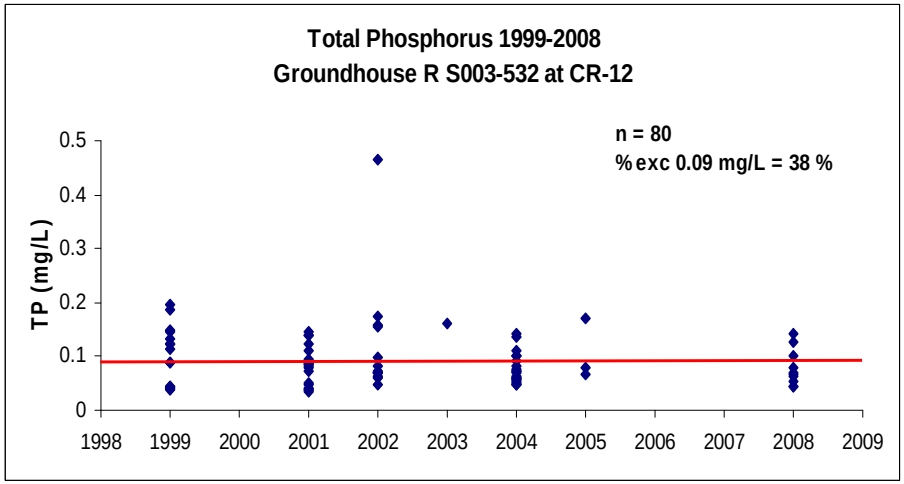

Figure 14

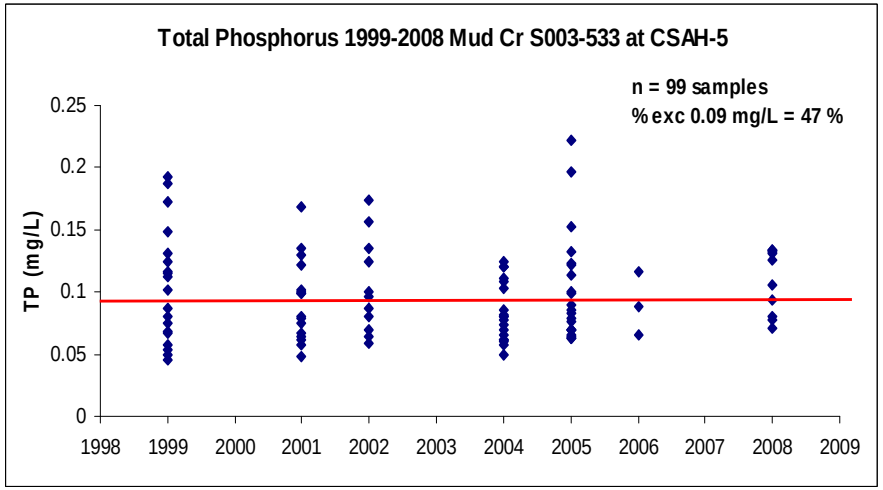

Figure 15

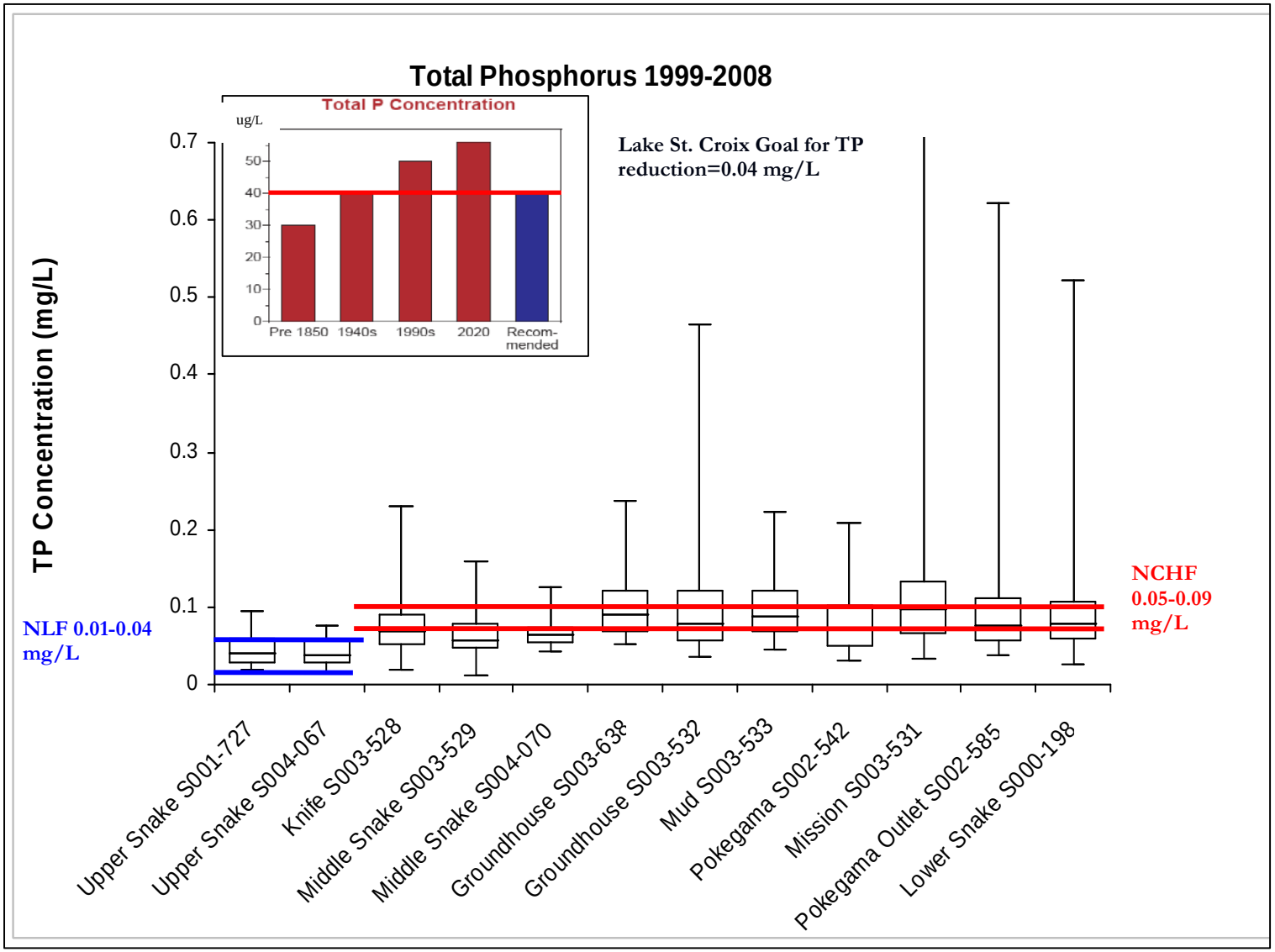
Total Phosphorus 1999-2008
Total P Concentration
ug/L
50
40
30
20
10
0
Pre 1850
1940s
1990s
2020
Recom-
mended
Lake St. Croix Goal for TP
reduction=0.04 mg/L
TP Concentration (mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
NLF 0.01-0.04
mg/L
NCHF
0.05-0.09
mg/L
Upper Snake S001-727
Upper Snake S004-067
Knife S003-528
Middle Snake S003-529
Middle Snake S004-070
Groundhouse S003-638
Groundhouse S003-532
Mud S003-533
Pokegama S002-542
Mission S003-531
Pokegama Outlet S002-585
Lower Snake S000-198

Figure 16

2.4. ORTHO-PHOSPHORUS

Ortho Phosphorus is soluble reactive phosphorus that is readily available for biological uptake. Therefore, a particular concern with this inorganic phosphorus is that is readily available to algae growth leading to depletion of dissolved oxygen in the water column (NHDES, 2008).

The primary sources of ortho-phosphorus are wastewater treatment plants, feedlot runoff, and failing septic systems.

When we examined the total phosphorus and ortho-phosphorus monitoring data, there were some instances where the ortho-phosphorus values were greater than the total phosphorus values. By definition ortho-phosphorus values should be less than total phosphorus. According to ERA Laboratories, the most likely cause for this result is the fact that ortho-phosphorus lab tests are affected by the silica content in the water sample while the total phosphorus tests are not affected by the silica content causing the discrepancy in the lab results.

There are not water quality standards or minimally impacted stream values for the ecoregions in the Snake River watershed; therefore it was not possible to compare the ortho-phosphorus values against a benchmark. The conclusion that could be drawn from the monitoring data (Figure 17, 18) is that Mission Creek had the highest 75th percentile values in the watershed while Knife River had the lowest 75th percentile value in the NCHF ecoregion. Similarly, S004-067 (Upper Snake River) 75th percentile values were the highest in the NLF ecoregion. See Appendix B-Table 9 for statistics results on this parameter.

The EPA recommends total phosphorus to be in between 0.01 to 0.03 mg/L to prevent algae blooms in streams. According to this recommendation, about half the sites in the watershed would not comply with these referenced numbers.

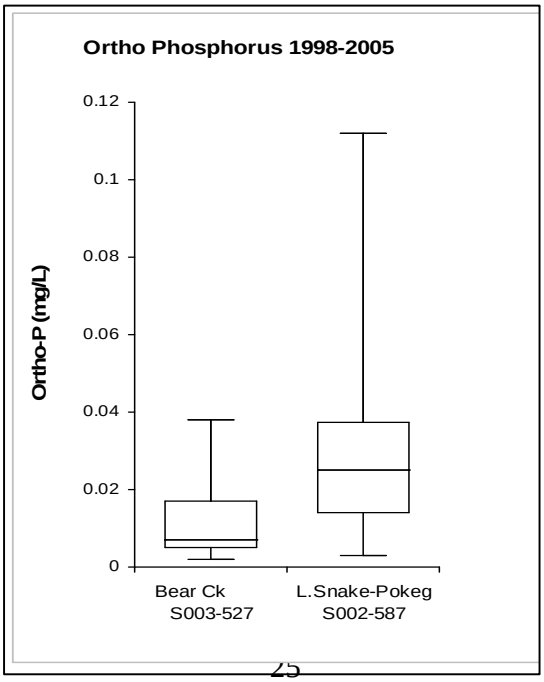

Figure 17

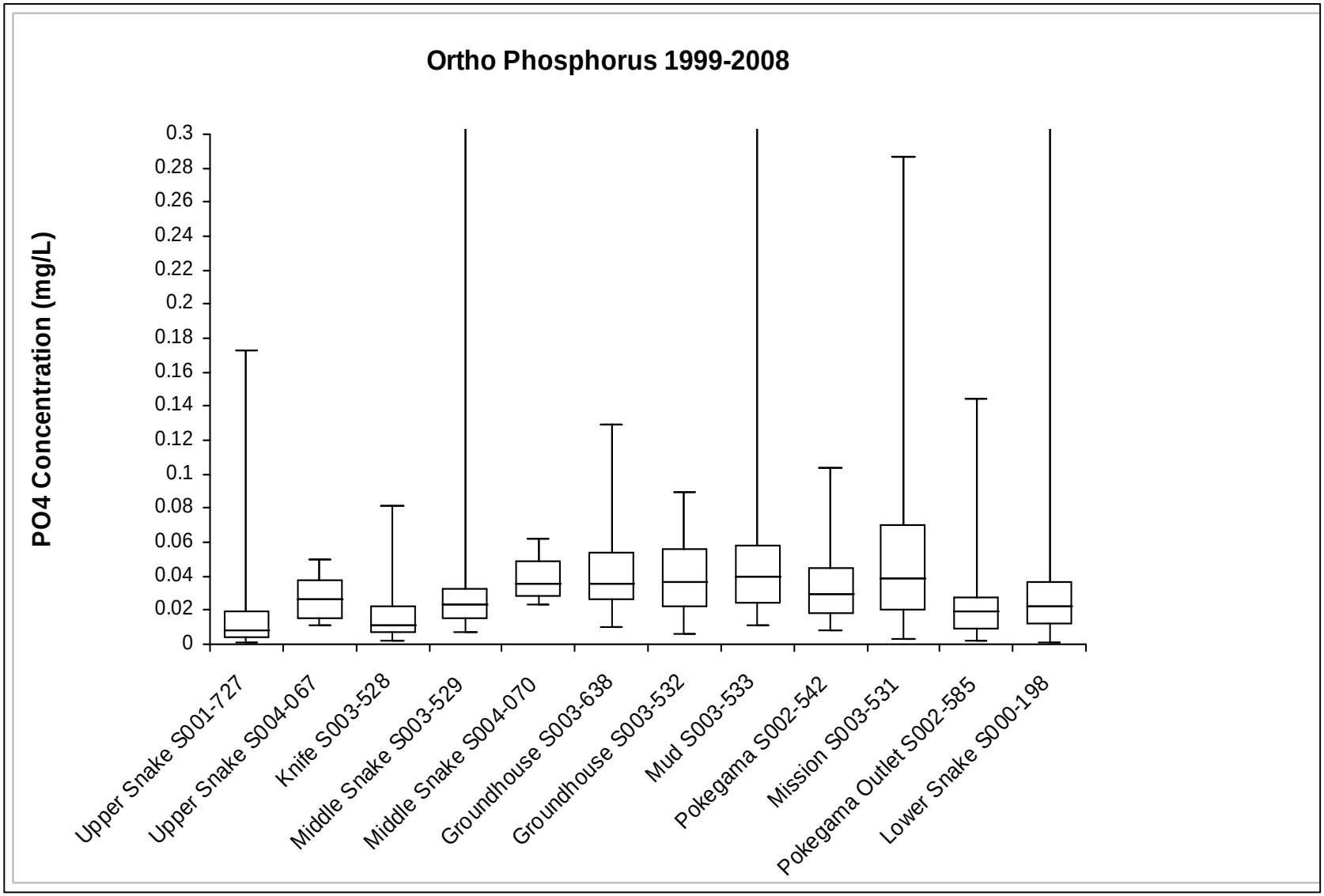
Ortho Phosphorus 1999-2008
PO4 Concentration (mg/L)
0.3
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Upper Snake S001-727
Upper Snake S004-067
Knife S003-528
Middle Snake S003-529
Middle Snake S004-070
Groundhouse S003-638
Groundhouse S003-532
Mud S003-533
Pokegama S002-542
Mission S003-531
Pokegama Outlet S002-585
Lower Snake S000-198

Figure 18

2.5. TOTAL SUSPENDED SOLIDS (TSS)

Total suspended solids measures the amount of sediment and organic material (i.e. algae) suspended in the water column. Sediment of size less than 2 mm was one of the stressors found in the Groundhouse River TMDL study done in 2008. Although these fine sediments are not specifically collected as part of the water quality monitoring, total suspended solids lab analysis can still give us some insight into the levels of sediment transported through the system at the time of sampling (MPCA, 2008).

The 75th percentile levels for total suspended solids concentrations were below the NCHF and NLF minimally impacted streams benchmarks for all the sites across the watershed. Consider these results careully. The low total suspended solids values do not imply that sediment could not be the cause of biota impairment in the watershed; it only means that TSS is not a candidate for impairment. Total suspended solids is only one of parameters used to determine sediment impairment. Data collected for TMDL studies to determine sediment impairment in watersheds include percentage fine sediments, percent embeddedness, maximum depth of fine sediment, turbidity and total suspended solids (Groundhouse TMDL).

Most of the maximum values occurred during rain events. The highest levels occurred at site S003-532 (Groundhouse River), 185 mg/L in June 2002 during a one inch rain event. Pokegama Outlet had the highest 75th percentile values in the watershed. These high values are due to algae blooms in the lake during the summer months.

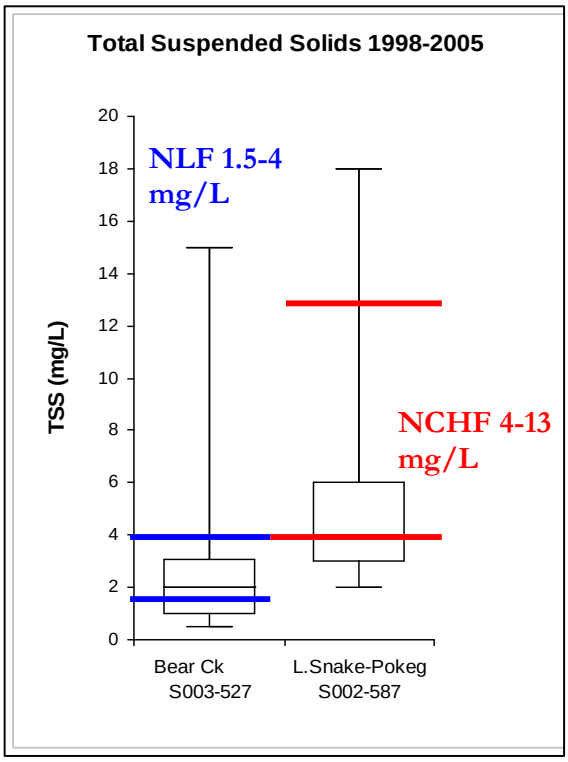

Figure 19

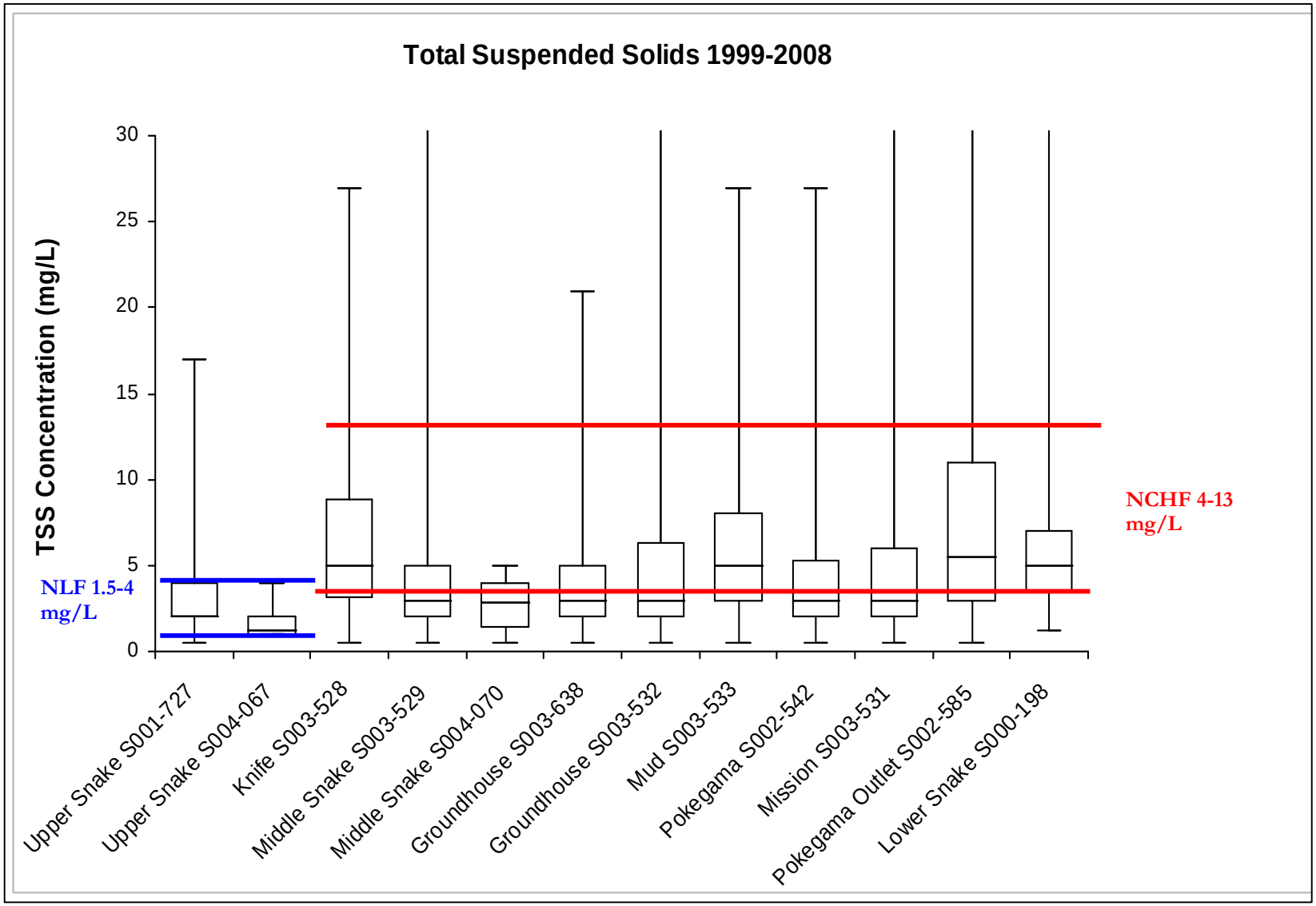
Total Suspended Solids 1999-2008
TSS Concentration (mg/L)
30
25
20
15
10
5
0
NLF 1.5-4 mg/L
NCHF 4-13 mg/L
Upper Snake S001-727
Upper Snake S004-067
Knife S003-528
Middle Snake S003-529
Middle Snake S004-070
Groundhouse S003-638
Groundhouse S003-532
Mud S003-533
Pokegama S002-542
Mission S003-531
Pokegama Outlet S002-585
Lower Snake S000-198

Figure 20

2.6. TRANSPARENCY

Stream transparency is an indirect measure of the amount of dissolved and suspended materials present in the water column. For instance, both of the Upper Snake River sites have transparency that resembles tea color due to dissolved organic material from the surrounding bog areas in this northern part of the watershed.

In general, a low transparency reading reflects a large amount of sediment (silt and clay particles) or other suspended material like algae in the water. Too much sediment in the water is a significant pollutant itself, whether it is suspended in the water column or deposited on stream bottoms stressing biota habitat. Suspended sediment reduces light penetration needed for the growth of beneficial aquatic plants. Finally, these soil particles can transport phosphorus and other pollutants attached downstream (MPCA, 2006).

The MPCA has established the following categories as benchmarks for transparency interpretation. These categories relate primarily to materials suspended in the water:

- < 20 cm – Poor Transparency
- 20 cm - 40 cm – Fair Transparency
- 41 cm - 60 cm – Good Transparency
- >60 cm – Excellent Transparency

Transparency readings have formerly been collected with a 60 cm transparency tube. Later in 2006, these readings were collected using 100 cm transparency tube. The analysis of the transparency readings was performed only for year 2008 to be able to compare all sites with data collected using the same tube for same year. The transparency readings in the streams and rivers of the Snake River watershed are “good” to “excellent” (Figure 21). There was only one instance when Mission Creek dropped to a “fair” transparency level. This fair condition occurred during a rainfall event which generated surface runoff from urban (impermeable surfaces) and agricultural land experiencing soil erosion. Bank erosion and turbulence due to high flow conditions are also a cause of poor and fair transparency. See Appendix B-Table 11 for statistics results on this parameter.

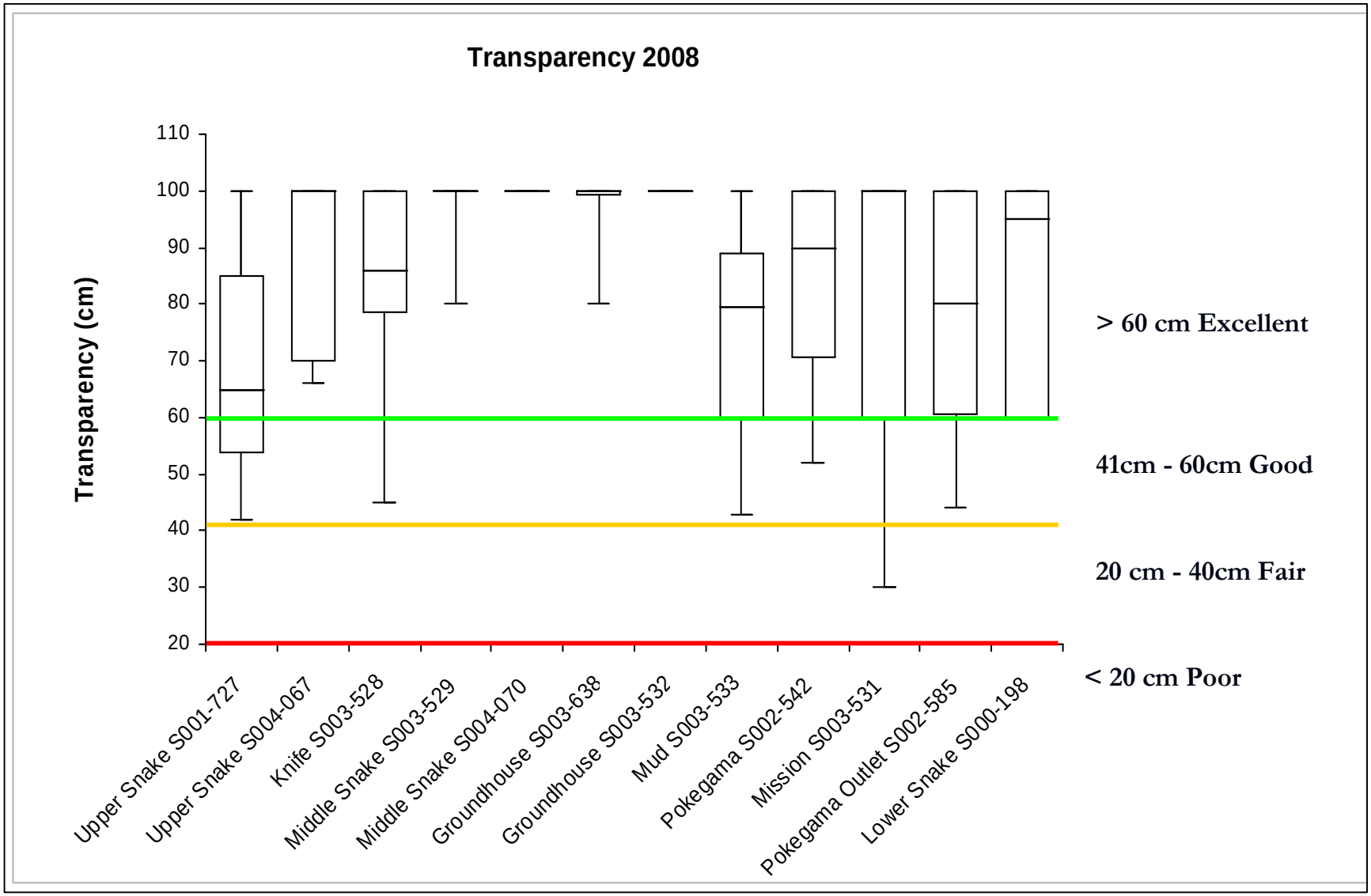
Transparency 2008
Transparency (cm)
110
100
90
80
70
60
50
40
30
20
> 60 cm Excellent
41cm - 60cm Good
20 cm - 40cm Fair
< 20 cm Poor
Upper Snake S001-727
Upper Snake S004-067
Knife S003-528
Middle Snake S003-529
Middle Snake S004-070
Groundhouse S003-638
Groundhouse S003-532
Mud S003-533
Pokegama S002-542
Mission S003-531
Pokegama Outlet S002-585
Lower Snake S000-198

Figure 21

2.7. CHLORIDE

Although chloride can originate from natural sources, most of the chloride that enters the water systems comes from application of road salt (most often sodium chloride) applied in the winter months. Higher than normal levels of chloride concentrations in freshwater are detrimental to water quality.

Chloride commonly enters the surface waters from runoff during late spring snowmelt when the ground is frozen. Sodium chloride is also part of the human diet; therefore it is present in human waste. High levels of chloride in water could sometimes indicate sewage pollution.

Chloride ions do not degrade in the environment, meaning that once dissolved, they tend to remain in solution. Chloride ions that enter the ground water can ultimately reach the surface water (NHDES, 2008).

The state water quality standards are:

- Chronic (four day average) = 230 mg/L
- Acute duration (one hour) = 860 mg/L

Chronic standards: The highest concentration of a toxicant to which organisms can be exposed indefinitely with no harmful effects (MPCA, 2009).
Final Acute value: concentration that could kill about half of the exposed organisms of a very sensitive aquatic species (MPCA, 2009).

Chloride values for the Snake River watershed are well below the water quality standard (Figures 22 and 23) with exception of a maximum high at Lower Snake River (Cross Lake Outlet in Pine City) of 160 mg/L in October 2008. This high value could be due to a snow fall event followed by the application of road salt. The second largest Chloride values (150 mg/L) occurred in late spring 2007 at the same site. See Appendix B-Table 12 for statistics results on this parameter.

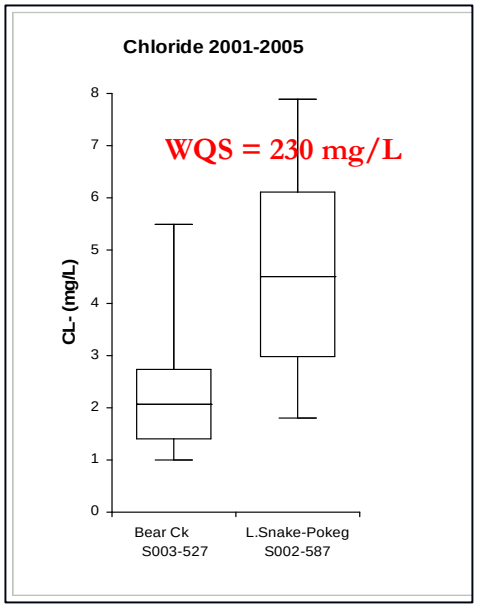

Figure 22

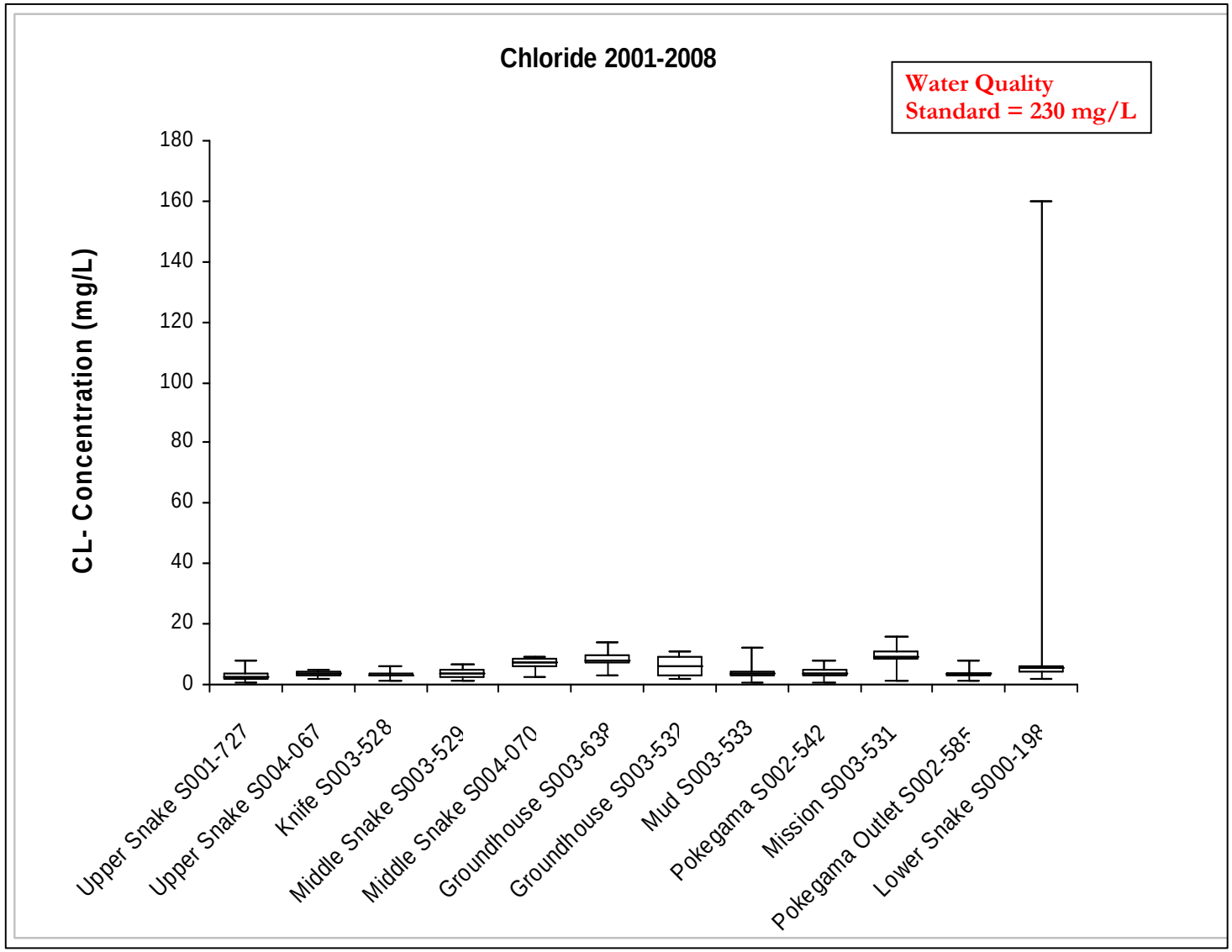
Chloride 2001-2008
Water Quality
Standard = 230 mg/L
CL- Concentration (mg/L)
180
160
140
120
100
80
60
40
20
0
Upper Snake S001-727
Upper Snake S004-067
Knife S003-528
Middle Snake S003-529
Middle Snake S004-070
Groundhouse S003-638
Groundhouse S003-537
Mud S003-533
Pokegama S002-542
Mission S003-531
Pokegama Outlet S002-585
Lower Snake S000-198

Figure 23

2.8. FECAL COLIFORM AND ESCHERICHIA COLI

The fecal colifom bacteria group consists of several genera of bacteria. Not all the species of bacteria of this category are harmful, but they are usually associated with harmful organisms transmitted by fecal contamination. They are found in the intestines of warm-blooded animals (including humans). The presence of fecal coliform bacteria in water suggests recent contamination from fecal matter and the possible presence of harmful bacteria (e.g. some strains of e.coli) that are pathogenic to humans when ingested (USEPA, 2001).

Escherichia coli bacteria is and indicator of fecal pollution and the possible presence of pathogens in fresh water. Several factors can contribute to elevated e.coli levels, including rain storms, low river flows, presence of wildlife, manure and septic systems.
The most significant sources of e.coli in the watershed are animal operations and failing septic systems.

Historically, the indicator bacteria for fecal contamination have been fecal coliform bacteria. When fecal coliform bacteria were used for monitoring, the national standard was set at not to exceed 200 organisms per 100 milliliter as a monthly geometric mean or 2,000 organisms per 100 milliliter for 10% of the samples for recreational waters. Recently, EPA determined that e.coli, instead of fecal coliform, would be used as the standard indicator bacteria for the coliform group. The e.coli standard for recreational waters is not to exceed 126 organisms per 100 milliliters as a monthly geometric mean or 1,260 organisms per 100 milliliter for 10% of all samples.

Due to inconsistency in the monitoring of these water quality parameters, fecal coliform and e.coli analysis was in four groups which had similar years of data collected. S003-527 (Bear Creek) was the only site that did not exceed the fecal coliform standard in 2004 and 2005 (Figure 26). Fecal coliform and e.coli counts for all other sites were found to exceed both the monthly geometric mean and the daily not to exceed thresholds.

Sites on figure 27 are currently being monitored; all other sites were discontinued in 2005 or early 2006. From the analysis on the sites that are currently being monitored, the highest counts of bacteria were observed in October 5th 2005 during a storm event of 6 inches of rain. The highest fecal coliform bacteria count was found at site S003-532 (Grounhouse River) with 25,000 org/100 mL. The lowest counts of e.coli were observed at S003-529 (Middle Snake site near Mora), 240 org/100 mL (Figure 27) was the maximum count for this site in September 14th 2008 after one inch of rain events. See Appendix B-Table 13 and 14 for statistics results on these parameters.

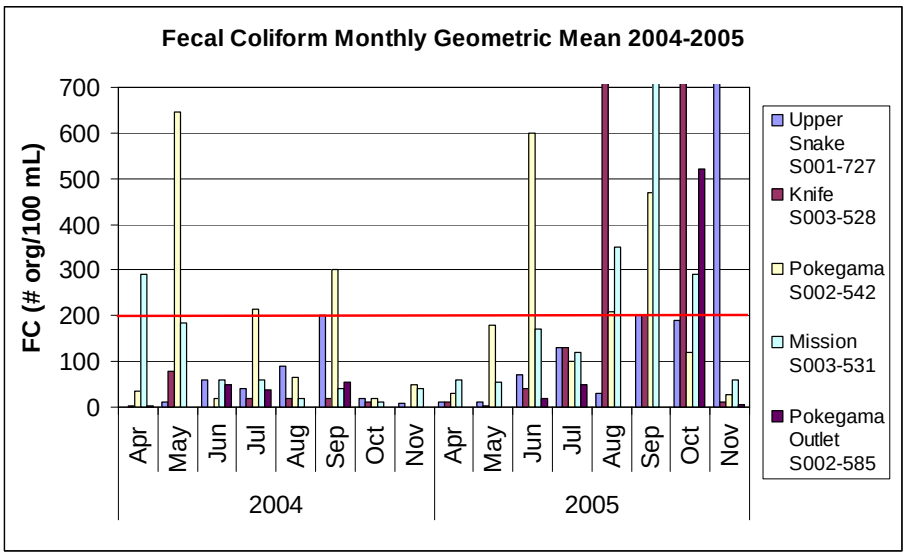

Figure 24

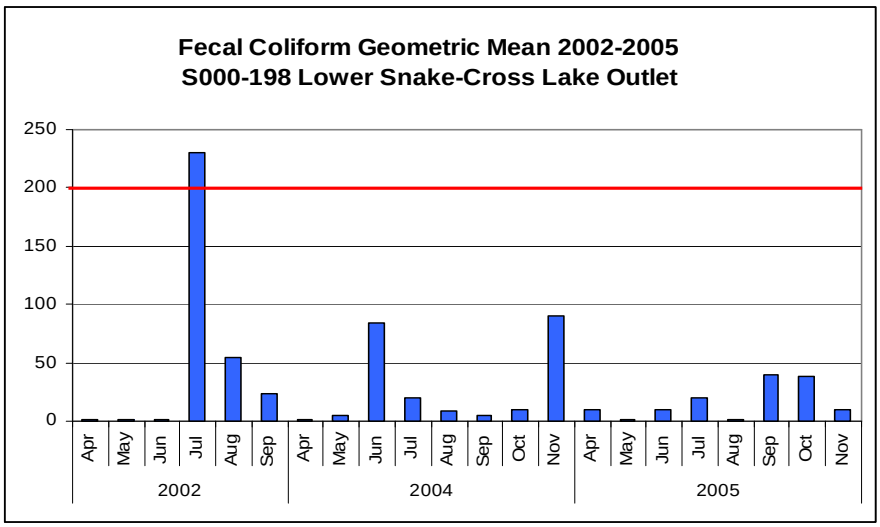

Figure 25

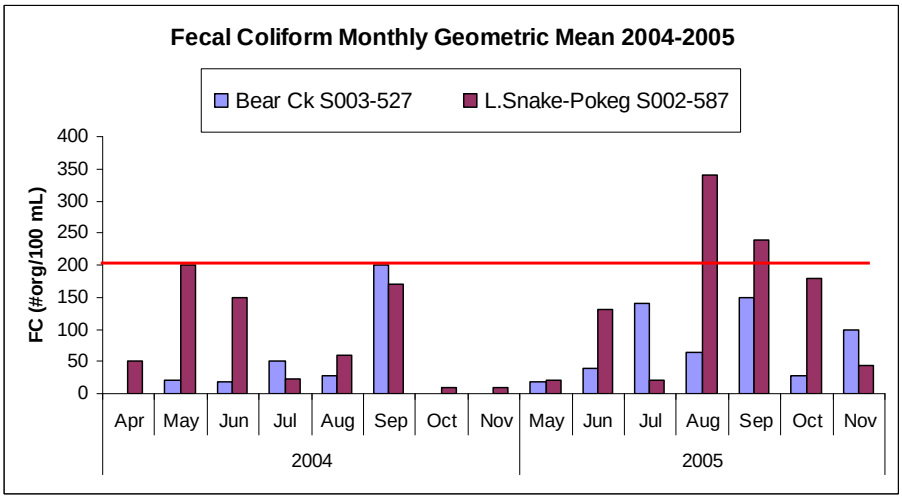

Figure 26

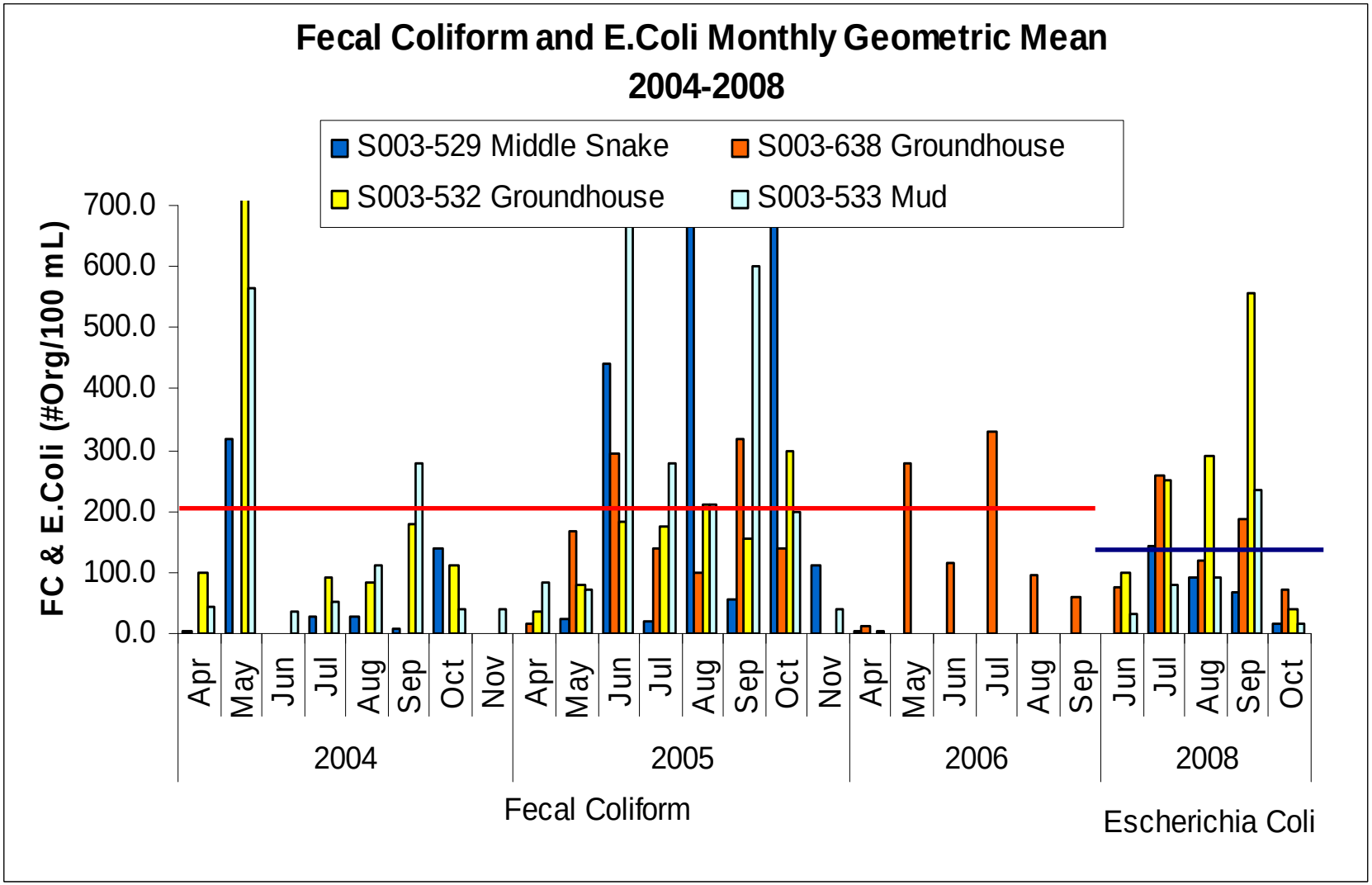
Fecal Coliform and E.Coli Monthly Geometric Mean
2004-2008
S003-529 Middle Snake
S003-638 Groundhouse
S003-532 Groundhouse
S003-533 Mud
FC & E.Coli (#Org/100 mL)
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
2004
2005
2006
2008
Fecal Coliform
Escherichia Coli

Figure 27

2.9. DISSOLVED OXYGEN

Dissolved oxygen is a measurement of the amount of oxygen in the water column. It is a critical water quality parameter required in sufficient amounts to support aquatic life.
The aquatic life standard for warm water fisheries (Class 2B waters) is a daily minimum of not less than 5.0 mg/L (MPCA, 2009).

Appendix B-Table 15 shows the statistics for the monitoring done at each location. Dissolved oxygen levels across the watershed are generally very good with the exception of site S003-531 (Mission Creek) (Figures 29 and 30). The dissolved oxygen at this site has been decreasing since 2004 (Figure 28). One of the causes of the reduction in oxygen levels could be attributed to the dense plant growth in the main channel which consumes large amounts of oxygen during photosynthesis. This explosion in plant growth could be in part attributed to the low flow conditions in the watershed in the last few years. At low flow conditions, sunlight can penetrate deeper into the water column allowing more plant production. The physical characteristics of this site indicate that it is functioning more as a wetland than a stream. The lowest level of oxygen found at this site was 0.05 mg/L.

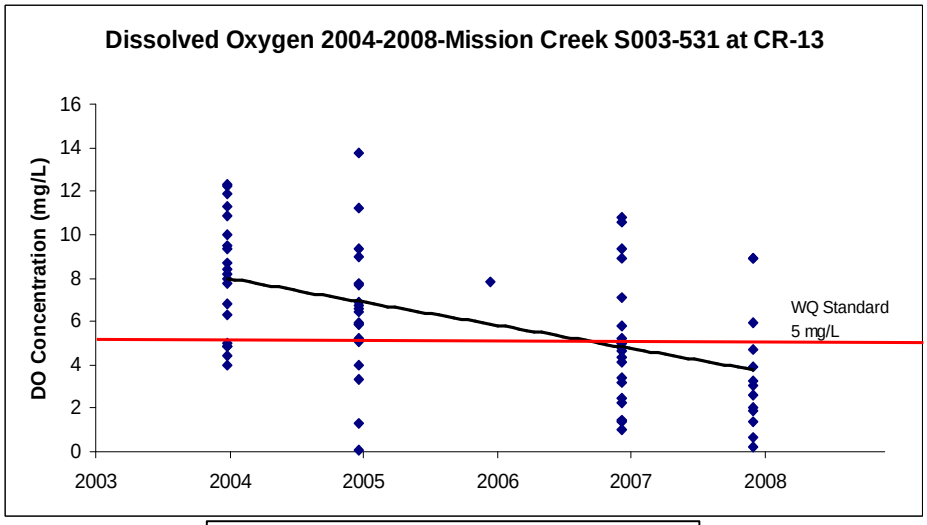

Figure 28

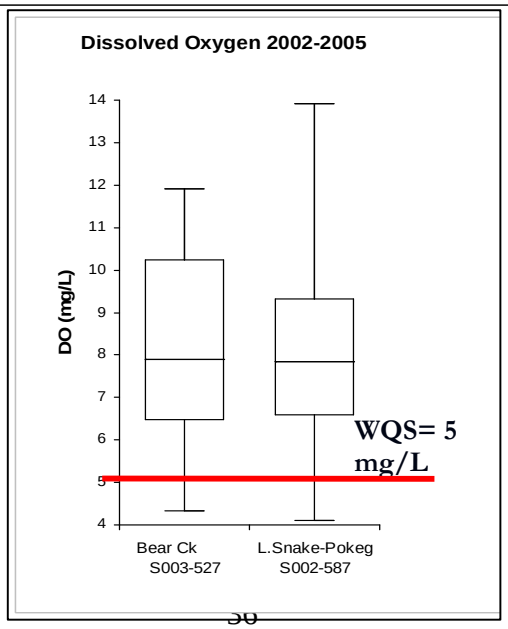

Figure 29

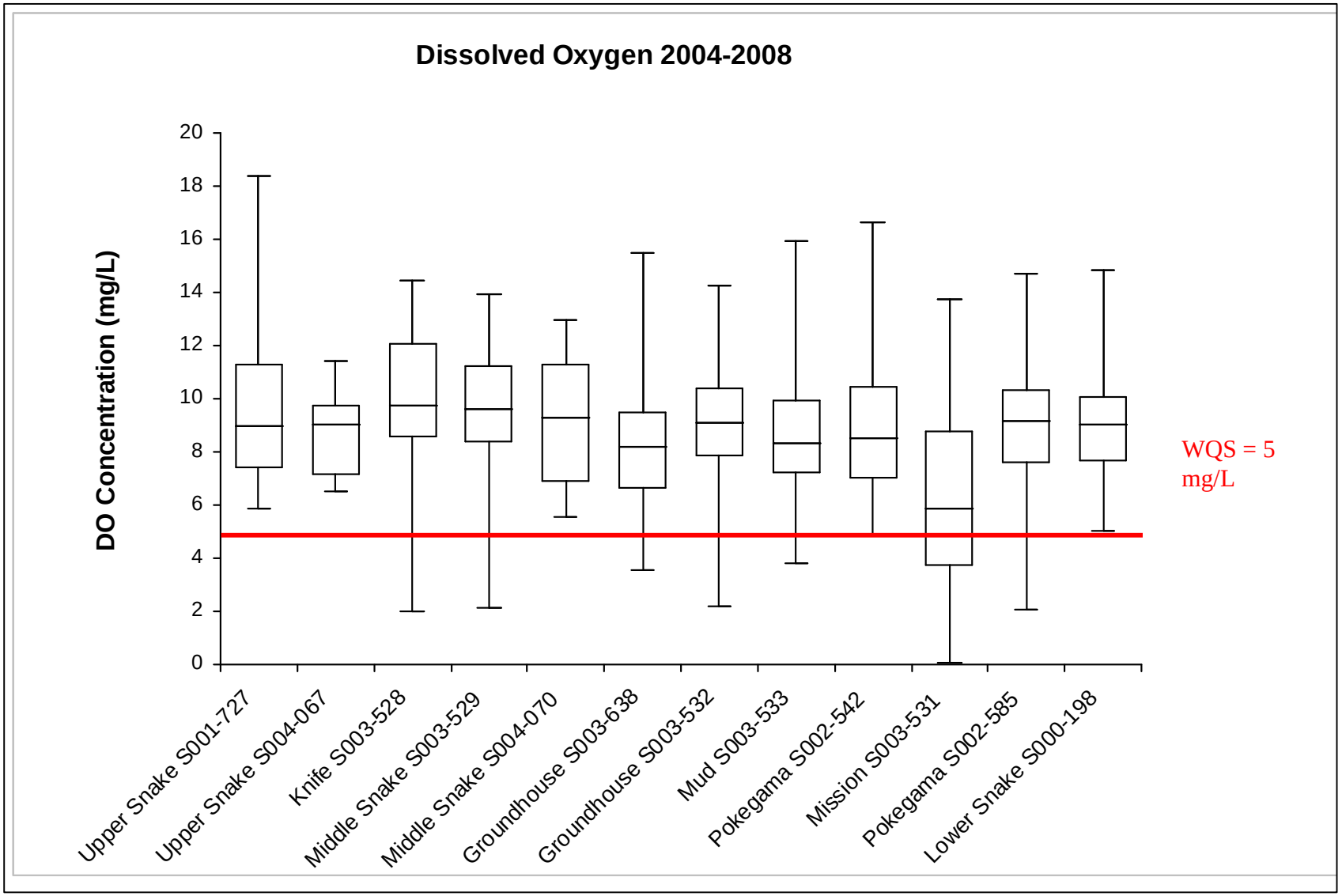
Dissolved Oxygen 2004-2008
DO Concentration (mg/L)
20
18
16
14
12
10
8
6
4
2
0
Upper Snake S001-727
Upper Snake S004-067
Knife S003-528
Middle Snake S003-529
Middle Snake S004-070
Groundhouse S003-638
Groundhouse S003-532
Mud S003-533
Pokegama S002-542
Mission S003-531
Pokegama S002-585
Lower Snake S000-198
WQS = 5 mg/L

Figure 30

2.10. PH

PH is a measurement of the hydrogen ion activity in water. A high PH indicates alkaline (basic) conditions and low PH indicates acidic conditions. It is influenced by geology and soils, organic acids (decaying leaves and other matter) and acid rain. Extreme high or low pH values can indicate some type of water quality issue and can be harmful to aquatic life.

The water quality standard for Class 2B waters is a minimum of 6.5 and a maximum of 8.5 pH levels. Review of the monitoring data for all the sites show that PH falls well within this range (Figures 31 and 32) but does show that the 25th percentile values are consistently below those seen in the minimallyly impacted streams for both ecoregions (Appendix B-Table 16). The 25th percentile pH values for NLF and NCHF for minimally impacted streams are 7.5 and 8 respectively. While the values do not indicate a water quality problem, some type of influence is apparent.

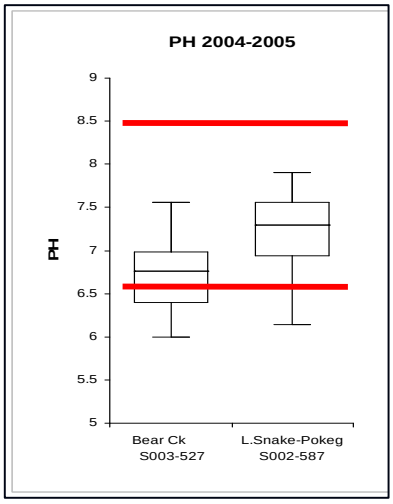

Figure 31

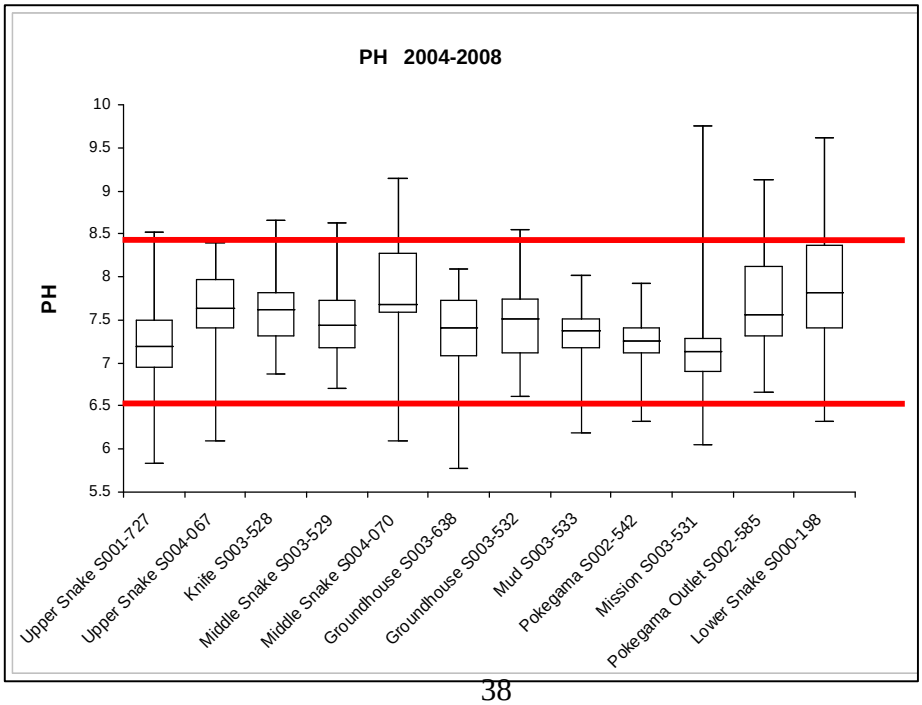

Figure 32

2.11. TEMPERATURE

Water temperature is a critical parameter for aquatic life. It has an impact on other water quality parameters such as dissolved oxygen concentrations and bacteria activity in water. A number of factors can have an impact on water temperature including the quantity and maturity of riparian vegetation along the banks, the flow rate of the stream, the percent of impervious surfaces contributing to stormwater, thermal discharges, impoundments and groundwater.

The monitoring data statistics show that most of the sites are within the 25th and 75th percentiles benchmarks for minimally impacted streams for both ecoregions with the exception of Upper Snake River site S004-067 (Figure 34 and 35). 68 % of the total samples collected exceeded the NFL minimally impacted streams 75th percentile benchmark. These warm temperatures could be a result of low flow conditions during those years. Dissolved oxygen measurements at this site were high despite the high temperatures levels during the summer months (Figure 33). See Appendix B-Table 17 for statistics results on this parameter.

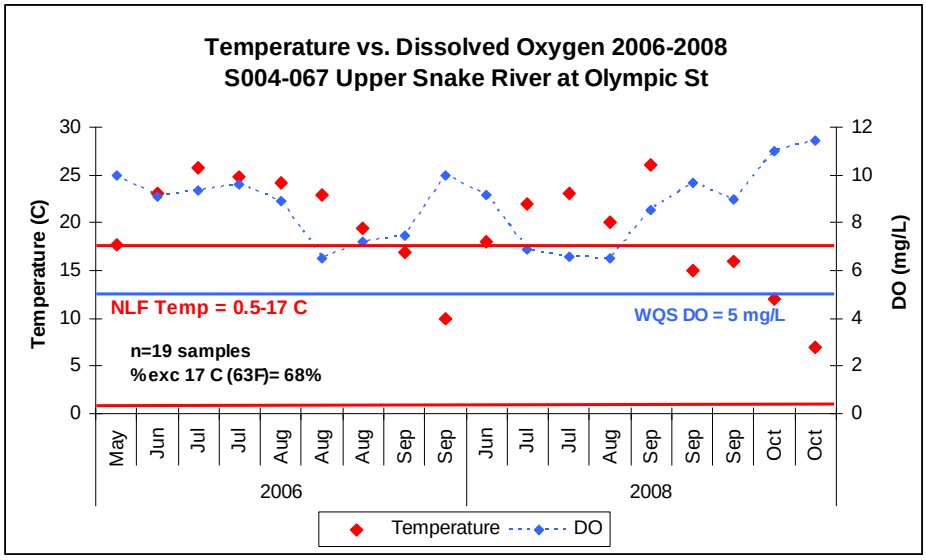

Figure 33

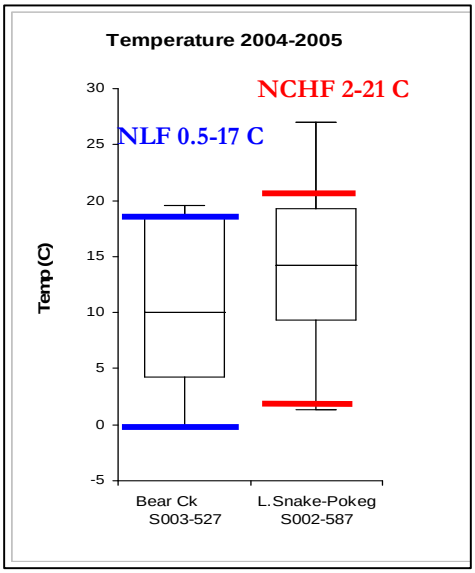

Figure 34

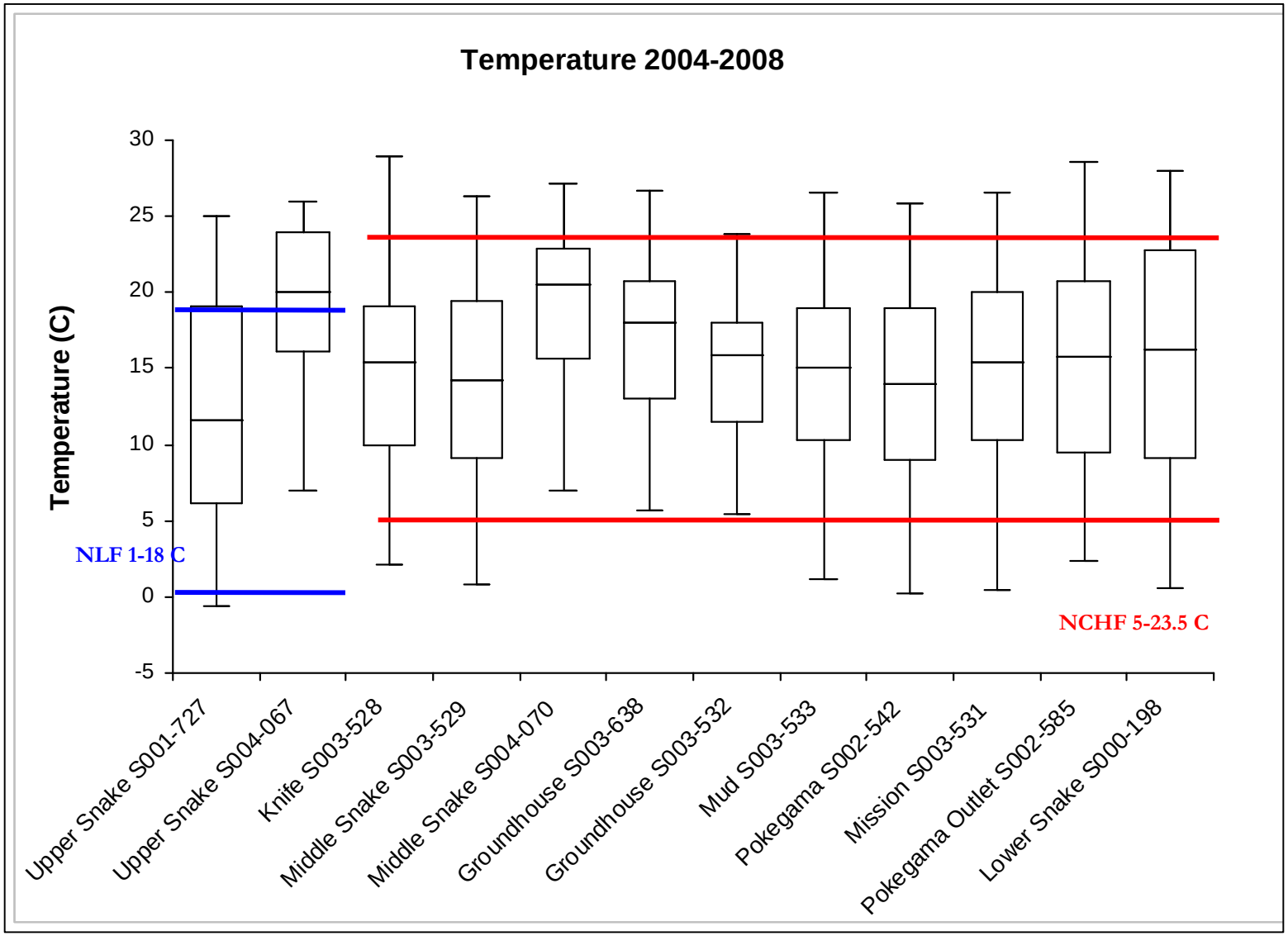
Temperature 2004-2008
Temperature (C)
30
25
20
15
10
5
0
-5
NLF 1-18 C
NCHF 5-23.5 C
Upper Snake S001-727
Upper Snake S004-067
Knife S003-528
Middle Snake S003-529
Middle Snake S004-070
Groundhouse S003-638
Groundhouse S003-532
Mud S003-533
Pokegama S002-542
Mission S003-531
Pokegama Outlet S002-585
Lower Snake S000-198

Figure 35

2.12. SPECIFIC CONDUCTANCE

It measures the free ion (charged particles or electrical current) content in water at a specific water temperature. These ions can come from natural sources such as bedrock, or human sources such as storm water runoff. Specific conductance can be used to indicate the presence of ions such as chlorides, nitrates and phosphates; therefore it can help locate potential sources of pollution. High specific conductance values often indicate pollution from road salt, septic systems, wastewater treatment plants or urban and agricultural runoff (NHDES, 2008).

Comparison of the monitoring data with the minimally impacted streams for both ecoregions showed that the specific conductance values are well below the 75th percentile benchmarks (Figures 36 and 37). There were a few instances where a spike was observed. For instance the maximum levels observed at Lower Snake Site S000-198 correlate with the high levels Chloride at that site in October 2008. See Appendix B-Table 18 for statistics results on this parameter.

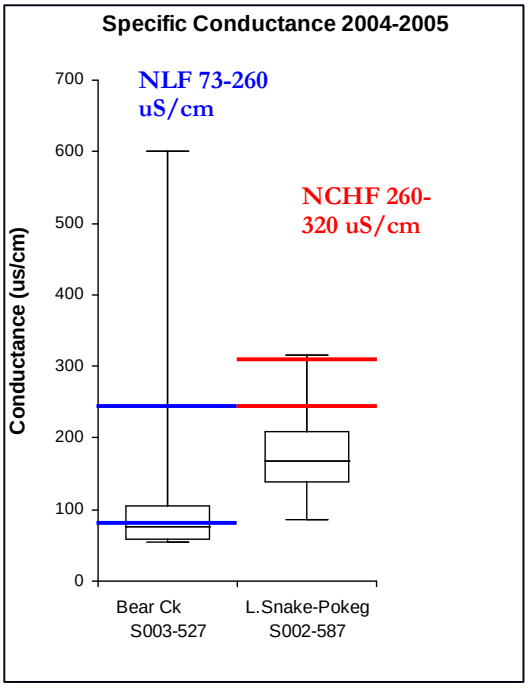

Figure 36

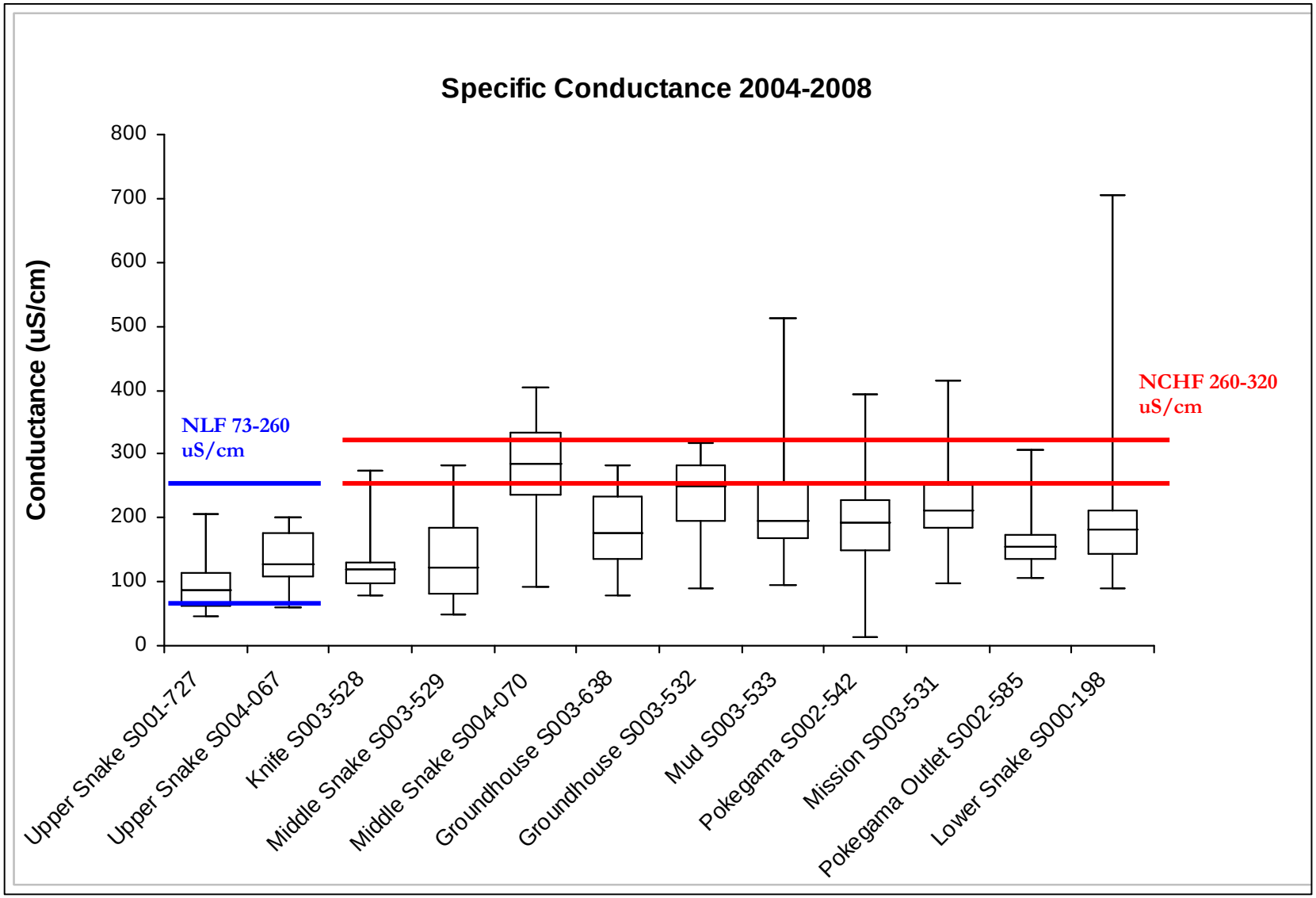
Specific Conductance 2004-2008
Conductance (uS/cm)
800
700
600
500
400
300
200
100
0
NLF 73-260
uS/cm
NCHF 260-320
uS/cm
Upper Snake S001-727
Upper Snake S004-067
Knife S003-528
Middle Snake S003-529
Middle Snake S004-070
Groundhouse S003-638
Groundhouse S003-532
Mud S003-533
Pokegama S002-542
Mission S003-531
Pokegama Outlet S002-585
Lower Snake S000-198

Figure 37

SUMMARY AND RECOMENDATIONS

Results from this analysis suggest that some of the major impairments in the watershed are nitrates, phosphorus, bacteria and dissolved oxygen.

Kendall test results showed decreasing trends for site S003-529 (Snake River in Mora) for Nitrite plus Nitrate, Total Phosphorus, Ortho-Phosphorus and Total Suspended Solids parameters. On the other hand, increasing trends for Nitrite plus Nitrate were observed for sites S003-531 (Mission Creek), S002-585 (Pokegama Lake outlet) and S002-542 (Pokegama Creek). Site S003-533 (Mud Creek) showed an increasing trend in Total Suspended Solids.

From these results we can observe a spatial trend in the water quality of the streams. Decreasing Nitrates and Total Suspended Solids trends were observed for sites to the north and central part of the watershed while increasing trends were observed for sites to the southeast part of the watershed.

Most of the Seasonal Kendall Test results indicated “No Trend”. There are two possible explanations for these results. There is “No Trend” because the water quality parameters’ concentrations measured at a site are neither increasing nor decreasing. The second explanation is that the cause for “No Trend” is due to the gap in the data for years 2000, 2003, 2006 and 2007 which influenced the results. The Seasonal Kendall statistical analysis tool is designed to make the best of such gaps in data, however.

In order to avoid any uncertainty in the results for future trend analysis, it is recommended to continue consistent monitoring of the water quality parameters. Some “good” monitoring plans suggest collecting water quality data bi-weekly for four years to establish a baseline for evaluating trends. Once a baseline is established, sampling frequency can be reduced to monitor trends in subsequent years (i.e. from bi-weekly to monthly) (USGS, 2004).

The high levels of Nitrite plus Nitrate were found at both Groundhouse River sites which correlated with the results of TMDL study currently in process in this sub-watershed. The maximum values occurred in relatively dry periods, which could be an indication of point sources such as leaching nitrates from agricultural farms, individual septic systems, and manure application.

In addition, both of the Groundhouse River sites, Middle Snake River site and Mud Creek site exceeded Fecal coliform and E. coli state standards from 2004 to 2008. However, in 2008 there were signs of improvement for the Middle Snake River site in Mora. E.coli levels have dropped at this site and it only exceeded state standards during July sampling. This decrease of e.coli at Middle Snake River site could be due to fewer non-point source input and/or low flow conditions in the river.

Phosphorus is the major pollutant in several streams in the watershed. Eight sites exceeded the 75th percentiles total phosphorus levels of the minimallyly impacted streams benchmark in both ecoregions. The highest total phosphorus levels were observed at site S003-531 (Mission Creek). Currently there is a lot of effort to reduce phosphorus load coming from non-point and point sources into the Snake River (25,000 kg/year) which discharges into the St. Croix River. The Lake St. Croix TMDL Nutrient study is looking for a phosphorus load reduction from 25,000 kg/year to 9,500 kg/year (38% reduction) from the Snake River (Barr Engineering, 2009).

Oxygen levels in the streams across the watershed are high with the exception of Mission Creek which failed to meet the water quality standard of minimum of 5 mg/L for oxygen levels. Dissolved oxygen has been decreasing since the beginning of monitoring at this site (2004). The physical and chemical characteristics of this site indicate that it is functioning more like a wetland. There are a lot of plants growing in the main channel which in turn consume oxygen during photosynthesis.

This study focused on the fourteen sites monitored as part of the ten year monitoring program from which twelve sites are still being monitored. The analysis of the monitoring data provides some insight to the health of some sections of streams in the Snake River watershed. However, additional work is needed to better understand the cause of biota and biological impairments in the watershed for which some of the streams are listed as impaired in the state 303(d) list. More detailed examination of the water quality parameters during dry and wet conditions should be pursued in a watershed approach that integrates other stream and lake sites monitored by partners (MPCA, SWCDs, volunteers) within the Snake River watershed.

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Appendix

Appendix A

Appendix B-Statistic Results

TOTAL KJELDAHL NITROGEN

Site ID	N	MIN	25%	MEDIAN	75%	MAX
S003-528 Knife R	49	0.100	0.800	0.900	1.000	2.100
S003-529 Middle Snake R	50	0.300	0.600	0.800	1.000	8.000
S004-070 Middle Snake R	10	0.500	0.500	0.800	0.900	1.100
S003-638 Groundhouse R	30	0.300	0.700	0.900	1.100	1.400
S003-532 Groundhouse R	39	0.400	0.600	0.700	1.000	1.500
S003-533 Mud Ck	57	0.390	0.800	1.000	1.100	1.600
S002-542 Pokegama Ck	54	0.300	0.746	0.900	1.008	1.600
S003-531 Mission Ck	64	0.600	0.900	1.100	1.300	2.100
S002-585 Pokegama Outlet	54	0.500	0.900	1.100	1.600	5.100
S000-198 Lower Snake R	83	0.100	0.900	1.000	1.242	2.890
S003-527 Bear Ck	19	0.600	0.800	0.900	1.380	1.800
S002-587 Lower Snake-Pokegama	25	0.500	0.670	1.000	1.200	1.800
North Central Hardwood Forest	**-**	**0.050**				**1.500**
S001-727 Upper Snake R	46	0.600	0.800	1.000	1.300	1.800
S004-067 Upper Snake	10	0.600	1.000	1.300	1.408	1.500
Northern Lakes and Forests	**-**	**0.050**				**1.500**

Table 6. N = Number of Samples

NITRITE PLUS NITRATE AS NITROGEN

Site ID	N	MIN	25%	MEDIAN	75%	MAX
Knife S003-528	49	0.005	0.030	0.080	0.180	0.570
Middle Snake S003-529	48	0.005	0.070	0.160	0.210	0.500
Middle Snake S004-070	21	0.040	0.167	0.210	0.303	0.530
Groundhouse S003-638	41	0.005	0.077	0.470	1.100	4.500
Groundhouse S003-532	38	0.005	0.207	0.540	0.823	1.700
Mud-S003-533	57	0.005	0.008	0.040	0.800	0.470
Pokegama S002-542	57	0.002	0.005	0.015	0.050	0.394
Mission S003-531	79	0.002	0.005	0.020	0.150	2.240
Pokegama Outlet S002-585	55	0.002	0.012	0.060	0.150	1.600
Lower Snake S000-198	115	0.005	0.040	0.100	0.168	0.700
S003-527 Bear Ck	39	0.002	0.005	0.005	0.013	0.200
S002-587 Lower Snake-Pokegama	48	0.005	0.070	0.140	0.220	0.450
North Central Hardwood Forest	**-**	**0.010**	**0.040**	**0.080**	**0.240**	**0.650**
Upper Snake S001-727	47	0.005	0.005	0.020	0.078	0.240
Upper Snake S004-067	21	0.030	0.030	0.030	0.150	0.150
Northern Lakes and Forests	**-**	**0.010**	**0.010**	**0.020**	**0.070**	**0.570**

Table 7. N = Number of Samples

TOTAL PHOSPHORUS

Site ID	N	MIN	25%	MEDIAN	75%	MAX
S003-528 Knife R	100	0.020	0.053	0.069	0.091	0.231
S003-529 Middle Snake R	103	0.013	0.048	0.058	0.079	0.159
S004-070 Middle Snake R	21	0.042	0.054	0.065	0.073	0.125
S003-638 Groundhouse R	46	0.052	0.069	0.091	0.121	0.238
S003-532 Groundhouse R	80	0.035	0.058	0.79	0.122	0.466
S003-533 Mud Ck	99	0.046	0.069	0.087	0.122	0.222
S002-542 Pokegama Ck	106	0.032	0.051	0.071	0.012	0.210
S003-531 Mission Ck	120	0.033	0.057	0.096	0.133	1.010
S002-585 Pokegama Outlet	97	0.038	0.058	0.075	0.112	0.621
S000-198 Lower Snake R	162	0.027	0.059	0.078	0.106	0.521
S003-527 Bear Ck	84	0.015	0.024	0.037	0.058	0.113
S002-587 Lower Snake-Pokegama	91	0.028	0.058	0.070	0.097	0.214
North Central Hardwood Forest	**-**	**0.010**	**0.050**	**0.070**	**0.090**	**0.430**
S001-727 Upper Snake R	97	0.019	0.028	0.041	0.059	0.096
S004-067 Upper Snake	21	0.014	0.029	0.037	0.056	0.077
Northern Lakes and Forests	**-**	**0.010**	**0.010**	**0.030**	**0.040**	**0.430**

Table 8. N = Number of Samples

ORTHO PHOSPHORUS

Site ID	N	MIN	25%	MEDIAN	75%	MAX
S003-528 Knife R	65	0.002	0.007	0.011	0.022	0.081
S003-529 Middle Snake R	68	0.007	0.015	0.023	0.032	0.440
S004-070 Middle Snake R	10	0.023	0.029	0.036	0.049	0.062
S003-638 Groundhouse R	27	0.010	0.026	0.036	0.054	0.129
S003-532 Groundhouse R	54	0.006	0.022	0.037	0.056	0.089
S003-533 Mud Ck	72	0.011	0.024	0.039	0.058	0.306
S002-542 Pokegama Ck	71	0.008	0.018	0.029	0.045	0.104
S003-531 Mission Ck	79	0.003	0.020	0.039	0.070	0.287
S002-585 Pokegama Outlet	70	0.002	0.009	0.019	0.027	0.144
S000-198 Lower Snake R	111	0.001	0.012	0.022	0.038	0.496
S003-527 Bear Ck	50	0.002	0.005	0.007	0.017	0.038
S002-587 Lower Snake-Pokegama	71	0.003	0.014	0.025	0.038	0.112
North Central Hardwood Forest	-	-	-	-	-	-
S001-727 Upper Snake R	58	0.001	0.004	0.008	0.019	0.173
S004-067 Upper Snake	10	0.011	0.015	0.027	0.038	0.050
Northern Lakes and Forests	-	-	-	-	-	-

Table 9. N = Number of Samples

TOTAL SUSPENDED SOLIDS

Site ID	N	MIN	25%	MEDIAN	75%	MAX
S003-528 Knife R	99	0.500	3.170	5.000	8.830	27
S003-529 Middle Snake R	102	0.500	2.000	3.000	5.000	370
S004-070 Middle Snake R	21	0.500	1.470	2.800	4.000	5
S003-638 Groundhouse R	41	0.500	2.000	3.000	5.000	21
S003-532 Groundhouse R	93	0.500	2.000	3.000	6.330	185
S003-533 Mud Ck	99	0.500	3.000	5.000	8.000	27
S002-542 Pokegama Ck	97	0.500	2.000	3.000	5.330	27
S003-531 Mission Ck	94	0.500	2.000	3.000	6.000	33
S002-585 Pokegama Outlet	96	0.500	3.000	5.500	11.00	94
S000-198 Lower Snake R	158	1.200	3.600	5.000	7.000	48
S003-527 Bear Ck	78	0.500	1.000	2.000	3.080	15
S002-587 Lower Snake-Pokegama	90	2.000	3.000	4.000	6.000	18
North Central Hardwood Forest	**-**	**1.400**	**4.000**	**7.700**	**13.00**	**29**
S001-727 Upper Snake R	95	0.500	2.000	2.000	4.000	17
S004-067 Upper Snake	21	1.000	1.000	1.200	2.000	4
Northern Lakes and Forests	**-**	**0.500**	**1.500**	**2.000**	**4.000**	**9.8**

Table 10. N = Number of Samples

TRANSPARENCY

Site ID	N	MIN	25%	MEDIAN	75%	MAX
S003-528 Knife R	10	45	79	86	100	100
S003-529 Middle Snake R	9	80	100	100	100	100
S004-070 Middle Snake R	10	100	100	100	100	100
S003-638 Groundhouse R	10	80	99	100	100	100
S003-532 Groundhouse R	10	100	100	100	100	100
S003-533 Mud Ck	10	43	60	80	89	100
S002-542 Pokegama Ck	11	52	71	90	100	100
S003-531 Mission Ck	14	30	60	100	100	100
S002-585 Pokegama Outlet	11	44	61	80	100	100
S000-198 Lower Snake R	21	60	60	95	100	100
S001-727 Upper Snake R	9	42	54	65	85	100
S004-067 Upper Snake	9	66	70	100	100	100

Table 11. N = Number of Samples

CHLORIDE

Site ID	N	MIN	25%	MEDIAN	75%	MAX
S003-528 Knife R	39	1.500	2.800	3.200	3.783	5.800
S003-529 Middle Snake R	32	1.000	2.642	3.750	5.000	6.700
S004-070 Middle Snake R	21	2.500	5.800	7.200	8.467	9.300
S003-638 Groundhouse R	22	3.200	7.242	8.200	9.433	14.00
S003-532 Groundhouse R	30	1.700	3.200	5.850	9.308	11.00
S003-533 Mud Ck	45	0.600	2.833	3.800	4.500	12.00
S002-542 Pokegama Ck	43	0.500	2.800	3.400	4.750	8.000
S003-531 Mission Ck	45	1.100	8.233	9.300	11.00	16.00
S002-585 Pokegama Outlet	43	1.400	3.217	3.600	3.900	7.800
S000-198 Lower Snake R	70	1.800	4.183	5.280	6.200	160.0
S003-527 Bear Ck	24	1.000	1.400	2.050	2.720	5.500
S002-587 Lower Snake-Pokegama	34	1.800	2.980	4.500	6.110	7.900
S001-727 Upper Snake R	35	0.900	1.750	2.600	3.600	7.900
S004-067 Upper Snake	21	1.900	3.033	3.400	4.033	5.100
Water Quality Standard	-					**230.0**

Table 12. N = Number of Samples

FECAL COLIFORM

Site ID	N	MIN	25%	MEDIAN	75%	MAX
S003-529 Middle Snake R	24	1	21.7	51.0	161.7	8100
S003-638 Groundhouse R	52	1	64.0	125	297.5	16000
S003-532 Groundhouse R	42	20	59.0	120	298.3	25000
S003-533 Mud Ck	32	3	38.3	87.5	189.2	16000
S003-527 Bear Ck	12	18	22.9	45.0	122.5	200
S002-587 Lower Snake-Pokegama	18	10	19.8	50.0	172.5	12000
S001-727 Upper Snake R	16	1	10	50	145	1100
S003-528 Knife R	15	2	10	20	140	6400
S002-542 Pokegama Cr	19	20	46	160	365	800
S002-585 Pokegama Outlet	19	1	1	1	26	140
S003-531 Mission Cr	20	10	40	60	200	1700
S000-198 Lower Snake R	32	1	1	10	57	930
Water Quality Standard	-	-	-	-	-	**200**

Table 13. N = Number of Samples

ESCHERICHIA COLI

Site ID	N	MIN	25%	MEDIAN	75%	MAX
S003-529 Middle Snake R	8	10	25.4	69.0	149.2	240
S003-638 Groundhouse R	21	40	87.3	110	246.7	580
S003-532 Groundhouse R	9	36	82.7	190	323.3	2400
S003-533 Mud Ck	10	8	36.4	87.5	105.0	1400
Water Quality Standard	-	-	-	-	-	**160**

Table 14. N = Number of Samples

DISSOLVED OXYGEN

Site ID	N	MIN	25%	MEDIAN	75%	MAX
S003-528 Knife R	50	2.020	8.564	8.564	12.06	14.48
S003-529 Middle Snake R	50	2.110	8.397	8.397	11.23	13.94
S004-070 Middle Snake R	19	5.540	6.873	6.873	11.28	12.96
S003-638 Groundhouse R	47	3.580	6.617	6.617	9.458	15.50
S003-532 Groundhouse R	57	2.200	7.893	7.893	10.36	14.28
S003-533 Mud Ck	50	3.820	7.223	7.223	9.945	15.91
S002-542 Pokegama Ck	47	4.830	7.002	7.002	10.48	16.66
S003-531 Mission Ck	73	0.050	3.730	3.730	8.77	13.77
S002-585 Pokegama Outlet	49	2.070	7.607	7.607	10.32	14.74
S000-198 Lower Snake R	92	5.050	7.671	7.671	10.06	14.83
S003-527 Bear Ck	18	4.330	6.484	7.910	10.23	11.91
S002-587 Lower Snake-Pokegama	37	4.120	6.593	7.850	9.307	13.93
S001-727 Upper Snake R	37	5.84	7.407	9.040	11.29	18.40
S004-067 Upper Snake	18	6.49	7.173	8.970	9.712	11.41
Water Quality Standard	**-**	**5.00**	**-**	**-**	**-**	**-**

Table 15. N = Number of Samples

pH

Site ID	N	MIN	25%	MEDIAN	75%	MAX
S003-528 Knife R	50	6.87	7.131	7.625	7.823	8.66
S003-529 Middle Snake R	50	6.71	7.177	7.435	7.733	8.63
S004-070 Middle Snake R	20	6.10	7.589	7.680	8.278	9.15
S003-638 Groundhouse R	53	5.78	7.087	7.400	7.720	8.09
S003-532 Groundhouse R	61	6.61	7.120	7.520	7.743	8.55
S003-533 Mud Ck	50	6.18	7.178	7.380	7.511	8.01
S002-542 Pokegama Ck	47	6.32	7.112	7.260	7.405	7.92
S003-531 Mission Ck	73	6.05	6.897	7.130	7.287	9.75
S002-585 Pokegama Outlet	49	6.66	7.310	7.560	8.120	9.13
S000-198 Lower Snake R	102	6.32	7.400	7.815	8.363	9.62
S003-527 Bear Ck	18	6.00	6.399	6.760	6.891	7.56
S002-587 Lower Snake-Pokegama	38	6.14	6.939	7.295	7.561	7.90
North Central Hardwood Forest	**-**	**7.6**	**8**	**8.1**	**8.4**	**8.9**
S001-727 Upper Snake R	39	5.84	6.952	7.200	7.492	8.52
S004-067 Upper Snake	19	6.10	7.403	7.630	7.972	8.40
Northern Lakes and Forests	**-**	**6.9**	**7.5**	**7.8**	**8**	**8.3**
Water Quality Standard	**-**	**6.50**	**-**	**-**	**-**	**8.50**

Table 16. N = Number of Samples

TEMPERATURE

Site ID	N	MIN	25%	MEDIAN	75%	MAX
S003-528 Knife R	50	2.13	9.999	15.39	19.03	28.88
S003-529 Middle Snake R	50	0.84	9.113	14.28	19.50	26.30
S004-070 Middle Snake R	20	7.00	15.67	20.50	22.93	27.10
S003-638 Groundhouse R	48	5.68	13.03	18.00	20.74	26.68
S003-532 Groundhouse R	57	5.50	11.53	15.87	18.06	23.85
S003-533 Mud Ck	50	1.18	10.28	15.00	19.00	26.55
S002-542 Pokegama Ck	48	0.24	8.941	14.00	18.91	25.85
S003-531 Mission Ck	73	0.46	10.32	15.35	20.03	26.55
S002-585 Pokegama Outlet	50	2.40	9.524	15.75	20.79	28.52
S000-198 Lower Snake R	92	0.62	9.100	16.21	22.80	28.00
S003-527 Bear Ck	2	-0.30	4.258	10.00	18.52	19.60
S002-587 Lower Snake-Pokegama	36	1.33	9.289	14.25	19.31	27.02
North Central Hardwood Forest	**-**	**0**	**5**	**15**	**23.5**	**28**
S001-727 Upper Snake R	77	-0.60	6.100	11.59	19.10	25.00
S004-067 Upper Snake	19	7.00	16.15	20.00	23.92	26.00
Northern Lakes and Forests	**-**	**0**	**1**	**10**	**18**	**26**

Table 17. N = Number of Samples

SPECIFIC CONDUCTANCE

Site ID	N	MIN	25%	MEDIAN	75%	MAX
S003-528 Knife R	50	80	98.92	119.5	131.1	275
S003-529 Middle Snake R	50	50	80.92	122.5	185.1	283
S004-070 Middle Snake R	48	93	235.8	285.0	334.8	404
S003-638 Groundhouse R	57	78	135.3	177.0	232.0	281
S003-532 Groundhouse R	20	90	194.3	248.5	281.2	317
S003-533 Mud Ck	50	96	167.0	195.0	255.9	512
S002-542 Pokegama Ck	47	13.5	149.7	192.0	228.5	393
S003-531 Mission Ck	73	98	184.0	212.0	253.0	416
S002-585 Pokegama Outlet	49	105	135.0	154.0	173.3	307
S000-198 Lower Snake R	93	89	144.7	182.0	211.3	706
S003-527 Bear Ck	18	54	76.00	76.0	105.1	600
S002-587 Lower Snake-Pokegama	36	86	168.5	168.5	208.9	315
North Central Hardwood Forest	**-**	**210**	**260**	**295**	**320**	**840**
S001-727 Upper Snake R	39	47	61.67	86.90	112.7	205
S004-067 Upper Snake	19	59	107.5	128.0	176.5	202
Northern Lakes and Forests	**-**	**36**	**72.5**	**180**	**260**	**480**

Table 18. N = Number of Samples