Trends in Total Phosphorus Concentrations in Urban and Non-Urban Environments

A thesis submitted to the faculty of the University of Minnesota by

Ann Halbach

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Dr. Robert W. Sterner

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Abstract

A study of lake trends was conducted across Minnesota and Wisconsin to determine the effects of actions to improve water quality. A comparison between urban and non-urban environments helped determine drivers of change, as many factors contribute to water quality and they differ between environments. Though evidence of both increasing and decreasing trends in phosphorus were observed, there were more lakes with decreasing trends than increasing trends, especially in the urban environment. Similar trend patterns were not found with nitrogen. Trends in nitrogen were more often positive, and trends in N:P were generally strongly positive. Climatic and morphometric factors were not significantly related to trends, but there was a connection between the amount of lawn at lake edge and phosphorus reduction. The results indicate that phosphorus concentrations in the study lakes are improving more frequently than not. This may be due to the adoption of phosphorus control measures.

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Introduction

Quality of surface waters is of widespread concern and many factors contribute to changes, positive or negative, in water quality. Though there are many individual cases of improvement or deterioration in water quality at individual sites, rather than taking a case-by-case perspective, a broader, landscape perspective of lake trends can tell us if overall progress is being made in improving water quality, or alternatively, if additional actions are needed. Assessing trends in different environments, such as urban versus non-urban, can provide additional information about different drivers of change.

Lakes are not isolated on the landscape. They are connected to flowing waters and to their watersheds through both surface and subsurface flows (Soranno, 1996). In Minnesota, Ramstack et al. (2004) found that in both urban and agricultural areas, there have been increasing trends in total water phosphorus between the 19th and 21st centuries. Numerous other studies have also documented the negative impacts of both urbanization and agriculture on water quality, especially phosphorus concentrations (Siver et al., 1996, Carpenter et al., 1998, Smith et al., 2014, Edmondson et al., 1956, Walsh et al., 2005, Schindler, 1978, Paul and Meyer, 2001, Osborne and Wiley, 1986, Räike et al., 2003, Hasler, 1947, Oswald and Golueke, 1966).

There are many reasons for the deterioration of water quality including excess nutrients being applied to the landscape (Domagalski and Johnson, 2012, McDowell et al., 2004), increased erosion and sediment transport (Nelson and Booth, 2002), removal of native perennials (Turner and Rablais, 2003), loss of buffer zones and wetlands around waterbodies (Dahl, 2011 and Zedler, 2003), inadequate wastewater treatment (Hasler, 1969; Litke, 1999), leaky septic systems (Moore et al., 2003), combined sewage and stormwater sewers (In Re Wastewater Treatment Facilities, 1985), high levels of landscape imperviousness (Walsh et at., 2005; Lee et al., 2002; Weibel et al., 1964; Tong and Chen, 2002), and even atmospheric deposition (Mahowald et al., 2008).

In the United States, the Clean Water Act of 1972 began to decrease the excess nutrient contribution from point sources via increased regulation and permitting (National Pollution Discharge Elimination System). This initial emphasis on point source pollution reduction over non-point source pollution reduction was largely successful in improving the condition of waterways (Litke, 1999, Sharpley et al., 1994).

The more complex issue of non-point source pollution reduction was not strongly enforced by the EPA or the states until after 1992 when lawsuits demanding enforcement began to be filed (Copeland, 1998). Being more dispersed, non-point sources of pollution were dealt with through a variety of actions and policies which differed between urban and non-urban areas. Non-point source pollution reductions take the form of best management practices in agriculture (Prokopy et al., 2008) such as more precise timing and placement of fertilizers (Matson et al., 1997), increasing buffer zones around waterways (Wenger, 1999), and improved tillage practices to reduce erosion and soil loss (Gaynor and Findlay, 1995). In more urbanized areas, best management practices can take the form of low impact design and green infrastructure including the installation of rain gardens and pervious surfaces to promote infiltration

(Dietz and Clausen, 2005, Dreelin et al., 2006), reductions in fertilizer usage on residential yards (Lehman et al., 2011), and stormwater management plans (Garrison and Hobbs, 2011), among others. Although water quality may still be impaired compared to pre-settlement conditions (Ramstack et al, 2004), there is little information to allow us to assess whether water quality continues to improve in the 21st century as a result of these non-point source control efforts.

Urban versus non-urban landscapes may be under different forces, resulting in contrasting trends in water quality. Though urban and non-urban areas have many similarities; they are both heterogeneous and humans make decisions on the landscape. Major differences exist between urban and non-urban areas including the number and density of people (U.S. Census, 2010), the spatial and temporal dynamics of the landscape (Pickett and Cadenasso, 2009, Rebele, 1994), and the regulation of non-point source controls on the landscape. All of these play a major role in why urban and non-urban areas may respond differently to efforts to control non-point source pollution.

Urban areas by definition have high human population density and have a high degree of impact by human activity. As of 2010, 81% of the United States population lived in urban areas, although urban areas only made up 3.0% of the land area in the United States (U.S. Census, 2010). The patches which comprise the heterogeneity of the non-urban environment are larger than the patches typically found in urban areas (American Housing Survey, 2002 and 2013). In the non-urban areas there may be hundreds, or thousands, of acres of forest or agriculture land and these may all be owned or managed by one individual, such as a farmer or the federal government (Radatz, 2010, Butler and Leatherberry, 2004). With more people and smaller patches, there are an increased number of decision makers in urban areas.

Non-urban and urban areas both include diverse and overlapping land covers including residential, industrial, commercial, agricultural, and forested patches. Change occurs in both urban and non-urban environments, with land-use types being converted to other uses (Hibbard et al., 2011, MetCouncil, 2014); however, the rates and types of disturbance are different. In urban areas, Rebele (1994) explained that anthropogenic disturbances are caused by social, cultural, political, and economic factors, making them hard to predict. In their 2009 paper, Pickett and Cadenasso address the impacts of natural and anthropogenic disturbances on urban soils. Although not discussed by Pickett and Cadenasso, these natural and anthropogenic disturbances also directly impact urban water. These urban disturbances can vary from large scale construction to lawn management or gardening decisions that vary from house to house, year to year (Pickett and Cadenasso, 2009, Rebele, 1994). Because of the varied reasons for land use change in the urban environment and the large number of decision makers, it is more likely that the pattern of land use will change in an urban area than non-urban area.

Actions to control water quality degradation are taken in both urban and non-urban areas. Agricultural best management practices to control non-point sources are most often voluntary (Prokopy et al., 2008). In contrast, non-point controls in urban areas are often regulated by building permits which require stormwater management plans (Garrison and Hobbs, 2011), laws restricting residential phosphorus based fertilizers (MDA, 2007), and institutional decisions about street sweeping (Barten et al., 2006) or installations of pervious pavement (Dreelin et al., 2006). As an example of the impact of regulations on urban versus non-urban areas, in 2002, Minnesota became the first state to ban the use of phosphorus based residential lawn fertilizers (MS Stats 18c.60-61). The ban went into effect for the Twin Cities Metro Area (TCMA) on January 1, 2004 and for the entire state on January 1, 2005. The ban prohibits the use of phosphorus based residential lawn fertilizers on established lawns without a phosphorus deficiency. It also calls for the immediate clean-up of spilled fertilizer onto impervious surfaces such as driveways and roads. The ban is only applicable to residential lawns; however, so there has been no impact on agriculture, sod farms, or on golf courses (MDA, 2007). Though this ban impacted the entire state of Minnesota, lawns are most highly concentrated in the urban areas so it would be expected that urbans areas had the most benefit from this control measure. Wisconsin put a similar ban into effect in 2010 (WI Stat 94.643).

Even though there is variability in the adoption and compliance with water quality regulations throughout the United States (MSDGC, 2007), there are more opportunities for regulations to work in urban than non-urban areas because compared to urban areas, non-urban areas have fewer houses, fewer homes built, fewer manufacture and construction establishments, lower road density, and fewer lawns (American Housing Survey, 2002 and 2013, Censtats, 2010, Watts et al., 2005). Additionally, because best management practices are voluntarily implemented in non-urban areas there can be no enforcement. Overall, many of these changes to reduce non-point pollution in both the urban and non-urban areas are put into practice at the level of an individual, and there are more individuals in urban areas leading to greater cumulative impact, so it is likely that the urban landscape would be more rapidly implementing actions that may influence water quality.

Given the above described differences in population, patch size, rates of change, and control of non-point sources, we need to ascertain specifically if the efforts to reduce non-point sources have been equally successful in urban and non-urban areas. This will allow us to better understand the drivers of change in water quality.

To investigate these questions, evidence of trends in lakes across the landscape and between collections of lakes in urban and non-urban areas were compared. The Twin Cities Metro Area (TCMA) was selected as a representative urban area. The TCMA is a 7-county political unit located in eastern Minnesota. It is home to nearly 2.85 million people within approximately 7,200 km^2 (3.5% of Minnesota's total area) (U.S. Census, 2010). Greater Minnesota and Wisconsin were selected as two representative non-urban areas. The populations of Minnesota and Wisconsin are 5.3 million and 5.7 million, respectively (U.S. Census, 2010). These areas were selected based on the availability of data and the placement of the urban area within the non-urban area (Figure 1).

Phosphorus concentrations in lakes were examined because phosphorus is an important cause of eutrophication and actions have been taken to limit phosphorus runoff. In Minnesota, each ecoregion has a maximum allowable in-lake concentration for phosphorus. In addition, phosphorus is second only to Secchi depth in frequency with which it is measured and reported in lakes. Phosphorus is also considered the most common limiting nutrient in freshwater systems (Schindler, 1981). Though other nutrients, such as nitrogen, have also been found to be limiting or co-limiting (Lewis and Wurtsbaugh, 2008 and Haustein, 2010, Elser et al., 2009, Guildford and Hecky, 2000), there has been substantial empirical evidence to convince policy makers and water resources managers that in the long term, phosphorus control will help reduce the effects of cultural eutrophication (Lee et al., 1978, Schindler, 1977 and 1981, Edmondson et al., 1956). Evidence of long-term trends in phosphorus concentration are likely to be associated with a shift in water quality. In addition, evidence of trends in nitrogen concentration were examined in a subset of sites where the data was available.

The most comprehensive lake monitoring done in the TCMA is by the Metropolitan Council. They report lake grades based on Secchi depth, chlorophyll-a concentration, and total phosphorus each year. Other organizations within the TCMA, greater Minnesota, and Wisconsin also monitor water quality. Each of these organizations collect their own data and has their own method of analysis. This patchwork of information, which is found in multiple locations, is not useful for making overarching conclusions about the impacts of urbanization and non-urbanization on lakes across a landscape. Therefore, to meaningfully interpret changes in water quality across the study area, data was collected from multiple sources and trends, rather than absolute concentrations, were evaluated to put all lakes on the same scale, increasing or decreasing, regardless of the collection or analysis methods.

The hypotheses of this study are 1.) In both urban and non-urban settings, overall trends in water quality will be negative (lower phosphorus concentration over time) owing to management actions that have taken place, and 2.) Urban lakes will demonstrate more decreases in phosphorus concentration than non-urban lakes.

Methods:

Two types of analysis were done. First, a trend analysis was completed using the Seasonal Kendall test to determine the strength of evidence for trends in total phosphorus (TP) concentrations in Metro lakes (lakes within the TCMA) as compared to lakes in Non-Metro areas (lakes in greater Wisconsin and Minnesota). This part of the study is called "Trend Analysis." Second, to better understand the impact of landcover on nutrient concentrations, both lawn and crops in the area surrounding the lake were associated with the evidence of trends in phosphorus concentrations. This part of the study is called "Landcover Analysis".

Trend Analysis

The trend analyses performed in this study utilized data obtained from the following sources: The Minnesota Pollution Control Agency (contact Ms. Kelly O'Hara), the Environmental Protection Agency STORET (STOrage and RETrieval Data Warehouse – available online at http://www.epa.gov/storet/), the Wisconsin Department of Natural Resources (contact Ms. Jennifer Filbert), the Metropolitan Council Environmental Services (contact Ms. Terrie O'Dea), and the Shakopee Mdewakanton Sioux Community (contact Mr. Scott Walz).

Each lake was defined based on its unique 8 digit DNR ID (Minnesota Lakes) or unique Station ID (Wisconsin Lakes). Distinct basins from the same lake, such as the bays of Lake Minnetonka in Hennepin County, Minnesota, were considered as distinct lakes. Of the 441 lakes in the study, 17 were multiple basins within a single water body.

The data were divided into lake groups: Metro TP, Non-Metro TP (WI), Non-Metro TP (MN), and Metro Total Kjeldahl Nitrogen (TKN). Because of data availability, Non-Metro TP (MN) lakes were congregated to the west and north of the Metro area and Non-Metro TP (WI) lakes were congregated in the northern part of the state (Figure 1). Lakes within Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington counties were considered part of the Metro TP lake group. Lakes from all other counties in Minnesota were grouped into the Non-Metro TP (MN) lake group. In Wisconsin, all lakes were considered part of the Non-Metro TP (WI) except those in Dane, Milwaukee, Waukesha, Racine, Washington, and Ozaukee counties, which are part of the Madison and Milwaukee Metro areas. Lakes in these Metro Wisconsin areas were not included. Metro TKN lakes are a subset of the Metro TP lake group that were analyzed for trends in TKN in addition to being analyzed for TP. TKN was chosen as the form of nitrogen included in this analysis because of data availability within the metro lake group. TKN trends were evaluated to determine if nitrogen concentrations are changing similarly to phosphorus concentrations.

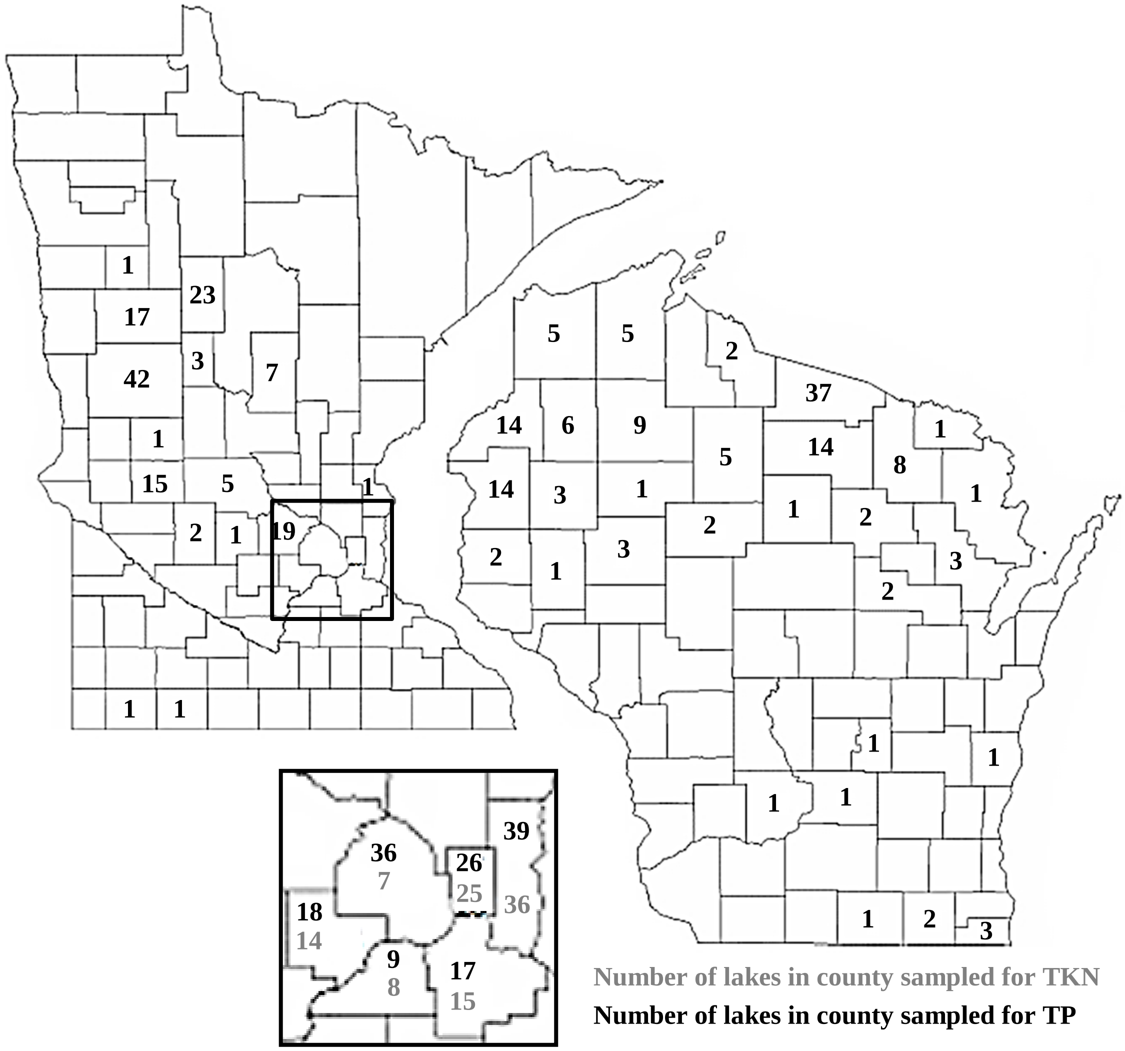


Figure 1. Geographic distributions of lakes. Lake counts are provided by county. Within the Metro area (boxed above), a subset of the lakes sampled for TP were also sampled for TKN.

Data was first prepared by averaging all sample values for a given lake from the upper two meters of the water column from each day, including field replicates, lab replicates, and values from different analytical protocols. The upper two meters were selected to ensure that samples were only taken from the epilimnion when the lake is stratified.

For each lake, the data were then organized to determine which months had multiple years of data. The minimum requirement for inclusion was for there to be at least one value from at least one calendar month over nine consecutive years. In cases where there was more than one observation within a single calendar month, only the first observation from the month was utilized. Monthly values were not averaged, per the recommendations of Hirsch and Slack (1984). The number of months used in the analysis ranged from one to seven. Consistent numbers of months were not used for analysis from lake to lake. This was done to ensure the inclusion of the maximum number of lakes. Lakes with fewer than nine consecutive years of data were excluded. Yu et al. (1993) found that when at least nine years of data are included in a Seasonal Kendall test, the power of the test is comparable to other non-parametric tests. The timeframe for this study was from 2000-2011, this allowed for a sufficient number of years for analysis leading up to the current time.

The estimation method of Yu et al. (1993) was used if no lake samples were taken in a given month but samples were taken in the months immediately preceding and following. The value from the unsampled month was estimated as the average of the sample values from the preceding and following months. For any given lake, no more than 15% of the total monthly values were estimated. If a month could not be estimated because there was not data for the months preceding and following, that month, for all years, was excluded from analysis.

When there were different possible year and month combinations for a given lake, the year and month combination resulting in the greatest number of total values was used. If there was a tie, the combination with the largest number of years was used. The average numbers of total values used in the analysis were 57.28 for Metro TP, 41.49 for Non-Metro TP (MN), 25.89 for Non-Metro TP (WI), and 53.94 for Metro TKN.

The rigorous nature of the data preparation eliminated a large number of lakes from the analysis. Of the data received from the organizations, all of the lakes that met the minimum data requirements for the trend analysis were included (Table 1). This resulted in a total of 441 lakes throughout Minnesota and Wisconsin. All of these lakes were analyzed for trends in TP. Additionally, 110 of the Metro lakes were analyzed for trends in TKN.

Table 1. Lakes meeting minimum data requirements.

	Lakes with Surface Data Provided	Lakes with 9+ Years of Data	Number of Lakes Analyzed	Lakes with Multiple Basins in Analysis
Metro TP	495	153	151	4
Non-Metro TP (MN)	986	145	139	5
Non-Metro TP (WI)	1376	207	151	7
Metro TKN	368	111	110	1

Though limits of detection and quantitation are part of quality control assurance and important to understanding the integrity of a laboratory analysis (WDNR, 2008), when receiving data from multiple sources it becomes clear that the emphasis on tracking and reporting these limits varies from laboratory to laboratory. Some data in each of the data sets received was marked at below the limit of detection or limit of quantitation but the laboratory-specific limits were not provided and could not be obtained. Because a rank order test was performed, data below the limits were set to consistent values throughout the entire lake group so that all values below these limits would tie (Helsel and Hirsch, 2002). This conservative approach prevented assumptions of more precision in the data for the lake groups than was actually present.

The data received was analyzed as four separate lake groups. Limits were set for each lake group. When limits were not provided by the laboratory, the applicable limits based on the methods reported were utilized; this is called "method lookup" in Table 2.

Table 2. Data source limits of detection and quantitation.

Lake Group	Nutrient	Data Source	Limit Source	Limit of Detection	Limit of Quantitation	Data Values
Metro TP	TP	MPCA, EPA, MCES, and the Shakopee Mdewakanton Sioux Community	Method lookup for EPA 365.1, 365.3, 365.4	0.01 mg/L	N/A	< 0.01 mg/L and "below detection limit" = 0.00 mg/L
Non-Metro TP (MN)	TP	MPCA and EPA	Method lookup for EPA 365.1, 365.3, 365.4	0.01 mg/L	N/A	< 0.01 mg/L and "below detection limit"= 0.00 mg/L
Non-Metro TP (WI)	TP	WI DNR	WI DNR Personal Communication	0.005 mg/L	0.016 mg/L	< 0.005 mg/L and "below limit of detection" = 0.00 mg/L; ≥ 0.005 mg/L but < 0.016 mg/L and "below limit of quantitation" = 0.005 mg/L
Metro TKN	TKN	MPCA, EPA, MCES, and the Shakopee Mdewakanton Sioux Community	Method lookup for EPA 351.2 and Personal Communication	0.2 mg/L	0.5 mg/L	< 0.2 mg/L and "below the detection limit"= 0.00 mg/L; ≥ 0.2 mg/L but < 0.5 mg/L and

						“below limit of quantitation” = 0.2 mg/L

Two Metro TKN data points were removed from analysis because they were marked suspect by the data provider and upon inspection varied substantially from a reasonable value (outside the maximum range for all other data values). The excluded samples were from Parkers Lake on April 28, 2009 and Loon Lake on August 4, 2010.

The Seasonal Kendall test was used to find evidence of TP and TKN trends. This test assesses the randomness of the data in a ranked matrix where seasons are columns and years are rows. For the purpose of this study, months are the seasons. The null hypothesis is for each of the seasons the data for each year will be randomly ordered. The alternative hypothesis is that for one or more seasons there will be a monotonic trend in the data for each year (Hirsch and Slack, 1984). The test statistic is a sum of the Mann-Kendall statistics computed for each season. Further explanation of the test can be found in Hirsch and Slack (1984).

The Seasonal Kendall test is appropriate to determine evidence of trends when seasonality is present. Although other tests could also be appropriate, the Seasonal Kendall test is very common for this type of analysis of water quality data. As examples, the Seasonal Kendall test was used by the MPCA to find evidence of trends in water clarity (MPCA, 2012) and by the U.K. Acid Water Monitoring Network to look for trends in dissolved organic carbon throughout the United Kingdom (Evans et al., 2005).

As a non-parametric test, the Seasonal Kendall test is suited for water quality data because it does not require normal distributions. The non-normality of the data in this study was assumed based on other research which indicates that in water quality data, only temperature, pH, and dissolved oxygen are frequently normally distributed. Nutrients that are attached to particles and involved in runoff have been found to be non-normal and often positively skewed (Hirsch and Slack, 1984). Additionally, because the Seasonal Kendall test is rank-order, it can handle censored data as long as the data is appropriately organized (Hirsch and Slack, 1984). The Seasonal Kendall test is not ideal for serially correlated data but it handles serially correlated data as well or better than any of the parametric options (Hirsch et al., 1982).

The software program R and the Kendall package were used to perform the Seasonal Kendall test. To calculate the statistic, the values for each lake were converted into a time series using the ts function, then the SeasonalMannKendall function was used to calculate the tau score. The output from the SeasonalMannKendall function is a tau score and a two-sided p-value (McLeod, 2015). Tau is a test statistic that indicates strength of evidence for a nonrandom distribution of values in a given time series. Tau scores for TP were calculated for each lake within all four lake groups. TKN was also calculated for each lake within the Metro TKN lake group.

In addition to calculating tau scores in TP and TKN for each lake in the Metro TKN lake group, the TKN to TP (N:P) ratio for each lake was calculated. This ratio is not a 1:1 comparison as TN:TP would be because TKN only includes a subset of the species of nitrogen possible (organic nitrogen, ammonium, and ammonia (O'Dell, 1993)) and TP is all inclusive. The Seasonal Kendall test was used to calculate a tau score based on the N:P ratio to determine if there was a correlation between TKN and TP within an individual lake. The N:P ratios were calculated by dividing the first TKN sample of the month by the first TP sample of the month. If a lake had a TP concentration below the limit of detection and the quotient could not be calculated, the value for that month and year combination was set to 1000. This was done to ensure that all lakes with a TP concentrations below the limit of detection were ranked the highest for N:P ratio and set equal to one another.

A year-by-year analysis of how TP concentrations in a lake compared to the median TP concentration for that lake over the timeframe of the study was conducted. Patterns in the median difference from median were assessed as a visual description of the data. Results were binned into above timeframe median, below timeframe median, or equal to timeframe median.

Equation 1. yearly median – time frame median = median difference from median

Temporal synchrony was also evaluated between 2003 and 2008 to determine if interannual variation made lakes in the same lake group more synchronous than lakes across groups. The Pearson correlation coefficient (r) was calculated for each of the lake pairs, then the median r value for the lake pairs in the lake groups was calculated.

The impacts of potential confounding factors including temperature and precipitation were taken into account. Temperature and precipitation data was obtained from the climatology working group (www.climate.umn.edu) for the TCMA (taken at the St. Paul airport – station 217377 Saint Paul) from 2000 – 2011. The Seasonal Kendall test was again used to analyze the evidence of trends in this data. Because daily observations were available, the monthly means were calculated and compared for the analysis. As an additional investigation into the temperature and precipitation patterns, patterns in the yearly average difference from timeframe average were assessed. It is acknowledged that temperature and precipitation vary throughout Minnesota and Wisconsin; however, tau scores at only one weather station were calculated as a general inquiry into substantial seasonal climate differences in the upper Midwest.

Other potentially confounding factors include lake surface area, maximum depth, average initial TP concentration, latitude, longitude, months in analysis, total values in analysis, years in analysis, and starting and ending years of analysis. Data on lake surface area and maximum depth was obtained for all possible lakes (406 with maximum depths and 427 with surface areas). This information was provided by the Wisconsin DNR. Data for Minnesota lakes, was accessed through the Minnesota DNR Lake Finder website (https://www.dnr.state.mn.us/lakefind/index.html). Average initial TP concentration for each lake was calculated as the annual mean in the first year of the trend analysis. The mean was calculated based only on the months used in the trend analysis. The tau score was then calculated using the subsequent years for those months (minimum of 8 years) so that the same value was not part of both the independent and dependent variables. These three lake characteristics, in addition to latitude and longitude, were then used as the explanatory variables in linear models to assess their significance in explaining lake TP tau scores. The significance of months, total values, and years in analysis, along with starting and ending years of analysis, were analyzed with a one way ANOVA test followed by a Tukey Honestly Significant Difference test if significant factors were found in the ANOVA.

Landcover Analysis

In 2002, a study to connect water chemistry and landcover was conducted by the Sterner lab (unpublished). Data from the 2002 study indicated that the percentage of crops surrounding a lake was the most important landcover factor controlling TP concentration; however, in lakes with a low percentage of crops, lawn was the most important factor. These results indicated that the landcover surrounding urban lakes can impact nutrient concentration and that these impacts differ between agricultural and urban areas.

In the 2002 study, 100 points throughout the TCMA were randomly selected using the method of Hooge and Eichelaub (1997), with 25 points placed in the urban core of Hennepin and Ramsey counties, 25 points placed in a suburban ring surrounding the urban core, and 50 points placed in the non-urban areas of the TCMA. The lake located closest to each point was selected for study inclusion. These 100 lakes were located on both public and private land. In 2010, the focus was to hone in on the impact of lawn, so only the 64 low crop lakes were selected for resampling.

In 2010, the same sampling protocols were used as during the 2002 study. Each of the lakes was sampled in mid-summer. Samples were collected away from shore. The lakes were separated into thirds, with the center of each third selected as the sampling location. The GPS coordinates of the locations were recorded in 2002, and were matched as closely as possible in 2010. Although there was not a significant difference in the precipitation received in 2010 and 2002, lake water levels in 2010 were lower than in 2002 so not all areas sampled in 2002 were available for sampling in 2010. Ultimately, 61 of the 64 lakes could be re-sampled with reliable data results.

At each sampling location in-lake measurements were taken throughout the water column. Depth was measured, and at equal spacing from surface to sediment, temperature, dissolved oxygen, and conductivity were measured. These profiles determined the water collection depths. Using a Kemmerer, a water sample was taken from the surface layer of a stratified lake or from the mid water column of an unstratified lake. The water samples were stored in a 2-liter bottle with a sample from each third of the lake filling one third of the bottle. The complete sample was a composite of water from all three locations on the lake to mitigate potential spatial differences within the lake.

At each lake, the land-use surrounding the lake was observed directly at the shoreline (0 meters) and at an estimated 10 meters. These areas were classified into percentages of each of nine land-use classes: Wetland/Marsh, Lawn/Suburban, Grassland/Pasture, Cultivated Cropland, Impervious, Upland forest/shrubland, Lowland forest/shrubland, Construction, and Other.

After collection, water samples were stored in the dark and processed within 24 hours. The samples were analyzed for TP and Total Dissolved Nitrogen (TDN), among other parameters. During processing, samples were filtered through an 80 µm filter to remove large particles and organisms. The sample to be tested for TP was poured into a 60 mL bottle and frozen. The sample to be tested for TDN was filtered through a 0.7 µm GF/F filter then frozen in a 60 mL bottle. TP samples were analyzed using the method of Murphy and Riley (1962). TDN samples were acidified prior to analysis using the Shimadzu TOC-Vcsh with attached TNM-1 autoanalyzer (Standard Methods for Examination of Water and Wastewater 5310B – high temperature combustion method).

The normalized changes in TP and TDN concentrations between 2002 and 2010 in these 61 Metro lakes were regressed against the average amount of lawn in the immediate watershed in 2002 and 2010 to look for a relationship between change in nutrient concentration and land-use. Normalized concentrations were calculated by subtracting the average 2002 concentration from the individual lake 2002 concentration, then subtracting the average 2010 concentration from the individual lake 2010 concentration, and finally subtracting the normalized 2002 concentration from the normalized 2010 concentration. TDN was used as the form of nitrogen in this portion of the analysis instead of TKN. Ideally, TKN would have been measured in this study, however TKN data was not available. The analysis done on the lake samples in 2002 only measured TDN. Although, TDN is not directly comparable to TKN, TDN serves as a suitable comparison to TP for this portion of the study as the major difference between TKN and TDN is that TDN also includes nitrate and in urban surface waters nitrate concentrations are low as compared to surface waters with watersheds dominated by row crops (Schilling and Libra, 2000).

In the 2002 study, crops in the area surrounding the lake were the most important factor controlling phosphorus concentration. Because lakes with high crop were not resampled in 2010, using Google Earth, the 441 lakes in the trend analysis were binned into “some crop” and “no crop” in the area surrounding the lake. A two tailed t-test was conducted to determine whether tau scores differed between the two categories of lakes.

Results:

Trend Analysis

Tau scores representing TP trends for all 441 lakes studied ranged from approximately -0.6 to 0.6 with a relatively symmetric distribution (Figure 2). The distribution of tau scores was shifted to the negative, indicating a larger representation of decreasing than increasing TP trends. Of the total, 254 lakes (58%) had negative tau scores. Significant tau scores ($\alpha=0.05$) were found in 111 of the lakes studied with 75% showing evidence for decreases in TP concentration. Both median and average tau scores were negative; -.06 and -.05, respectively. A one sample t-test found the mean tau for TP concentration to be significantly different than zero, p-value = 5.65×10^{-7}.

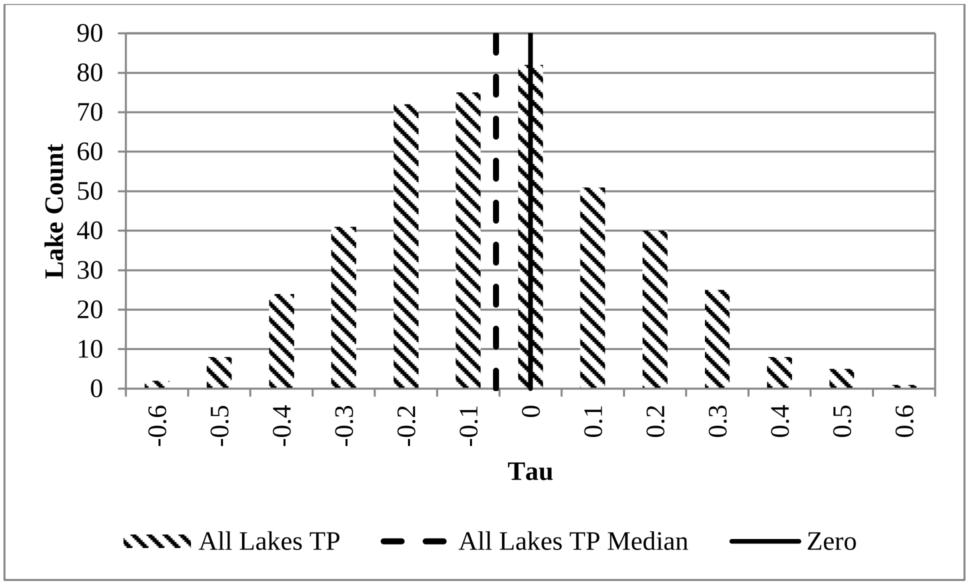


Figure 2. Distribution of tau scores compared with the median tau score for all lakes (dashed line) and a tau score of zero (solid line).

To examine more closely how phosphorus concentrations change over time and whether trends were continuous or exhibit sudden shifts, the year-by-year variations in median difference from median were analyzed. A negative median tau score for a lake group was supported if there was a transition from more lakes above the timeframe median TP concentration to below. No pattern was found in the year-by-year variations in median difference from median TP concentration for all lakes. There was a transition nearly every year between more lakes above and below the median TP concentration (Figure 3).

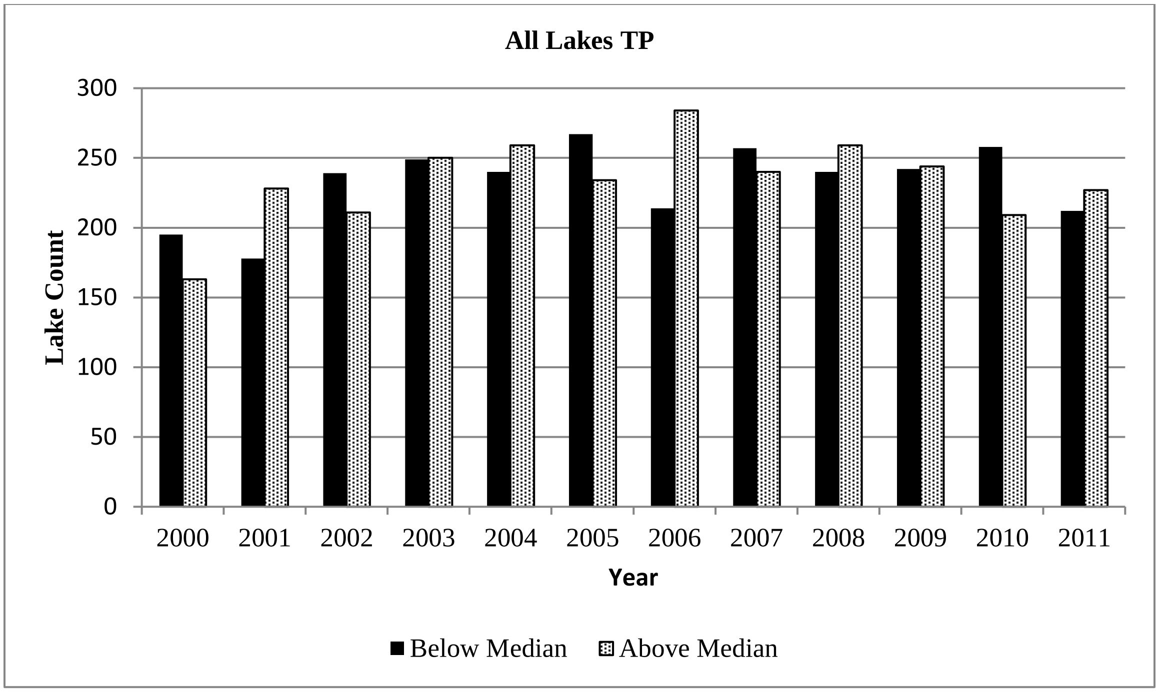


Figure 3. Year-by-year variations in median difference from median TP concentration for lakes.

When comparing the synchrony of all lakes in the study, i.e. whether they vary similarly in TP concentrations, 5.9% of the pairwise comparisons were significant at a two-tailed value of r(4)= 0.811 $p<0.05$, with a median correlation coefficient of 0.03. The median correlation coefficient was not significant (α=0.05).

When the Metro to Non-Metro lake groups were compared, differences in evidence for trends were found among the groups (Figure 4). In the Non-Metro TP (All) lake group, which includes Minnesota and Wisconsin, the median tau was negative, -0.02, but very close to zero (Figure 4a). Of the 290 lakes studied, 148 lakes (51%) had negative tau. Significant tau scores (α=0.05) were found in 47 of the lakes studied with 68% showing decreases. A one sample t-test found the mean tau was not significantly different than zero, p-value = 0.15. In the Metro TP lake group, the median tau was also negative, -0.13, but farther from zero (Figure 4b). Of the 151 lakes studied, 106 lakes (70%) had negative tau. Significant tau scores (α=0.05) were found in 64 of the lakes studied with 80% showing evidence for decreases in TP concentration. A one sample t-test found the mean tau was significantly different than zero, p-value = $1.28\text{x}10^{-10}$.

Dividing this group further, more negative tau scores were found in the Non-Metro TP (MN) lake group than the Non-Metro TP (WI) lake group. In the Non-Metro TP (MN) lake group, the median tau was negative, -0.08. Of the 139 lakes studied, 97 lakes (70%) had decreasing tau. Significant tau scores (α=0.05) were found in 33 of the lakes studied with 85% showing evidence for decreases in TP concentration (Figure 4c). A one sample t-test found the mean tau was significantly different than zero, p-value =$1.94x10^{-8}$. Alternatively, in the Non-Metro TP (WI) lake group, the median tau was positive, 0.05. Of the 151 lakes studied, 84 lakes (56%) had increasing tau. Significant tau scores (α=0.05) were found in 14 of the lakes studied with 71% showing evidence for increases in TP concentration (Figure 4d). A one sample t-test found the mean tau was significantly different than zero, p-value = 0.005.

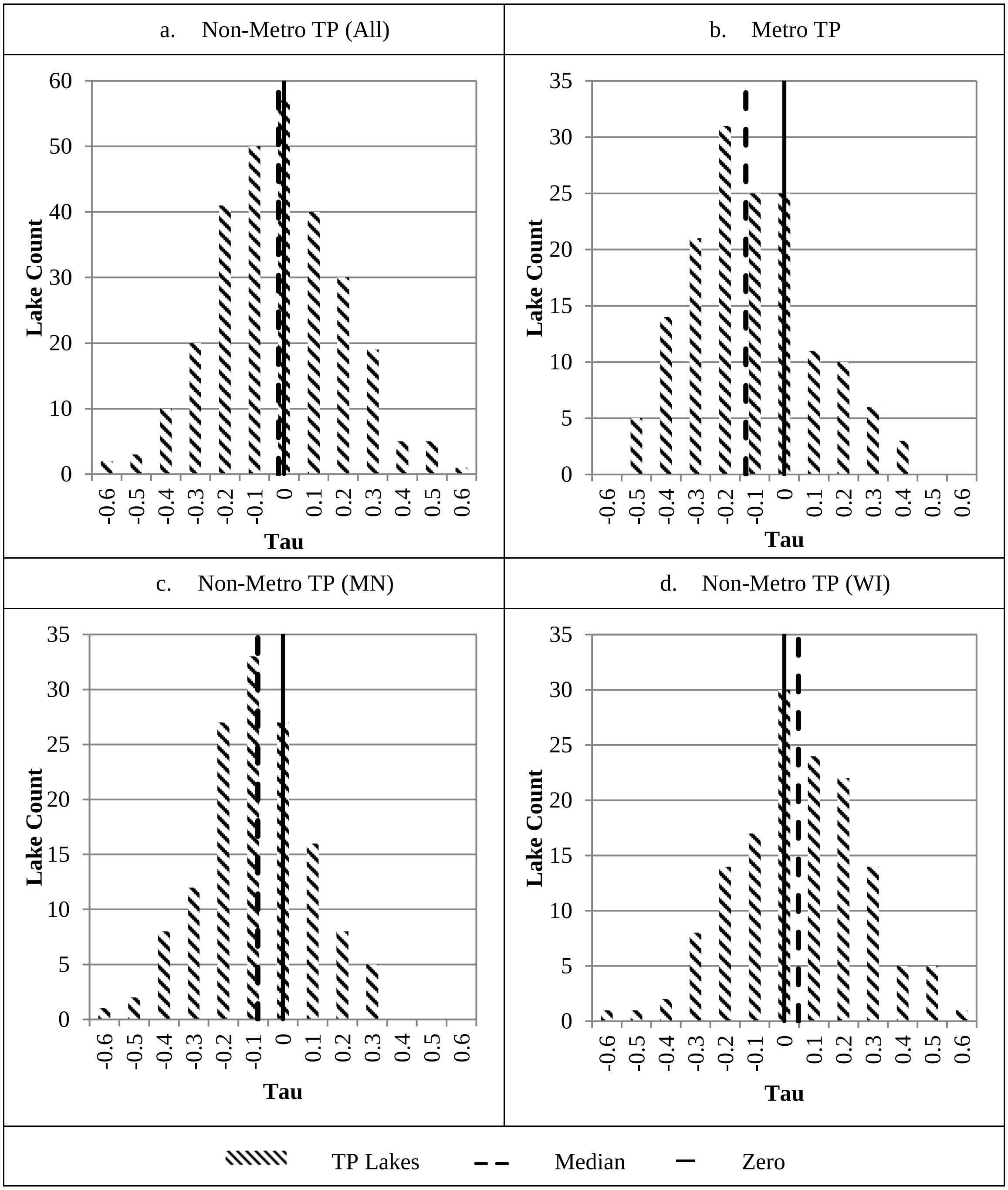
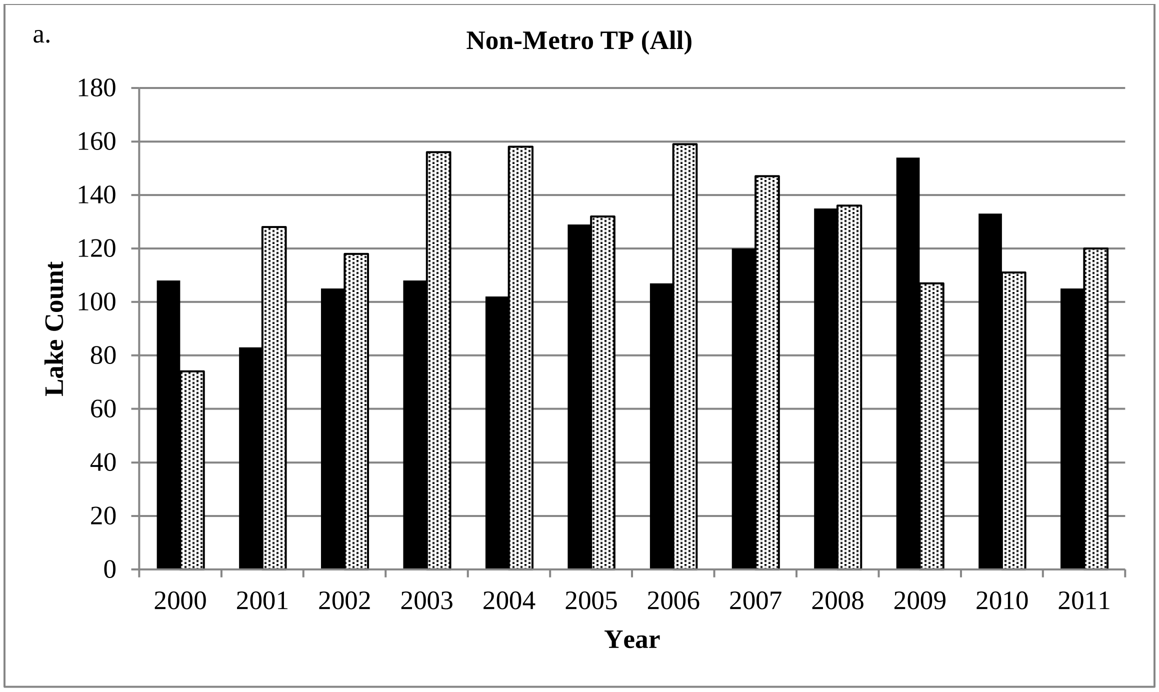


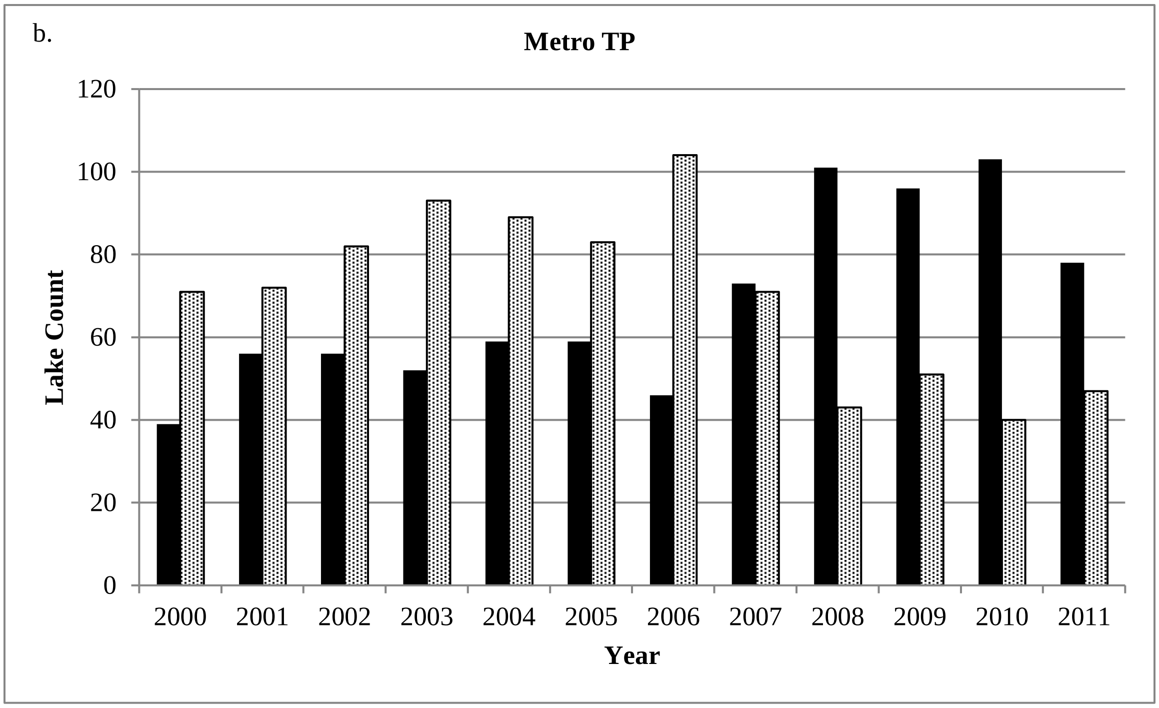
Figure 4. Distribution of tau scores compared with the median tau score for the lake group (dashed line) and a tau score of zero (solid line). Metro TP (a), Non-Metro TP (All) (b), Non-Metro TP (MN) (c), and Non-Metro TP (WI) (d).

The year-by-year variations in median difference from median TP concentration are displayed in Figure 4 for the lake groups. In the Non-Metro TP (All) lake group, for years other than 2000, 2009, and 2010, there were more lakes with median TP above the time frame median TP concentration (Figure 5a). In contrast, in the Metro TP lake group, there was a transition over the course of the study timeframe. At the beginning of the study, 2000-2006, there were more lakes with median TP above the timeframe median TP concentration. In 2007 there was a transition with nearly equal lake counts above and below the time frame median TP concentration. From 2008-2011, there were more lakes with median TP below the timeframe median TP concentration (Figure 5b). This supports the finding of a more negative median tau score in the Metro TP lake group than the Non-Metro TP (All) lake group.

When the Non-Metro TP (All) group was sub-divided, a difference was seen between Non-Metro TP (MN) and Non-Metro TP (WI). As was seen in the Non-Metro TP (All) lake group, there was a great deal of variability within the Non-Metro TP (WI) lake group. Above and below timeframe median TP concentration lake counts switched nearly year to year (Figure 5c). The findings support the low percentage of significant tau scores found in the Non-Metro TP (WI) lake group (9.3%) with so little consistency in the year-by-year analysis. In the Non-Metro TP (MN) dataset there appeared to be a transition. From 2001-2004, there were more lakes with median TP above the timeframe median TP concentration. In 2005 there was a transition with nearly equal lake counts above and below the time frame median TP concentration. From 2006-2011 (with the exception of 2007), there were more lakes with median TP concentrations below the timeframe median. The results support the finding of a negative tau score in the Non-Metro TP (MN) lake group (Figure 5d).

Only lakes below and above the timeframe median were counted in Figure 4. In the Non-Metro TP (All) and Non-Metro TP (WI) lake groups there were a large number of lakes with equal to timeframe median TP (median yearly counts of 86 and 69.5, respectively). Many values in the Non-Metro TP (WI) lake group were at or near the detection limit, therefore, for 79 lakes the difference between the yearly and timeframe medians was zero. In the Metro TP and Non-Metro TP (MN) data sets there were only 6 and 14 lakes with the difference between the yearly and timeframe medians equal to zero, respectively.


a.
Non-Metro TP (All)
Lake Count
0
20
40
60
80
100
120
140
160
180
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year


b.
Metro TP
Lake Count
0
20
40
60
80
100
120
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year

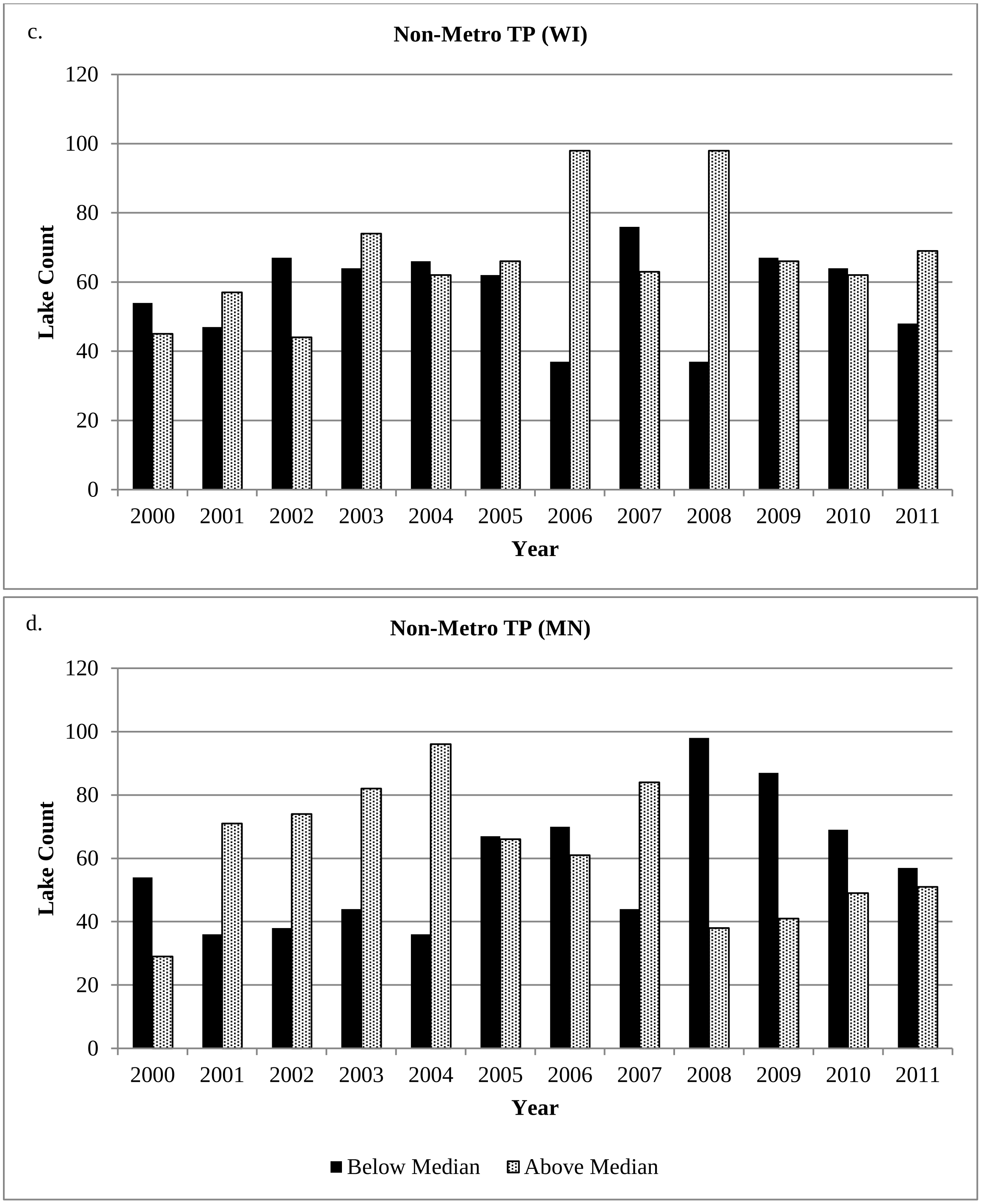


Figure 5. Year-by-year variations in median difference from median TP concentration for lakes in Non-Metro TP (All) (a), Metro TP (b), Non-Metro TP (WI) (c), and Non-Metro TP (MN) (d) lake groups.

Lake synchrony was examined to determine if lakes were changing more similarly to other lakes in the same lake group or different lake groups (Table 3). The lakes in the Metro TP and Non-Metro TP (MN) groups changed more similarly to lakes within the same lake group. In the Non-Metro TP (All) and Non-Metro TP (WI) lake groups, lakes did not change more similarly to other lakes in the same lake group. Overall, the median correlation coefficients were not significant in any of the lake groups. Additionally, the percentage of correlation coefficients which were individually significant in each lake group was low, ranging from 5.3% to 7.7%.

Table 3. Lake synchrony correlation coefficients.

	Metro TP	Non-Metro TP (All)	Non-Metro TP (MN)	Non-Metro TP (WI)	Metro TP (110)	Metro TKN
	Median r Value	Median r Value	Median r Value	Median r Value	Median r Value	Median r Value
	% Significant	% Significant	% Significant	% Significant	% Significant	% Significant
Metro TP	0.15	0.03	0.05	0.02		
	7.7	5.8	5.3	6.1		
Non-Metro TP (All)		0.01	-0.02	-0.02		
		5.7	5.5	5.6		
Non-Metro TP (MN)			0.15	-0.08		
			6.0	5.3		
Non-Metro TP (WI)				0.05		
				6.1		
Metro TP (110)					0.23	-0.06
					8.5	8.1
Metro TKN						0.39
						16

Evidence was found that TKN concentrations in many lakes in the Metro area were increasing. In the Metro TKN lake group, the median tau was positive, 0.10. Of the 110 lakes studied, 70 lakes (64%) had positive tau. Significant tau scores ($\alpha=0.05$) were found in 41 of the lakes studied with 85% showing evidence for increases in TKN concentration (Figure 6). A one sample t-test found the mean tau for TKN concentration was significantly different than zero, p-value = 0.002.

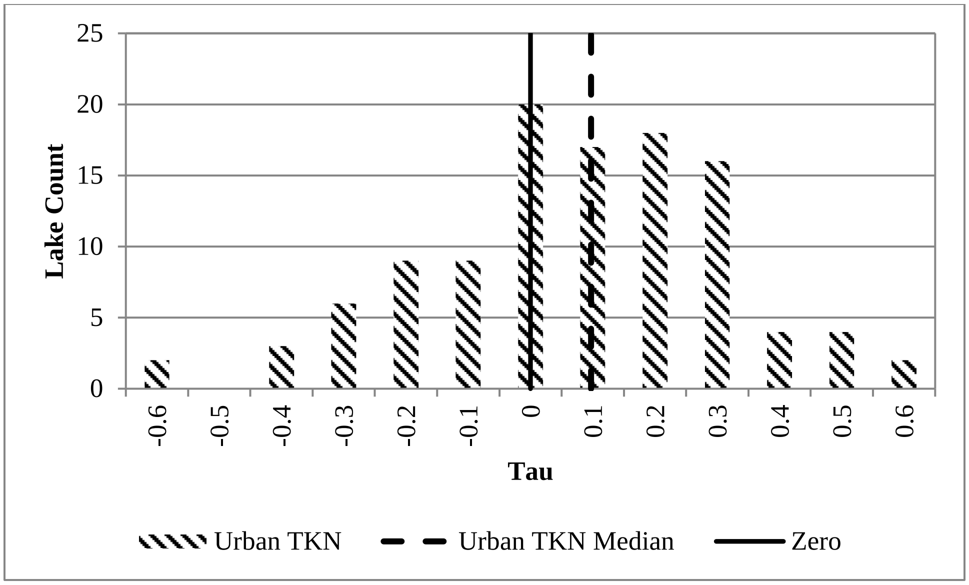


Figure 6. Distribution of tau scores compared with the median tau score for Metro TKN lakes (dashed line) and a tau score of zero (solid line).

The year-by-year variations in median difference from median TKN concentration (Figure 7) appeared to be a near reversal of the Metro TP patterns. At the beginning of the study period, from 2000-2005 (except for 2001), there were more lakes with yearly median TKN concentrations below the timeframe median. After 2005, a change occurred and from 2006-2009 there were more lakes with yearly median TKN concentrations above the timeframe median. Unlike the Metro TP dataset; however, a second perturbation occurs and the balance again shifted in 2010. In 2010 and 2011 there were more lakes with yearly median TKN concentrations below the timeframe median. A positive median tau score was found for this lake group.

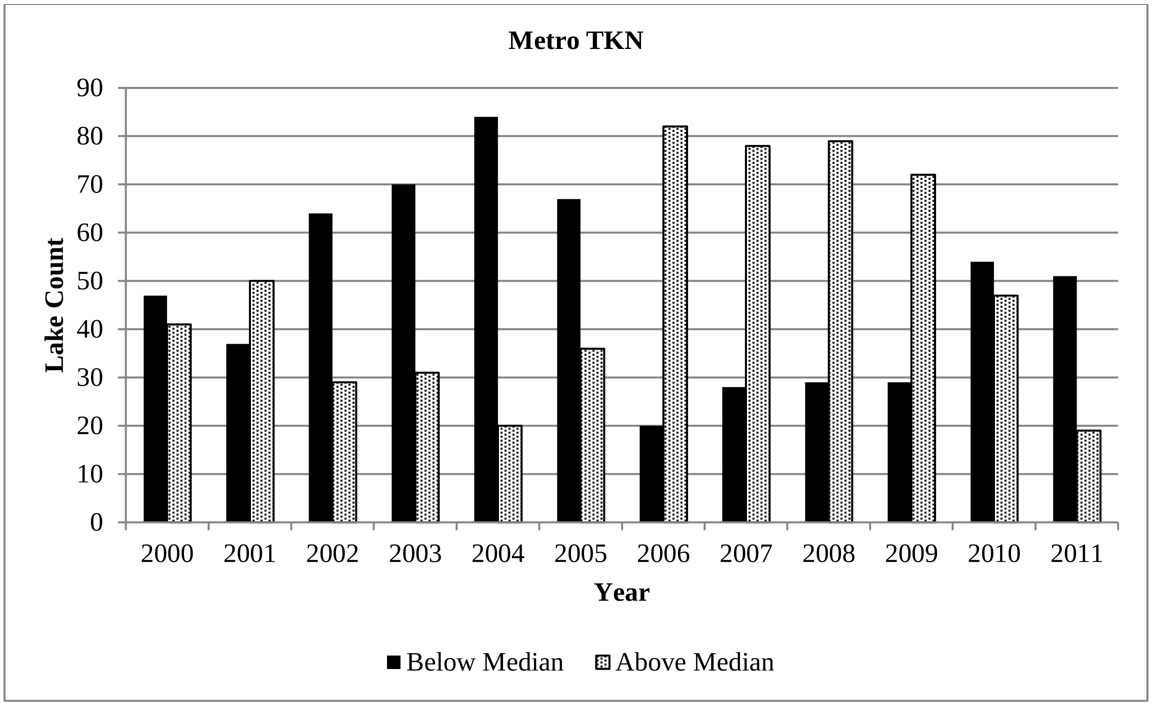


Figure 7. Year-by-year variations in median difference from median TKN concentration for lakes in the Metro TKN lake group.

To allow for direct comparison between the Metro TP and Metro TKN lake groups, the 110 lakes in the Metro TP lake group which also comprise the Metro TKN lake group are referred to as the Metro TP (110) lake group. Lake synchrony within and between the Metro TP (110) and Metro TKN lake groups were analyzed. Within the Metro TP (110) lake group, 8.5% of the pairwise comparisons were significant at a two-tailed value of $r(4) = 0.811$, $p<0.05$, with a median correlation coefficient of 0.23. The median correlation coefficient was not significant ($\alpha=0.05$). Within the Metro TKN data set, 16% of the pairwise comparisons were significant at a two-tailed value of $r(4)=0.811$, $p<0.05$, with a median correlation coefficient of 0.39. Again, the median correlation coefficient was not significant (α-0.05). Although not significant, the median correlation coefficients for Metro TP (110) versus Metro TP (110) and Metro TKN versus Metro TKN were higher than for the pairwise comparisons between Metro TP (110) and Metro TKN. Only 8.1% of the Metro TKN and Metro TP (110) pairwise comparisons were significant at a two-tailed value of $r(4)=0.811$, $p<0.05$, with a median correlation coefficient of -0.06 (Table 3).

Many lakes in the Metro area had evidence for increasing N:P ratios (Figure 8). Of the 110 lakes, 98 lakes (89%), had positive tau, with a median N:P tau score of 0.217. Significant tau scores ($\alpha=0.05$) were found in 63 of the lakes with 92% showing evidence for increases in the N:P ratio. Tau scores ranged from -0.356 to 0.560. A one sample t-test found the mean tau in N:P was significantly different than zero, p-value = $6.04\text{x}10^{-20}$.

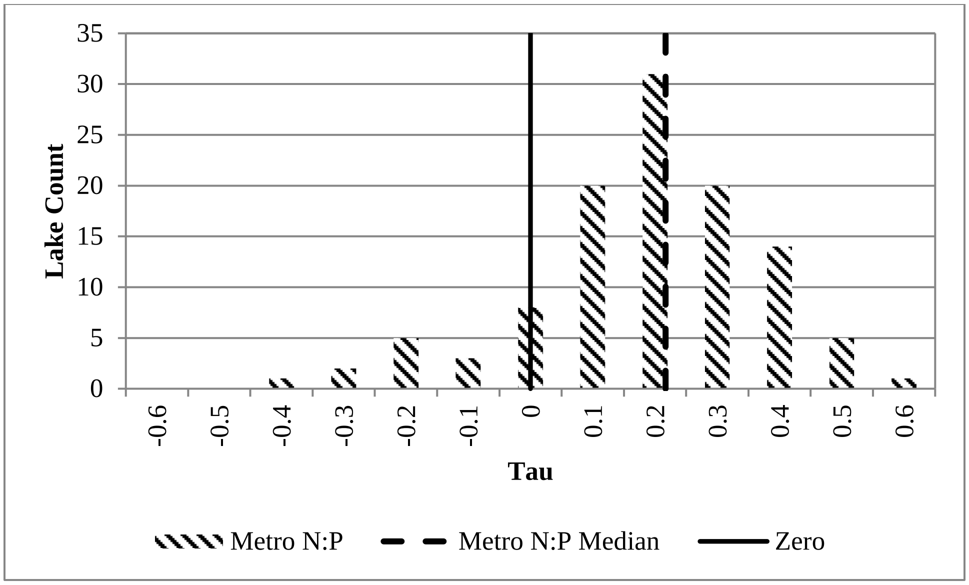


Figure 8. The distribution of tau scores compared with the median tau score for N:P ratio lakes (dashed line) and a tau score of zero (solid line).

Average monthly high temperatures and average monthly precipitation between 2000 and 2011 were evaluated to determine if general trends were present; i.e., the period went from wet to dry or hot to cold. Though there was an overall increase of +0.62 ^{0}C in mean high temperatures between the endpoint years of 2000 and 2011, as well as a slight decrease in precipitation between the same endpoints, there was no significant evidence of trends in average high temperature (tau score = - 0.03 and p-value = 0.64) or average precipitation (tau score = 0.02 and p-value = 0.70) found.

A year-by-year average difference from timeframe average analysis resulted in no consistent patterns in temperature or precipitation. Temperature varied in streaks of above and below average high temperatures. Precipitation was above average in the first three years of the study but then varied above and below average for the remainder of the study period (Table 4).

Table 4. Differences between yearly averages and timeframe averages for temperature and precipitation based on measurements taken at the airport in St. Paul, MN.

Year	Difference from Average High Temperature (degree C)	Difference from Average Precipitation (meters)
2000	-0.38	$7.11\text{x}10^{-5}$
2001	0.32	$3.32\text{x}10^{-4}$
2002	-0.34	$4.89\text{x}10^{-4}$
2003	-0.31	$-4.63\text{x}10^{-4}$
2004	-0.37	$-1.50\text{x}10^{-4}$

2005	0.56	2.75x10^{-4}
2006	1.21	-1.31x10^{-4}
2007	0.49	3.38x10^{-4}
2008	-1.16	-4.97x10^{-4}
2009	-0.88	-3.24x10^{-4}
2010	0.62	2.39x10^{-4}
2011	0.24	-1.77x10^{-4}

At the level $r(10)=0.546$, $p<0.05$, there were no significant correlations found between all lakes or any of the lake groups with either temperature or precipitation. Pearson's r values ranged from -0.43 for all lakes with precipitation and 0.30 for Metro TP and temperature. Pearson’s r values could not be calculated for the Non-Metro TP (WI) and Non-Metro TP (All) lake groups because the standard deviation of the median, median difference from median was zero.

There are inherent differences in both lake and data characteristics between the lake groups analyzed in this study (Table 5). These characteristics include number of lakes, months in analysis, years in analysis, total values in analysis, surface area, maximum depth, and average initial phosphorus concentration. These inherent differences may be confounding factors with differing levels of importance.

Table 5. Lake and data characteristics which may have an impact on tau. Mean, standard deviation, and range are provided for each characteristic for each lake group.

	Lake Count	Months in Analysis	Years in Analysis	Total Values in Analysis	Surface Area (hectares)	Maximum Depth (meters)	Average Initial [TP] (mg/L)	Tau Value Description
Metro TP	151	Mean: 5.23 SD: 1.27 Range: 1-7	Mean: 10.96 SD: 1.15 Range: 9-12	Mean: 57.28 SD: 14.79 Range: 9-84	Mean: 124.09 SD: 296.16 Range: 0.86-2883.02	Mean: 10.22 SD: 6.84 Range: 0.61-27.74	Mean: 0.08 SD: 0.08 Range: 0.008-0.75	Median: -0.13 SD: 0.21 Range: -0.54-0.41
Non-Metro TP (All)	290	Mean: 3.16 SD: 1.32 Range: 1-6	Mean: 10.50 SD: 1.20 Range: 9-12	Mean: 33.37 SD: 14.70 Range: 9-60	Mean: 384.20 SD: 661.30 Range: 11.49-5558.63	Mean: 13.92 SD: 8.69 Range: 1.52-71.93	Mean: 0.03 SD: 0.04 Range: 0.003-0.34	Median: -0.02 SD: 0.21 Range: -0.63-0.57

Non-Metro TP (MN)	139	Mean: 3.86 SD: 1.13 Range: 1-5	Mean: 10.73 SD: 1.21 Range: 9-12	Mean: 41.49 SD: 12.93 Range: 9-60	Mean: 443.54 SD: 714.08 Range: 13.37-5558.63	Mean: 15.33 SD: 8.58 Range: 1.52-41.15	Mean: 0.04 SD: 0.05 Range: 0.003-0.34	Median: -0.08 SD: 0.18 Range: -0.57-0.34
Non-Metro TP (WI)	151	Mean: 2.52 SD: 1.14 Range: 1-6	Mean: 10.28 SD: 1.16 Range: 9-12	Mean: 25.89 SD: 12.03 Range: 9-54	Mean: 329.58 SD: 605.96 Range: 11.49-5241.62	Mean: 12.63 SD: 8.61 Range: 2.13-71.93	Mean: 0.02 SD: 0.03 Range: 0.003-0.18	Median: 0.05 SD: 0.22 Range: -0.63-0.57
Metro TKN	110	Mean: 5.01 SD: 1.39 Range: 1-7	Mean: 10.72 SD: 1.07 Range: 9-12	Mean: 53.94 SD: 16.27 Range: 9-84	Mean: 91.11 SD: 195.82 Range: 1.22-1247.52	Mean: 8.68 SD: 5.90 Range: 0.61-27.74	N/A	Median: 0.09 SD: 0.24 Range: -0.61-0.59
All Lakes	441	Mean: 3.87 SD: 1.63 Range: 1-7	Mean: 10.66 SD: 1.20 Range: 9-12	Mean: 41.55 SD: 18.59 Range: 9-84	Mean: 297.10 SD: 578.69 Range: 0.86-5558.63	Mean: 12.80 SD: 8.34 Range: 0.61-71.93	Mean: 0.05 SD: 0.06 Range: 0.003-0.75	Median: -0.06 SD: 0.22 Range: -0.63-0.57
Specific information for each lake in the study is included in Tables 8 and 9.								

The Metro TP and Metro TKN lake groups had the most overall data in the trend analysis. The Metro TP and Metro TKN lake groups had the most months and years in the analysis, except for Non-Metro TP (MN) which had a mean of 10.73 years. Lakes in the Metro TP and Metro TKN lake groups had the smallest mean surface area and depth. Lakes in the Non-Metro TP (MN) lake group had the largest surface area and were also the deepest. TP concentrations were on average the highest in the first year of the analysis in the Metro TP lake group and lowest in the Non-Metro TP (WI) lake group. The average initial TP concentration in Metro TP lakes was 4x that found in Non-Metro TP (WI) lakes and 2x that found in Non-Metro TP (MN) lakes. These differences between the lake groups were significant ($\alpha<0.05$) according to the results of a Tukey Honestly Significant Difference (Tukey HSD) test.

Table 6. Analysis of the importance of different lake and data characteristics. For each characteristic the method of analysis as well as amount of variation explained and significance are reported. Analysis was performed on all lakes.

Factor/Characteristic	Method of Analysis	R^2	P-Value	Difference
Surface Area (hectares)	Linear Model/Regression	0.0024	0.308	

Maximum Depth (meters)	Linear Model/Regression	0.0089	0.245	
Initial Phosphorus (mg/L)	Linear Model/Regression	0.014	0.014	
Latitude	Linear Model/Regression	0.0004	0.050	
Longitude	Linear Model/Regression	0.0585	0.030	
Months in Analysis	One Way ANOVA/Tukey HSD	0.0385	2.146e-05	5 months
Total Values in Analysis	One Way ANOVA/Tukey HSD	0.0463	0.001	20 values
Years in Analysis	One Way ANOVA/Tukey HSD	0.0183	0.026	12 and 9 years
Starting Year of Analysis	One Way ANOVA/Tukey HSD	5e-05	0.317	
Ending Year of Analysis	One Way ANOVA/Tukey HSD	0.0323	0.002	2011 and 2008

The impact of inherent lake characteristics on tau scores differed (Table 6). Surface area and maximum depth were not significant factors in explaining the tau score. The year the analysis began also did not have an impact on the tau score. Initial TP concentration, latitude, longitude, months in analysis, total values in analysis, years in analysis, and ending year of analysis all had an impact on the tau score. The results of an one way ANOVA test indicated that not all factors in the categories; months in analysis, total values in analysis, years in analysis, and ending year of analysis, had the same impact on the tau score. Further investigation through a Tukey HSD test showed that for months in analysis, lakes which were analyzed with five months of data were significantly different from other lakes analyzed with 1, 2, 3, 4, 6, or 7 months of data. For total values in the analysis, lakes which were analyzed with twenty total values were significantly different from lakes analyzed with all other numbers of total values. For total years in analysis, lakes which were analyzed with nine years of data were significantly different from lakes which were analyzed with 12 years of data. For the ending year of analysis, lakes which were analyzed based on data ending in 2008 were significantly different from lakes which were analyzed based on data ending in 2011.

The results of a linear model showed that latitude and longitude were both significant explanatory variables of tau score. The R^2 value for linear regressions of latitude and longitude and tau score were not strong (0.0004 and 0.0585, respectively), indicating that although significant, a very small portion of the variability within tau scores can be explained by latitude and longitude. The results of a separate linear model also showed that the average initial TP concentration was a significant explanatory variable of tau score. Again, as was the case with latitude and longitude, the R^2 value of a linear regression of initial TP concentration and tau is not strong, 0.014, so only a small portion of the variability in tau score can be explained by the average initial TP concentration

To understand the potential impact of these factors on tau score, the factors were investigated within each lake group. At the level of the individual lake group, latitude, longitude, and average initial TP all continued to explain only a small portion of the variation in tau score (ranging from longitude in Non-Metro TP (MN) with an $R^2 = 0.03$ to average initial TP in Non-Metro TP (WI) with an $R^2 = 9.00x10^{-5}$). Additionally, when months, years, total values, and ending year of analysis were analyzed within each lake group, Tukey HSD tests found that the only values that were still significantly different from one another were the ending years 2008 and 2011 in the Metro TP lake group.

Landcover Analysis

The normalized difference in the concentrations of TP between 2010 and 2002 was plotted against the average percent lawn at the lake edge (Figure 9) and at 10 meters (Figure 10). According to a linear model, percent lawn at the lake edge and at 10m were both significant factors in explaining normalized differences in TP concentrations ($p<0.05$). The impact of lawn is most clear in the graph of the lawn at lake edge, however. Lakes with little to no lawn at the lake edge (<20%) did not show a pattern in reduction in normalized TP between 2002 and 2010. The relationship between percent lawn and normalized TP was strongest for lakes having between 20% and 60% lawn at the lake's edge. The R^2 value indicated that 9.5% of the variation in normalized TP concentrations in these lakes can be explained by lawn at the water's edge.

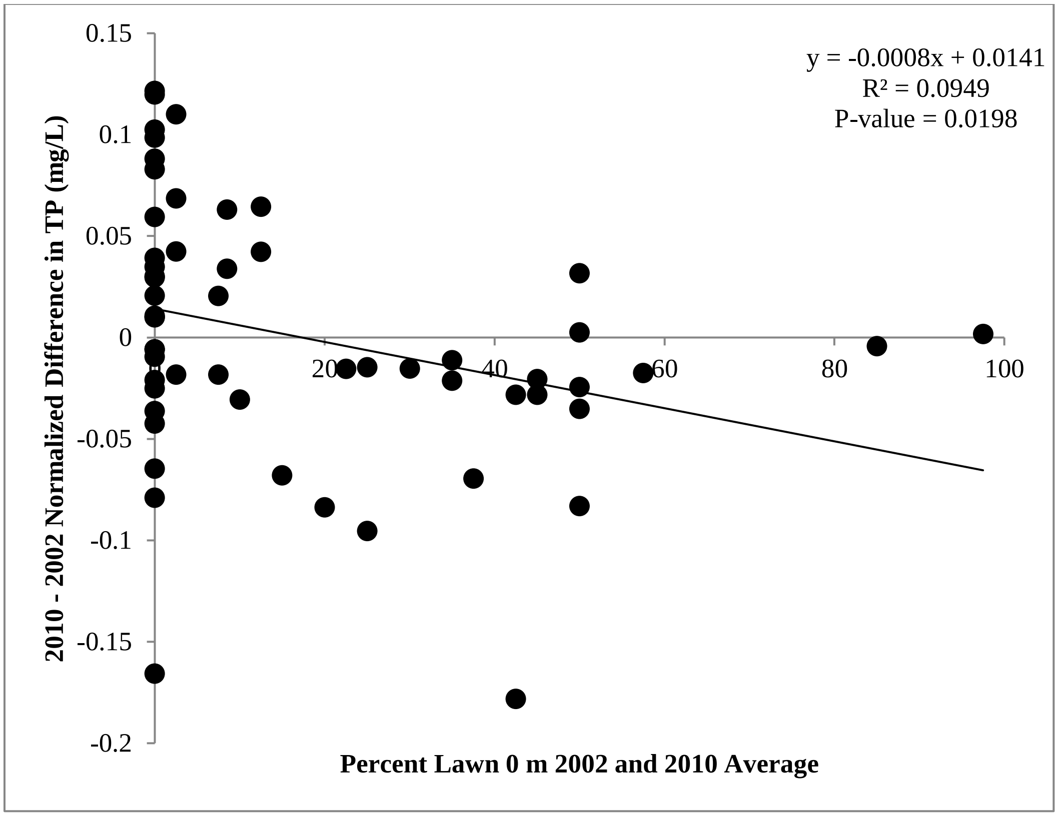


Figure 9. Scatter plot of the relationship between average lawn at the lake edge and the change in normalized lake TP concentration.

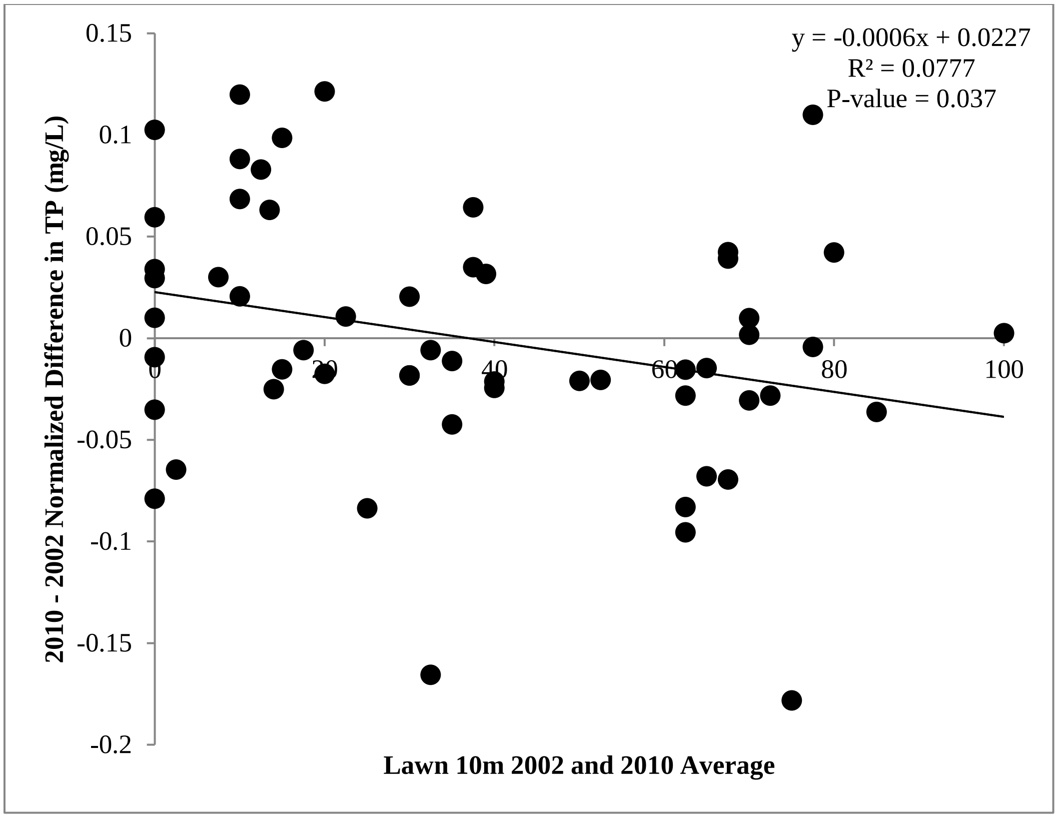


Figure 10. Scatterplot of the relationship between average lawn at 10m and the change in normalized lake TP concentration.

As a comparison, the same analysis was run for TDN. According to a linear model, percent lawn at the lake edge was not a significant factor in determining normalized TDN concentrations (p=0.29) (Figure 11).

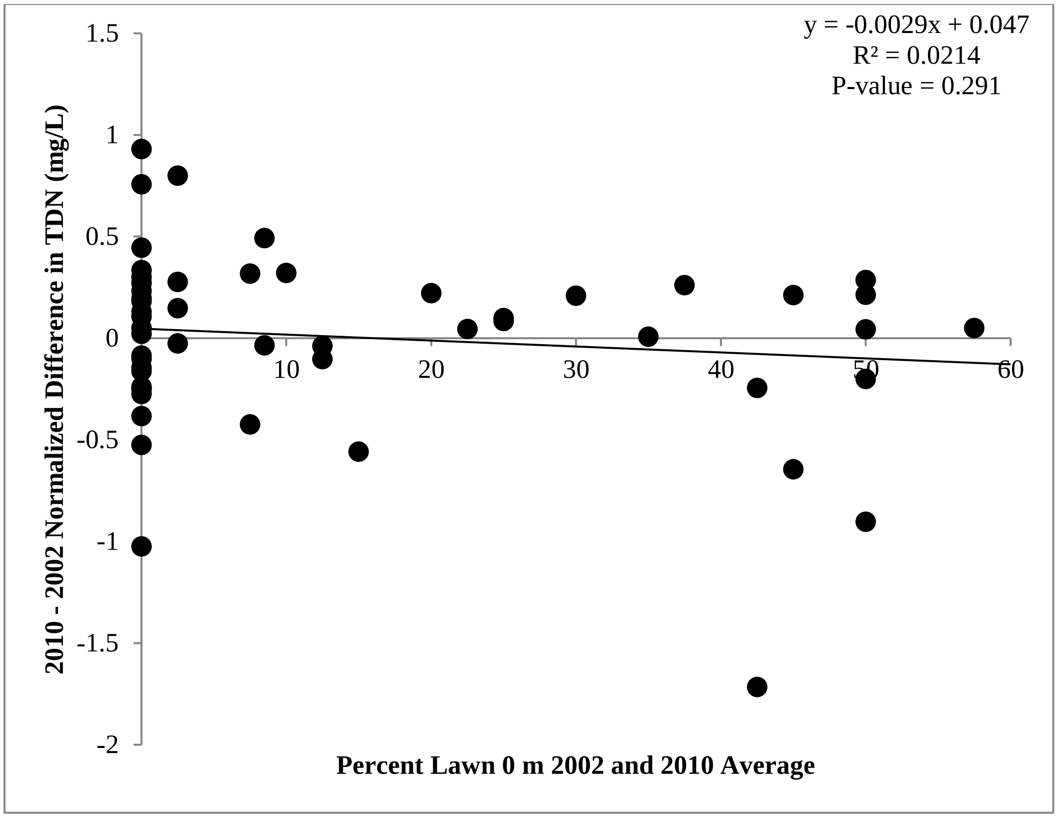


Figure 11. Scatter plot of the relationship between average percent lawn at the lake edge and the change in lake TDN concentration.

In this study, though lawn appeared to have an impact on phosphorus concentration, the evaluation of crop in the area surrounding the lake did not have the same effect (Table 7). The tau scores between lakes with some and no crop were not significantly different from one another when compared across the whole data set or within any of the lake groups.

Table 7. Median tau scores for "some crop" and "no crop" lakes across data sets.

	Number of lakes with Some Crop in area surrounding lake	Median tau score for lakes with Some Crop in area surrounding lake	Number of lakes with No Crop in area surrounding lake	Median tau score for lakes with No Crop in area surrounding lake
All Lakes	172	-0.054	261	-0.061
Metro TP	32	-0.139	119	-0.132
Non-Metro TP (MN)	101	-0.085	38	-0.080
Non-Metro TP (WI)	39	0.071	105	0.045

Discussion:

Prior to the Clean Water Act, the quality of surface waters in the United States was degraded. Since the passage of the act, reductions in point source pollution have improved the quality of our waterways on a case-by-case basis but it was not until the last twenty-five years when the more diffuse problem of non-point source pollution has been prioritized. Therefore, it has not been previously possible to determine if water quality is improving at a landscape scale from these efforts. In order to take a landscape scale perspective, trends in water quality, rather than absolute concentrations in nutrients is necessary. If current water quality only was assessed, the impacts of nutrient reductions might be masked. For example, as of 2012, there were 1,463 lakes listed on the Minnesota Impaired Waters List. Of these, 529 lakes were impaired for nutrient/eutrophication biological indicators (MPCA, 2012). The trend analysis performed in this study allows for investigation beyond the current condition of water quality to find evidence of whether lake water quality is improving or continuing to deteriorate. Because of the emphasis on non-point source pollution reductions in all areas, with more precise placement and timing of fertilizers, increasing buffer zones around waterways, improved tillage practices, green infrastructure to promote infiltration, street sweeping, neighborhood leaf clean-ups, reductions in lawn fertilizer, and stormwater management plans, the first hypothesis of this study was overall trends in water quality will be negative (lower phosphorus concentrations over time). Then, because of differences between urban and non-urban areas which would impact the implementation of these reduction strategies including the number of people and decision makers on the landscape, reasons for land-use change and frequency of landscape disturbance, and regulation of control measures, the second hypothesis was that urban lakes would demonstrate more decreases in phosphorus concentration than non-urban lakes. Both hypotheses were supported.

The results of this study are encouraging from a social policy standpoint; they indicate that in the 21st century water quality in many lakes is improving rather than deteriorating and that changes in water quality are not occurring universally which can help to narrow in on successful strategies for phosphorus control. However, there were still many lakes that have indications of positive trends in TP concentrations so the results should not be interpreted as though the issue of non-point source pollution has been solved. There is still a great deal of need for improvement. When separated into lake groups, the Metro TP lake group had more lakes with evidence of decreasing trends in TP concentration than the Non-Metro TP (All) lake group. There were also a greater number of significant tau scores found in the Metro TP lake group, indicating that there are differences in the changes in TP concentrations between Metro and Non-Metro areas. In the past, urbanization has been associated with declining water quality (Siver et al., 1996, Ramstack et al., 2004, Brezonik et al., 2007), with the U.S. EPA listing urban runoff as the third most important cause of lake deterioration in 1990 (U.S. EPA, 1990, Carpenter et al., 1998); however, this may need to be reconsidered as more lakes in the urban environment were found to have evidence of improvement as compared to the non-urban environment.

The results of the trend analysis in this study were supported by the visual interpretation of the yearly median difference from timeframe median TP concentration (Figure 5). In the Metro TP lake group the switch from more lakes with above timeframe median TP concentration to below timeframe median concentration occurred in 2006, this was shortly after the introduction of the ban on residential fertilizer use which went into effect in the Metro area in 2004. The Non-Metro TP (All) lake group did not experience this same unidirectional shift. Although, the phosphorus ban went into effect in 2005 for the non-metro areas of Minnesota and in 2010 for Wisconsin, it did not impact agriculture. Phosphorus fertilizer use in agriculture peaked in 1981 in the United States and has stabilized since so larger and larger quantities of phosphorus in the form of agricultural fertilizer are not being applied to the landscape (U.S. EPA, 2014). In 1997, however, a national soil test study found over 50% of soils tested in Wisconsin had more phosphorus than needed by their crops whereas only 25-50% of soils tested in Minnesota had more phosphorus than needed by their crops (Sharpley, 2001). When the Non-Metro TP (All) lake group was sub-divided, major differences were found between the Non-Metro TP (MN) and Non-Metro TP (WI) lake groups. A greater number of negative tau scores were found in the Non-Metro TP (MN) lake group; whereas, a greater number of positive tau scores were found in the Non-Metro TP (WI) lake group. It is not possible to tell if the implementation of the ban on residential fertilizer use at different times throughout the study had an impact on these MN versus WI lake groups results but it is possible.

Other studies have also found recent improvement in water quality. In a study conducted by the Minnesota Pollution Control Agency (MPCA), using the data from the Citizen Lake Monitoring Program (CLMP), water clarity trends, as measured by Secchi depth, in 1,270 lakes with at least eight years of data between 1972 and 2010 (MPCA, 2012) were analyzed. As with the current study of phosphorus concentrations, more increasing trends in clarity were also found, indicating improvements in water clarity throughout Minnesota over the study timeframe. To determine if differences in water clarity trends also existed between Metro and Non-Metro areas of Minnesota. I exported the CLMP data for the 1, 270 lakes, categorized the lakes by county, and then grouped them by Metro and Non-Metro. When this data set was compared as Metro vs. Non-Metro, of the 278 lakes in the Metro area that were analyzed, 106 lakes (38%) had an increasing trend, showing improvements in water clarity as measured by Secchi depth. The median increase in these 106 lakes was 0.25 m per decade. Of the 992 lakes in the Non-Metro area that were analyzed, 253 lakes (26%) had an increasing trend, showing improvements in water clarity as measured by Secchi depth. The median increase of these 253 lakes in the Non-Metro was 0.24 m per decade. In both the Metro and Non-Metro, the median increase was 0 m per decade across all lakes but more lakes were found with increasing trends than decreasing trends (106 increasing and 52 decreasing in the Metro and 253 increasing and 102 decreasing in the Non-Metro). Therefore, as with TP concentrations in the Metro and Non-Metro, this study showed that though there were improvements in water clarity overall, there were a higher percentage of lakes with improvements in the Metro than non-Metro. These trends in Secchi depth and TP concentrations may have followed similar patterns because there is a strong relationship between Secchi depth and phosphorus concentration (Carlson, 1977). This relationship is especially strong in

Minnesota lakes where water clarity is more often related to algal abundance than suspended solids or coloring due to dissolved organic matter (Brezonik et al., 2007). Unfortunately, the year-by-year variation is median Secchi depth versus timeframe median was not investigated in this study to determine if the shifts in depth happened at similar times as the shifts in TP concentration.

A study by Lottig et al. (2014) which compiled citizen collected Secchi depth information found the same pattern in lake clarity trends in Minnesota as the CLMP analysis – where trends were present, there were more trends in increasing clarity then decreasing clarity. Their study went beyond Minnesota; however, and found that in Wisconsin, increasing trends in clarity were not found as often or in as large of magnitude as in Minnesota (average increase of 1.59% annually in Minnesota, average increase of .88% annually in Wisconsin). This was contrary to the findings of Olmanson et al. (2008) who did not find statewide changes in water clarity in Minnesota and of Peckham and Lillesand (2006) who found that water clarity was improving in Wisconsin (increase in average clarity of 0.76 m between 1980 and 2000).

Olmanson et al. (2008) found that there was no change in water clarity in Minnesota lakes from 1985 through 2005 at the statewide level. For more than 10,500 lakes, Olmanson et al. (2008) used remote sensing data to estimate water clarity, calibrated the findings with field data, and then determined if the water clarity had increased or decreased from the start to the end of the study. This method, because it was only looking at one data point at approximately five year intervals, may not have been sensitive enough to pick up on trends, or have gone far enough into the future to see changes in water clarity, for example, major changes in TP concentration in the current study were found after 2005. Additionally, the lakes selected by Olmanson had to be at least 8 ha. This criterion would have excluded 22 lakes from the present study.

Although methods varied between the studies by Olmanson et al. (2008) and the MPCA (2012), the difference in results may also be due to lake selection. An analysis of water clarity in a subset of randomly selected (probability based selection) and volunteer selected (non-probability based selection) lakes in the Northeastern United States found that the non-probability based selected lakes were on average larger and more clear than the probability based selected lakes (Peterson et al., 1999). According to Olmanson et al. (2008) this same phenomenon held true between the CLMP and their study. Lakes monitored for clarity through CLMP have a mean and median size of 333 and 75 ha, respectively; whereas lakes monitored with remote sensing for clarity have a mean and median size of 99 and 18 ha, respectively. In the current study, bias may be present due to the non-probability selection of lakes, as well. Data from existing monitoring programs was used, therefore, many of the lakes selected are likely environmentally, recreationally, or economically important. The Minnesota lakes studied have a mean and median size of 297 and 119 ha, respectively. Overall, there are over 10,000 lakes in Minnesota. Data from 290 lakes was obtained and met the minimum data requirements for this study in Minnesota. Therefore, any conclusions drawn from this study are based on the trend results from less than 3% of Minnesota lakes. It would have been preferable to use data from randomly selected lakes and lakes analyzed by one method at one laboratory (Omernik et al., 1988); however, that was not feasible in completing this type of study

Temperature and precipitation over the course of the study period may have played a factor in the evidence for trends found. Other studies have found substantial impacts from climatic conditions on lake clarity (Brezonik et al., 2007). In the present study, there was no evidence of trend found in either precipitation or temperature found during the study period and no pattern in the average difference from average, indicating that lake trends were not simply following climatic conditions. There was no correlation found between the median difference from median each year or the average difference from average for all lakes or any lake group with temperature or precipitation. In this study, temperature and precipitation were measured at the St. Paul, MN airport in order to understand general changes in weather and climate patterns during the timeframe of the study, differences in the local temperature and precipitation experienced at each lake may have had an influence on the evidence of trends found but these are masked by the methods used.

Peckham and Lillesand (2006) also found evidence that lake morphometry impacted lake clarity, with the smallest lakes having the highest clarity. In the present study, although there were differences between the lake groups with regards to mean size and depth of lakes, neither maximum depth nor surface area was a significant factor in explaining the tau scores.

Aside from maximum depth and surface area, other differences in inherent characteristics existed between lake groups. The finding that months, years, and total values in analysis were not significant within individual lake groups decreases their overall impact. Whereas, the continued impact of ending year in analysis; with 2008 and 2011 being significantly different from one another within all lake groups and separated lake groups, indicates ending year may be a confounding factor in the analysis. There were only 26 lakes (16 of which were in WI) that ended in 2008 as compared to 328 lakes that ended in 2011; therefore, sample size may contribute to this finding. If difference in year is a factor, lakes with analysis ending in 2011 had more negative tau values than lakes with 2008 as the end year in analysis. This may be because there was more time to detect evidence of a trend. Longitude, latitude, and average initial TP concentration also differed between the lake groups but were found to explain only a small portion of the variation. Although possibly confounding, longitude, latitude, and average initial TP are likely not the main drivers in the differences found in tau scores between lake groups.

Synchrony was found to be low in all lake groups. Though overall correlations were not significant, all lake groups aside from the Non-Metro TP (All) and Non-Metro TP (WI) were more synchronous within their group than with the other lake groups. High synchrony is generated when lakes respond similarly to a common driver (Sorrano et al., 1999). Hence, though small, there may have been some regional control impacting changing nutrient concentrations in lakes. Cheruvelil et al. (2013), found a proportion of the control of phosphorus was at the regional level and suggested both regional and local controls be considered in broad scale research. Synchrony for TP was lower than for TKN. Lower synchrony in particulate phosphorus was found by Kling et al. (2000) in a study of lakes in Alaska, whereas synchrony among lakes for total dissolved nitrogen and soluble reactive phosphorus was higher. Magnuson et al. (1990) found low synchrony in TDP and other biologically active solutes, no measures of nitrogen were included in their study.

Within the Metro lake group, both the trend analyses done on TKN and the N:P ratio showed evidence that TKN concentrations and N:P ratios in Metro lakes are increasing. TKN is the sum of ammonia, ammonium, and organic nitrogen (O'Dell, 1993). Primary sources of ammonia emissions are from domestic animals and synthetic fertilizers (Bouwman et al., 1997). Ammonia and ammonium can be deposited onto freshwater systems via both wet and dry deposition (Asman et al., 1998). These forms can also be converted to nitrate. Increases in N:P ratios can change the limiting nutrients in freshwater systems. At lower N:P ratios, systems are nitrogen limited but at higher N:P ratios they shift to phosphorus limitations (Elser et al., 2009 and Guildford and Hecky, 2000, Lewis and Wurtsbaugh, 2008). Changes in nutrient limitations have impacts on phytoplankton diversity (Interlandi and Kilham, 2001) and food webs (Sterner and Elser, 2002). Globally, N:P ratios have increased (Peñuelas et al., 2013) because of the large increases in available nitrogen due to human actions (Vitousek et al., 1997), and the limited absolute supply of phosphorus. At regional scales: N:P ratios are likely much more dependent on environmental regulations. In China, in areas heavily impacted by human influence, concentrations of nitrogen and phosphorus in freshwater have both increased but the ratio of nitrogen to phosphorus decreased (Yan et al., 2016). Yan et al. (2016) concluded their findings were due to the increased contributions to freshwater ecosystems of fertilizer and untreated sewage because of poor regulation and increased growth. China and the United States are at very different places in their environmental protections, Yan et al. (2016) also looked at nitrogen, phosphorus, and N:P ratios in euro-America both pre and post 1990. In support of the findings in this current paper, they found that the N:P ratio increased and phosphorus concentrations decreased post 1990. However, they also found an associated decrease in nitrogen concentrations. In the current study, N:P ratios help to verify that increasing TKN and decreasing TP are being experienced at the individual lake level throughout the Metro area. It appears that the negative tau scores found in TP are due to factors which control phosphorus specifically as opposed to general nutrient control factors.

Unlike nitrogen, phosphorus is not volatile and only exists in the atmosphere when adsorbed on particulate matter (Pierrou, 1976). Therefore, its primary modes of transport are in dissolved, organic, or particulate forms or adsorbed to a particle (organic or inorganic) (Keller, 2000). Related to this, Soranno et al. (2009) found that local landscape variables are important for determining lake phosphorus concentrations and that land use/cover is a strong determinant of lake phosphorus. Moore et al. (2003) found that lakes at the urban/rural fringe which were undeveloped had lower epilimnetic and hypolimnetic concentrations of phosphours than lakes with septic or sewered houses at the shoreline. Land-use at the water's edge and near shore have an important impact on phosphorus concentrations. This is supported by the results of the present study's lawn analysis demonstrating that between 2002 and 2010, lakes with the most lawn in the immediate vicinity (0m and 10m) had a decrease in TP but no associated decrease in TDN. In the crop study, no difference was found between lakes with or without crops in the surrounding area. This is not surprising given the importance of lawn directly surrounding a lake and the variety of covers which were binned together in this rough look at the impact of crops For example, lakes surrounded by crops and lakes surrounded by a ring of homes and then crops were both binned as "some crops". Lakes surrounded by urban areas and lakes surrounded by forest and wetlands were both binned as "no crops". Further study with more precise landcover classification may find more impact of crops.

The residential lawn phosphorus use ban that went into effect for the TCMA in 2004 and the state of Minnesota in 2005 may be having a detectable impact. According to a report by the Minnesota Department of Agriculture in 2007, the ban was overall successful at decreasing the use of phosphorous based fertilizers. The report stated that as of 2006, phosphorous free fertilizer comprised 82% of lawn fertilizer used by weight. Stores increased availability, with 97% of stores surveyed offering phosphorous free fertilizer options; thereby making increased use possible (MDA, 2007). The impact of the state ban has not been officially evaluated with respect to improvement in water quality (MDA, 2007). But other studies have shown the positive impacts of residential lawn fertilizer bans and the use of reduced phosphorus fertilizer on water quality and in-water phosphorus concentrations; paired-watershed study (Barten et al., 2006), modeling urban watersheds (Waschbusch et al., 1999), test plot run-off study (Bierman et al., 2010), and pre-post ban analysis in Michigan (Lehman et al., 2009, Lehman et al., 2011).

The fertilizer ban is not the only non-point source reduction technique occurring on the landscape. In the TCMA, there has been a push to inform the public about water quality and to either mandate or encourage reductions in the amount of phosphorus being applied to the landscape, the amount entering into the water bodies, and the amount of runoff entering into water bodies. Street sweeping, which can help reduce the total suspended solids and phosphorus carried in runoff to receiving water bodies, has been implemented at regular intervals for the purpose of water quality protection in some cities (Barten et al., 2006). Neighborhoods, such as the Como neighborhood in St. Paul, MN, implemented a fall street clean-up to remove organic debris, thereby preventing nutrients from washing into Como Lake. In 2012, the Como neighborhood removed 1,303 bags of leaf litter (CLNN, 2012). To reduce stormwater runoff at new and redevelopment sites, the city of Minneapolis requires on-site stormwater management at sites of 1-acre or more. As a result of this ordinance, more than 370 sites in Minneapolis have stormwater management plans including an estimated 1,216 rain gardens as of 2010 (Garrison and Hobbs, 2011).

The evidence of trends found in this study are consistent with the trends expected from reduced non-point source TP contributions to lakes. Humans may in fact be having positive impacts on the environment. Because non-point sources are so diffuse, control is largely the responsibility of individuals; therefore, successful elimination of non-point sources relies on an informed and conscientious public. Minnesotans have expressed their concern for the protection of water resources at the polls with the passage of the Clean Water Legacy Act in 2006 (Clean Water Legacy Act of 2006) and the Clean Water, Land, and Legacy Constitutional Amendment in 2008 (MDNR, 2011). It would be expected that if there are improving trends in water quality, these trends would occur in areas with the largest human populations where the actions of individuals can have the most impact. This is consistent with the results of the present study which found evidence of more decreasing trends in TP concentrations and more significant evidence of trends in Metro areas as compared to Non-Metro areas.

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Appendix

Table 8. Individual lake information for all lakes analyzed for Total Phosphorus trends.

Lake ID	Lake Group	County	Latitude	Longitude	Months	Years	Total Values	Initial TP (mg/L)	Surface Area (hectares)	Maximum Depth (m)	Tau Value Description
02-0003-00	Metro	Anoka	45.124	-93.041	5	2000-2011	60	0.020	122.40	6.40	-0.16
02-0004-00	Metro	Anoka	45.179	-93.058	6	2000-2011	72	0.169	234.61	5.49	-0.08
02-0005-00	Metro	Anoka	45.176	-93.091	2	2001-2011	22	0.308	358.83	2.13	-0.30
02-0022-00	Metro	Anoka	45.368	-93.096	6	2003-2011	54	0.032	27.01	6.71	-0.03
02-0045-00	Metro	Anoka	45.139	-93.153	5	2000-2011	60	0.060	23.53	7.62	-0.23
02-0654-00	Metro	Anoka	45.140	-93.300	7	2001-2011	77	0.022	11.58	10.97	0.01
10-0002-00	Metro	Carver	44.836	-93.522	6	2002-2011	60	0.048	119.97	14.94	-0.13
10-0005-00	Metro	Carver	44.789	-93.590	7	2000-2011	84	0.029	4.05	17.37	-0.11
10-0006-00	Metro	Carver	44.878	-93.531	2	2003-2011	18	0.100	99.28	8.84	0.01
10-0010-00	Metro	Carver	44.874	-93.635	5	2001-2011	55	0.032	9.88	24.99	-0.16
10-0015-00	Metro	Carver	44.886	-93.633	4	2000-2011	48	0.040	42.48	10.36	-0.07
10-0018-00	Metro	Carver	44.876	-93.646	4	2002-2011	40	0.036	42.53	14.94	-0.16
10-0019-00	Metro	Carver	44.837	-93.639	6	2000-2011	72	0.045	67.41	20.12	0.02
10-0029-00	Metro	Carver	44.786	-93.742	6	2000-2011	72	0.410	57.62	4.27	-0.27
10-0041-00	Metro	Carver	44.883	-93.667	5	2000-2011	60	0.028	94.40	17.68	-0.05
10-0044-01	Metro	Carver	44.868	-93.694	6	2003-2011	54	0.033	115.15	25.60	-0.03
10-0052-00	Metro	Carver	44.839	-93.745	5	2000-2011	60	0.075	37.43	10.97	-0.21
10-0059-00	Metro	Carver	44.872	-93.782	5	2000-2011	60	0.032	1247.52	11.28	-0.02

10-0088-00	Metro	Carver	44.816	-93.876	6	2002-2011	60	0.100	90.27	5.49	0.38
10-0089-00	Metro	Carver	44.891	-93.844	6	2001-2011	66	0.123	159.57	3.05	-0.12
10-0095-00	Metro	Carver	44.930	-93.820	7	2002-2011	70	0.168	175.30	3.66	0.38
10-0121-00	Metro	Carver	44.809	-93.934	6	2000-2011	72	0.236	74.20	4.27	-0.18
10-0225-00	Metro	Carver	44.794	-93.600	6	2002-2011	60	0.015	6.89	13.11	0.10
10-0226-00	Metro	Carver	44.791	-93.604	7	2002-2011	70	0.021	3.44	7.01	-0.01
19-0021-00	Metro	Dakota	44.748	-93.248	5	2001-2011	55	0.091	36.13	3.51	-0.27
19-0022-00	Metro	Dakota	44.756	-93.174	6	2003-2011	54	0.371	15.80		-0.37
19-0023-00	Metro	Dakota	44.759	-93.164	6	2000-2011	72	0.171	27.14	3.05	-0.34
19-0024-00	Metro	Dakota	44.741	-93.266	7	2000-2010	77	0.043	3.65	4.27	0.05
19-0025-00	Metro	Dakota	44.727	-93.252	5	2000-2011	60	0.093	20.66	2.13	-0.11
19-0026-01	Metro	Dakota	44.666	-93.281	7	2000-2010	77	0.020	214.77	6.40	0.29
19-0027-00	Metro	Dakota	44.723	-93.266	7	2000-2011	84	0.048	116.90	11.28	-0.14
19-0028-00	Metro	Dakota	44.735	-93.277	2	2001-2011	22	0.032	7.29		-0.32
19-0029-00	Metro	Dakota	44.712	-93.288	5	2000-2010	55	0.082	8.91	4.27	-0.46
19-0030-00	Metro	Dakota	44.707	-93.299	7	2000-2010	77	0.018	30.38		-0.20
19-0031-00	Metro	Dakota	44.701	-93.309	6	2003-2011	54	0.044	95.28	10.06	-0.39
19-0033-00	Metro	Dakota	44.739	-93.297	4	2000-2011	48	0.052	11.34		-0.25
19-0057-00	Metro	Dakota	44.822	-93.163	5	2000-2008	45	0.049	12.11	10.21	0.41
19-0063-00	Metro	Dakota	44.798	-93.125	5	2000-2010	55	0.078	4.67	3.66	-0.20
19-0095-00	Metro	Dakota	44.883	-93.054	4	2000-2008	36	0.072	1.62		0.30
19-0348-00	Metro	Dakota	44.715	-93.209	7	2000-2010	77	0.049	2.84	3.35	0.31
19-0446-00	Metro	Dakota	44.721	-93.245	6	2002-2011	60	0.008	22.28	9.75	0.05
27-0014-00	Metro	Hennepin	44.942	-93.257	6	2000-2010	66	0.144	4.60	6.71	-0.27
27-0016-00	Metro	Hennepin	44.922	-93.305	6	2000-2010	66	0.030	138.19	26.52	0.23

27-0018-00	Metro	Hennepin	44.921	-93.236	6	2000-2010	66	0.079	21.44	10.06	0.03
27-0019-00	Metro	Hennepin	44.908	-93.242	7	2000-2010	77	0.065	81.50	10.06	-0.11
27-0022-00	Metro	Hennepin	44.901	-93.269	7	2000-2010	77	0.148	46.58	1.77	0.09
27-0031-00	Metro	Hennepin	44.941	-93.312	6	2000-2010	66	0.024	169.86	24.99	0.01
27-0035-01	Metro	Hennepin	44.993	-93.339	5	2000-2011	60	0.046	26.73	8.53	0.07
27-0037-00	Metro	Hennepin	44.982	-93.323	7	2000-2010	77	0.057	16.15	7.62	-0.40
27-0039-00	Metro	Hennepin	44.960	-93.321	6	2000-2010	66	0.020	66.33	15.54	0.30
27-0040-00	Metro	Hennepin	44.954	-93.309	6	2000-2010	66	0.032	45.32	9.45	-0.06
27-0070-00	Metro	Hennepin	44.859	-93.498	6	2003-2011	54	0.071	46.14	5.79	-0.40
27-0102-00	Metro	Hennepin	45.040	-93.433	1	2000-2011	12	0.054	14.99	7.62	-0.53
27-0104-00	Metro	Hennepin	45.007	-93.418	6	2000-2011	72	0.053	358.83	14.94	0.18
27-0107-00	Metro	Hennepin	44.994	-93.472	6	2000-2010	66	0.023	40.57	11.28	0.08
27-0117-00	Metro	Hennepin	45.110	-93.502	6	2000-2011	72	0.038	61.60	17.37	-0.18
27-0118-00	Metro	Hennepin	45.093	-93.463	6	2000-2011	72	0.057	96.28	14.63	0.08
27-0133-02	Metro	Hennepin	44.934	-93.590	5	2001-2009	45	0.023	2383.02	10.36	-0.09
27-0133-04	Metro	Hennepin	44.934	-93.590	5	2001-2009	45	0.024	65.21	25.60	-0.17
27-0133-05	Metro	Hennepin	44.934	-93.590	6	2000-2011	72	0.030	1698.17	25.30	-0.17
27-0133-09	Metro	Hennepin	44.934	-93.590	7	2002-2011	70	0.087	255.15	9.14	-0.23
27-0133-10	Metro	Hennepin	44.934	-93.590	6	2001-2011	66	0.027	321.98	21.34	-0.29
27-0133-11	Metro	Hennepin	44.934	-93.590	6	2001-2009	54	0.036	121.91	9.14	-0.08
27-0133-12	Metro	Hennepin	44.934	-93.590	6	2001-2009	54	0.058	78.17	27.74	-0.17
27-0133-13	Metro	Hennepin	44.934	-93.590	6	2001-2009	54	0.034	153.90	17.68	-0.19
27-0133-14	Metro	Hennepin	44.934	-93.590	6	2001-2011	66	0.071	324.41	27.74	-0.30
27-0133-15	Metro	Hennepin	44.934	-93.590	6	2001-2011	66	0.126	118.67	6.71	-0.37
27-0138-00	Metro	Hennepin	44.965	-93.536	5	2001-2009	45	0.065	3.65	19.20	-0.10

27-0139-00	Metro	Hennepin	44.957	-93.633	5	2001-2011	55	0.077	34.02	12.80	-0.30
27-0149-00	Metro	Hennepin	45.036	-93.619	6	2003-2011	54	0.100	32.36	11.58	0.29
27-0176-00	Metro	Hennepin	45.027	-93.644	5	2000-2011	60	0.049	336.96	17.68	0.05
27-0627-00	Metro	Hennepin	45.028	-93.394	6	2000-2011	72	0.144	6.08		0.08
27-0645-00	Metro	Hennepin			4	2000-2009	40	0.747	3.65		-0.12
27-0655-02	Metro	Hennepin	44.969	-93.284	6	2000-2010	66	0.147	2.09	4.88	-0.27
27-0656-00	Metro	Hennepin	44.959	-93.337	6	2002-2011	60	0.150	5.27		-0.04
27-0711-00	Metro	Hennepin	44.970	-93.389	4	2000-2011	48	0.029	45.77		-0.13
27-1118-00	Metro	Hennepin	45.034	-93.292	7	2000-2010	77	0.058	0.86	1.22	-0.30
62-0001-00	Metro	Ramsey	45.027	-93.988	5	2000-2011	60	0.025	29.16	5.49	0.29
62-0002-00	Metro	Ramsey	45.115	-93.017	5	2000-2011	60	0.090	423.88	10.97	-0.28
62-0006-00	Metro	Ramsey	45.024	-93.058	5	2000-2011	60	0.098	29.97	2.74	-0.39
62-0007-00	Metro	Ramsey	45.021	-93.071	5	2000-2011	60	0.033	95.18	12.50	-0.19
62-0010-02	Metro	Ramsey	45.008	-93.061	5	2000-2011	60	0.057	29.16	2.44	-0.05
62-0011-00	Metro	Ramsey	44.995	-93.036	5	2000-2011	60	0.140	8.69	2.44	-0.50
62-0012-00	Metro	Ramsey	44.994	-93.063	5	2000-2011	60	0.044	12.15		-0.30
62-0013-00	Metro	Ramsey	44.988	-93.054	5	2000-2011	60	0.028	80.06	27.74	-0.09
62-0016-00	Metro	Ramsey	44.973	-93.005	5	2000-2011	60	0.084	33.54	3.35	-0.22
62-0047-00	Metro	Ramsey	44.904	-93.151	4	2002-2011	40	0.094	19.44	5.79	0.08
62-0048-00	Metro	Ramsey	45.018	-93.141	5	2000-2011	60	0.162	11.52	2.74	-0.41
62-0054-00	Metro	Ramsey	44.998	-93.113	5	2000-2011	60	0.071	29.67	17.37	-0.54
62-0055-00	Metro	Ramsey	44.979	-93.141	5	2000-2011	60	0.124	27.72	4.72	-0.22
62-0056-00	Metro	Ramsey	45.038	-93.120	4	2000-2011	48	0.028	151.86	11.28	-0.14
62-0057-00	Metro	Ramsey	45.036	-93.153	5	2000-2011	60	0.024	47.05	13.41	0.01
62-0061-00	Metro	Ramsey	45.099	-93.138	5	2000-2011	60	0.022	182.25	8.53	-0.02

62-0067-00	Metro	Ramsey	45.073	-93.201	4	2000-2011	48	0.082	69.91	9.14	-0.37
62-0069-00	Metro	Ramsey	45.068	-93.208	3	2000-2008	27	0.070	14.18	4.88	0.09
62-0071-00	Metro	Ramsey	45.060	-93.168	5	2000-2011	60	0.056	29.97	3.96	-0.13
62-0073-00	Metro	Ramsey	45.073	-93.125	5	2000-2011	60	0.024	63.28	9.14	-0.13
62-0075-01	Metro	Ramsey	45.054	-93.136	5	2000-2011	60	0.081		3.35	-0.15
62-0075-02	Metro	Ramsey	45.058	-93.134	5	2000-2011	60	0.101	7.13	3.35	-0.44
62-0078-00	Metro	Ramsey	45.044	-93.170	5	2000-2011	60	0.026	85.82	13.11	-0.09
62-0082-00	Metro	Ramsey	45.045	-93.116	5	2000-2011	60	0.023	18.79	20.12	-0.11
62-0083-00	Metro	Ramsey	45.044	-93.226	4	2000-2011	48	0.057		14.33	-0.31
62-0231-00	Metro	Ramsey	44.976	-93.123	5	2003-2011	45	0.045	3.24	8.53	-0.34
70-0018-00	Metro	Scott	44.727	-93.391	6	2002-2011	60	0.020	10.94		-0.23
70-0022-00	Metro	Scott	44.693	-93.391	5	2001-2011	55	0.105	57.92	2.74	-0.38
70-0026-00	Metro	Scott	44.735	-93.415	5	2000-2011	60	0.028	387.44	18.29	-0.31
70-0054-00	Metro	Scott	44.701	-93.473	7	2003-2011	63	0.112	239.70	11.28	-0.26
70-0069-00	Metro	Scott	44.652	-93.460	5	2000-2011	60	0.051	70.04	8.53	-0.33
70-0072-00	Metro	Scott	44.715	-93.444	5	2002-2011	50	0.109	156.43	15.24	-0.36
70-0074-00	Metro	Scott	44.774	-93.444	5	2002-2010	45	0.142	90.32		0.21
70-0079-00	Metro	Scott	44.737	-93.468	3	2000-2011	36	0.163	24.71		-0.34
70-0085-00	Metro	Scott	44.720	-93.458	3	2001-2011	33	0.146	8.10		-0.23
82-0009-00	Metro	Washington	45.019	-92.852	5	2001-2011	55	0.035	14.18	8.53	0.04
82-0010-00	Metro	Washington	45.017	-92.844	5	2001-2009	45	0.048	16.20		0.15
82-0015-02	Metro	Washington	45.113	-92.837	6	2000-2010	66	0.104		5.18	0.16
82-0019-00	Metro	Washington	45.078	-92.848	6	2003-2011	54	0.057	21.47		0.00
82-0020-00	Metro	Washington	45.062	-92.829	6	2000-2011	72	0.039	27.95	3.81	0.04
82-0021-00	Metro	Washington	45.048	-92.853	6	2000-2011	72	0.152	44.55	6.71	-0.54

82-0023-00	Metro	Washington	45.048	-92.824	5	2000-2010	55	0.060	17.25	15.54	-0.25
82-0030-00	Metro	Washington	45.191	-92.840	5	2000-2011	60	0.042	28.71	3.66	-0.31
82-0034-00	Metro	Washington	45.165	-92.832	6	2000-2011	72	0.043	13.24	8.23	-0.18
82-0049-00	Metro	Washington	45.135	-92.809	1	2000-2010	11	0.020	185.10	20.12	-0.21
82-0052-02	Metro	Washington	45.224	-92.832	6	2000-2011	72	0.108	728.67	18.29	-0.25
82-0054-00	Metro	Washington	45.286	-92.860	4	2001-2011	44	0.046	89.69	9.14	-0.43
82-0064-00	Metro	Washington	45.239	-92.844	6	2001-2011	66	0.089	19.44	0.61	-0.24
82-0065-00	Metro	Washington	45.234	-92.814	5	2003-2011	45	0.078	22.68		-0.44
82-0067-00	Metro	Washington	45.230	-92.805	5	2002-2011	50	0.051	18.23	5.49	-0.07
82-0068-00	Metro	Washington	45.227	-92.820	6	2001-2011	66	0.058	16.61	2.13	-0.12
82-0077-00	Metro	Washington	45.133	-92.893	6	2000-2011	72	0.088	17.82		0.19
82-0087-00	Metro	Washington	44.806	-92.902	5	2000-2011	60	0.083	7.87	4.88	-0.18
82-0089-00	Metro	Washington	44.938	-92.899	6	2000-2011	72	0.111	14.58	2.44	0.12
82-0090-00	Metro	Washington	44.934	-92.917	5	2000-2011	60	0.093	13.37		-0.21
82-0092-00	Metro	Washington	44.926	-92.900	7	2003-2011	63	0.048	23.58	12.50	0.01
82-0094-00	Metro	Washington	44.907	-92.910	2	2000-2011	24	0.103	27.89	3.35	-0.20
82-0097-00	Metro	Washington	44.888	-92.970	3	2000-2011	36	0.078	17.01	3.05	0.20
82-0101-00	Metro	Washington	45.023	-92.940	5	2003-2011	45	0.025	63.61	7.32	0.20
82-0103-00	Metro	Washington	45.017	-92.944	5	2003-2011	45	0.019	35.29	4.57	0.01
82-0110-00	Metro	Washington	44.982	-92.866	1	2001-2009	9	0.142	13.37		-0.06
82-0115-00	Metro	Washington	44.952	-92.981	5	2000-2008	45	0.036	30.13	14.02	-0.27
82-0116-00	Metro	Washington	44.964	-92.939	6	2000-2011	72	0.105			-0.20
82-0116-02	Metro	Washington	44.963	-92.939	6	2000-2010	66	0.105			-0.13
82-0122-00	Metro	Washington	45.101	-92.954	1	2000-2011	12	0.033	48.60	9.45	-0.42
82-0130-00	Metro	Washington	45.080	-92.951	4	2003-2011	36	0.024	19.44	7.62	-0.23

82-0133-00	Metro	Washington	45.051	-92.911	6	2001-2011	66	0.031	6.08		-0.20
82-0153-00	Metro	Washington	45.133	-92.942	4	2000-2011	48	0.025	50.22	5.18	0.00
82-0159-00	Metro	Washington	45.271	-92.948	6	2000-2010	66	0.043	919.71	11.28	-0.04
82-0159-01	Metro	Washington	45.271	-92.948	6	2000-2011	72	0.043	919.71	11.28	0.00
82-0167-00	Metro	Washington	45.076	-92.984	5	2000-2011	60	0.009	983.20	25.30	0.21
82-0313-00	Metro	Washington	45.016	-92.866	3	2002-2010	27	0.038	4.46		0.17
82-0334-00	Metro	Washington	45.095	-92.891	6	2000-2011	72	0.068	4.05		-0.01
82-0368-00	Metro	Washington	45.033	-92.909	6	2002-2011	60	0.086	1.22		0.06
03-0358-00	Non-Metro (MN)	Becker	46.780	-95.909	3	2000-2011	36	0.016	54.68	7.32	-0.36
03-0359-00	Non-Metro (MN)	Becker	46.771	-95.897	3	2000-2010	33	0.034	515.52	15.24	-0.11
03-0360-00	Non-Metro (MN)	Becker	46.782	-95.878	3	2000-2010	33	0.032	27.18	5.49	-0.17
03-0366-00	Non-Metro (MN)	Becker	46.759	-95.827	2	2000-2008	18	0.028	108.95	2.13	-0.08
03-0374-01	Non-Metro (MN)	Becker	46.735	-95.838	3	2000-2009	30	0.022	65.21	9.14	-0.16
03-0381-00	Non-Metro (MN)	Becker	46.788	-95.821	3	2000-2011	36	0.021	1242.18	27.13	-0.23
03-0382-00	Non-Metro (MN)	Becker	46.803	-95.882	2	2000-2010	22	0.057	98.01		-0.17
03-0383-00	Non-Metro (MN)	Becker	46.821	-95.894	2	2000-2011	24	0.018	165.54	18.59	-0.13
03-0386-00	Non-Metro (MN)	Becker	46.875	-95.834	1	2000-2011	12	0.023	86.78	10.36	0.34
03-0387-01	Non-Metro (MN)	Becker	46.875	-95.857	2	2000-2011	24	0.042	477.03	10.36	0.00

03-0387-02	Non-Metro (MN)	Becker	46.875	-95.857	2	2000-2009	20	0.014	477.03	10.36	0.07
03-0400-00	Non-Metro (MN)	Becker	46.841	-95.883	3	2000-2009	30	0.029	161.19		-0.45
03-0475-00	Non-Metro (MN)	Becker	46.742	-95.894	3	2000-2010	33	0.023	749.30	11.28	-0.19
03-0486-00	Non-Metro (MN)	Becker	46.775	-95.939	3	2000-2011	36	0.023	108.52	16.46	0.01
03-0503-00	Non-Metro (MN)	Becker	46.738	-95.968	4	2003-2011	36	0.024	149.83	9.14	-0.48
03-0576-00	Non-Metro (MN)	Becker	46.771	96.060	4	2003-2011	36	0.019	1481.11	22.86	-0.24
03-0582-00	Non-Metro (MN)	Becker	46.734	-96.099	3	2000-2011	36	0.025	255.11	6.10	0.10
13-0053-00	Non-Metro (MN)	Chisago	45.320	-92.947	5	2000-2010	55	0.043	88.22	14.33	-0.22
18-0090-00	Non-Metro (MN)	Crow Wing	46.483	-93.920	4	2003-2011	36	0.018	446.88	19.81	-0.13
18-0251-01	Non-Metro (MN)	Crow Wing	46.579	-94.110	5	2003-2011	45	0.015	373.42	17.07	0.00
18-0251-02	Non-Metro (MN)	Crow Wing	46.586	-94.122	5	2003-2011	45	0.015	373.42	17.07	-0.04
18-0320-01	Non-Metro (MN)	Crow Wing	46.390	-94.185	5	2000-2011	60	0.007	149.45	13.72	-0.10
18-0376-00	Non-Metro (MN)	Crow Wing	46.567	-94.257	4	2000-2009	40	0.015	175.99	12.19	-0.07
18-0377-00	Non-Metro (MN)	Crow Wing	46.553	-94.262	3	2000-2008	27	0.007	160.64	14.63	0.15

18-0403-00	Non-Metro (MN)	Crow Wing	46.540	-94.291	3	2000-2008	27	0.005	226.78	11.89	0.11
21-0079-00	Non-Metro (MN)	Douglas	45.779	-95.368	3	2000-2011	36	0.014	336.29	23.77	0.08
29-0075-00	Non-Metro (MN)	Hubbard	47.161	-94.761	4	2002-2011	40	0.011	985.50	40.54	-0.21
29-0077-00	Non-Metro (MN)	Hubbard	46.860	-94.857	5	2000-2010	55	0.030	257.30	10.67	-0.08
29-0085-00	Non-Metro (MN)	Hubbard	46.837	-94.876	3	2003-2011	27	0.022	87.57	10.67	0.05
29-0086-00	Non-Metro (MN)	Hubbard	46.835	-94.843	5	2001-2009	45	0.054	210.54	4.57	-0.08
29-0092-00	Non-Metro (MN)	Hubbard	46.923	-94.891	4	2000-2011	48	0.019	162.04	10.67	-0.22
29-0093-00	Non-Metro (MN)	Hubbard	46.926	-94.867	3	2000-2011	36	0.023	137.53	12.19	-0.19
29-0117-01	Non-Metro (MN)	Hubbard	46.996	-94.853	5	2000-2011	60	0.005	230.65	29.26	-0.12
29-0146-00	Non-Metro (MN)	Hubbard	46.936	-94.898	1	2000-2008	9	0.013	606.15	17.07	0.09
29-0148-00	Non-Metro (MN)	Hubbard	47.043	-94.928	5	2000-2011	60	0.010	185.95	16.76	-0.04
29-0150-00	Non-Metro (MN)	Hubbard	46.991	-94.932	5	2000-2011	60	0.010	165.85	24.38	-0.34
29-0151-01	Non-Metro (MN)	Hubbard	47.066	-94.897	5	2000-2011	60	0.016	655.15	20.73	-0.05
29-0156-00	Non-Metro (MN)	Hubbard	47.392	-94.926	4	2003-2011	36	0.026	1024.25	19.81	-0.17

29-0161-00	Non-Metro (MN)	Hubbard	46.889	-95.000	3	2000-2011	36	0.014	780.06	41.15	-0.36
29-0172-00	Non-Metro (MN)	Hubbard	47.046	-94.954	3	2000-2011	36	0.029	35.64	7.62	-0.40
29-0180-00	Non-Metro (MN)	Hubbard	47.029	-94.949	5	2000-2011	60	0.011	259.67	33.53	-0.14
29-0184-00	Non-Metro (MN)	Hubbard	47.017	-95.005	5	2002-2011	50	0.012	136.22	25.60	-0.36
29-0185-00	Non-Metro (MN)	Hubbard	47.003	-94.964	4	2000-2011	48	0.003	662.21	41.15	-0.25
29-0186-00	Non-Metro (MN)	Hubbard	47.018	-94.947	5	2000-2008	45	0.023	31.76	15.24	-0.37
29-0188-00	Non-Metro (MN)	Hubbard	47.006	-94.932	5	2000-2011	60	0.003	36.86	16.46	-0.14
29-0242-00	Non-Metro (MN)	Hubbard	46.957	-95.065	5	2002-2010	45	0.016	665.22	23.16	-0.15
29-0243-00	Non-Metro (MN)	Hubbard	47.002	-95.055	5	2000-2011	60	0.011	848.90	26.52	-0.19
29-0250-00	Non-Metro (MN)	Hubbard	46.966	-95.120	5	2000-2011	60	0.047	171.03	5.18	-0.12
29-0256-00	Non-Metro (MN)	Hubbard	47.024	-95.101	4	2000-2011	48	0.004	171.53	23.47	-0.05
32-0018-03	Non-Metro (MN)	Jackson	43.846	-95.047	2	2002-2010	18	0.107	120.33	7.92	-0.01
34-0044-00	Non-Metro (MN)	Kandiyohi	45.184	-94.840	4	2002-2011	40	0.070	650.78	8.23	-0.22
34-0171-00	Non-Metro (MN)	Kandiyohi	45.185	-95.000	4	2000-2011	48	0.028	341.81	20.42	-0.02

44-0003-00	Non-Metro (MN)	Mahnomen	47.151	-95.604	4	2000-2009	40	0.034	336.99	13.11	-0.07
47-0002-00	Non-Metro (MN)	Meeker	45.221	-94.262	1	2000-2011	12	0.019	415.13	5.18	0.22
53-0028-00	Non-Metro (MN)	Nobles	43.615	-95.618	5	2000-2010	55	0.153	314.29	4.88	-0.34
56-0114-00	Non-Metro (MN)	Otter Tail	46.411	-95.485	4	2001-2011	44	0.019	283.49	16.76	-0.05
56-0116-01	Non-Metro (MN)	Otter Tail	46.403	-95.451	4	2001-2011	44	0.019	163.67	13.11	0.16
56-0116-02	Non-Metro (MN)	Otter Tail	46.398	-95.422	5	2001-2011	55	0.039	171.34	14.33	-0.05
56-0130-00	Non-Metro (MN)	Otter Tail	46.613	-95.492	5	2000-2011	60	0.046	1913.88	23.16	-0.21
56-0138-00	Non-Metro (MN)	Otter Tail	46.292	-95.553	5	2000-2011	60	0.012	803.95	26.52	-0.04
56-0141-00	Non-Metro (MN)	Otter Tail	46.486	-95.535	5	2000-2011	60	0.030	2119.63	20.73	-0.10
56-0142-00	Non-Metro (MN)	Otter Tail	46.636	-95.559	5	2003-2011	45	0.026	842.51	19.20	-0.10
56-0191-01	Non-Metro (MN)	Otter Tail	46.277	-95.580	1	2001-2010	10	0.025	302.55	14.94	-0.07
56-0212-00	Non-Metro (MN)	Otter Tail	46.516	-95.592	5	2002-2011	50	0.023	71.28	7.92	0.16
56-0238-00	Non-Metro (MN)	Otter Tail	46.256	-95.659	5	2000-2009	50	0.009	1028.49	21.03	-0.18
56-0239-00	Non-Metro (MN)	Otter Tail	46.295	-95.650	4	2001-2011	44	0.014	2253.96	32.92	-0.40

56-0242-00	Non-Metro (MN)	Otter Tail	46.400	-95.658	4	2000-2011	48	0.013	5558.63	36.58	0.16
56-0243-00	Non-Metro (MN)	Otter Tail	46.533	-95.672	5	2001-2011	55	0.017	657.61	18.90	0.18
56-0245-00	Non-Metro (MN)	Otter Tail	46.626	-95.659	3	2002-2010	27	0.014	143.89	20.42	0.32
56-0253-00	Non-Metro (MN)	Otter Tail	46.171	-95.693	4	2000-2011	48	0.014	367.47	14.02	-0.57
56-0297-00	Non-Metro (MN)	Otter Tail	46.363	-95.750	4	2000-2010	44	0.019	62.78	7.32	0.31
56-0298-00	Non-Metro (MN)	Otter Tail	46.359	-95.768	5	2000-2010	55	0.013	181.06	7.92	0.10
56-0306-00	Non-Metro (MN)	Otter Tail	46.293	-95.748	3	2000-2011	36	0.004	76.55	14.02	0.25
56-0310-00	Non-Metro (MN)	Otter Tail	46.434	-95.677	3	2000-2011	36	0.031	234.28	8.84	0.08
56-0328-00	Non-Metro (MN)	Otter Tail	46.610	-95.705	5	2001-2011	55	0.013	531.30	33.22	-0.51
56-0335-00	Non-Metro (MN)	Otter Tail	46.596	-95.700	4	2001-2011	44	0.010	140.33	24.69	0.04
56-0358-00	Non-Metro (MN)	Otter Tail	46.694	-95.779	4	2002-2011	40	0.007	103.02	27.43	0.06
56-0383-00	Non-Metro (MN)	Otter Tail	46.476	-95.754	5	2000-2011	60	0.021	3051.55	19.81	-0.04
56-0385-00	Non-Metro (MN)	Otter Tail	46.526	-95.810	3	2002-2011	30	0.020	1803.83	28.65	-0.16
56-0386-01	Non-Metro (MN)	Otter Tail	46.581	-95.767	4	2000-2011	48	0.016	401.63	14.02	0.10

56-0386-02	Non-Metro (MN)	Otter Tail	46.583	-95.789	4	2000-2011	48	0.009	241.73	18.90	0.09
56-0387-00	Non-Metro (MN)	Otter Tail	46.626	-95.785	5	2000-2009	50	0.010	276.06	22.56	-0.08
56-0437-00	Non-Metro (MN)	Otter Tail	46.208	-95.829	4	2000-2011	48	0.020	549.50	28.96	0.27
56-0475-00	Non-Metro (MN)	Otter Tail	46.427	-95.806	5	2000-2011	60	0.017	343.72	23.77	-0.26
56-0517-00	Non-Metro (MN)	Otter Tail	46.553	-95.850	4	2000-2011	48	0.009	125.55	14.63	-0.13
56-0519-00	Non-Metro (MN)	Otter Tail	46.548	-95.883	4	2000-2011	48	0.009	140.35	17.68	0.12
56-0532-02	Non-Metro (MN)	Otter Tail	46.686	-95.854	5	2002-2011	50	0.019	251.42	23.16	0.01
56-0747-01	Non-Metro (MN)	Otter Tail	46.583	-95.970	4	2000-2011	48	0.017	2232.96	17.68	-0.06
56-0747-02	Non-Metro (MN)	Otter Tail	46.539	-95.993	4	2000-2011	48	0.031	314.02	14.63	0.18
56-0760-01	Non-Metro (MN)	Otter Tail	46.641	-96.015	5	2002-2011	50	0.017	769.57	20.12	-0.31
56-0761-00	Non-Metro (MN)	Otter Tail	46.708	-95.949	2	2003-2011	18	0.020	139.73	7.62	0.03
56-0768-00	Non-Metro (MN)	Otter Tail	46.678	-96.004	4	2003-2011	36	0.010	112.27	21.03	0.11
56-0770-00	Non-Metro (MN)	Otter Tail	46.685	-96.011	2	2003-2011	18	0.017	19.44	10.06	-0.04
56-0786-00	Non-Metro (MN)	Otter Tail	46.700	-96.027	5	2003-2011	45	0.012	1604.97	16.76	-0.09

56-0877-00	Non-Metro (MN)	Otter Tail	46.412	-96.051	5	2000-2010	55	0.019	296.15	22.86	0.22
56-0931-00	Non-Metro (MN)	Otter Tail	46.663	-96.080	5	2002-2011	50	0.031	180.09	3.35	-0.29
56-1627-00	Non-Metro (MN)	Otter Tail	46.586	-95.801	5	2002-2011	50	0.026	60.75	4.88	-0.13
61-0023-00	Non-Metro (MN)	Pope	45.600	-95.187	4	2000-2011	48	0.043	147.68	9.45	-0.12
61-0037-00	Non-Metro (MN)	Pope	45.490	-95.366	4	2000-2008	36	0.022	70.84	15.24	0.28
61-0041-00	Non-Metro (MN)	Pope	45.453	-95.348	4	2000-2011	48	0.022	168.33	14.94	-0.05
61-0064-00	Non-Metro (MN)	Pope	45.694	-95.288	4	2000-2011	48	0.019	378.42	21.03	0.07
61-0066-00	Non-Metro (MN)	Pope	45.729	-95.285	4	2000-2011	48	0.049	114.20	10.06	-0.04
61-0067-00	Non-Metro (MN)	Pope	45.712	-95.292	4	2000-2011	48	0.036	220.47	4.88	-0.12
61-0072-00	Non-Metro (MN)	Pope	45.476	-95.367	4	2000-2011	48	0.076	136.06	7.32	-0.16
61-0078-00	Non-Metro (MN)	Pope	45.738	-95.423	2	2000-2011	24	0.061	1536.42	7.01	-0.22
61-0111-00	Non-Metro (MN)	Pope	45.644	-95.455	3	2000-2011	36	0.048	210.34	10.36	-0.21
61-0122-00	Non-Metro (MN)	Pope	45.702	-95.444	3	2002-2011	30	0.336	149.75	4.27	-0.05
61-0128-00	Non-Metro (MN)	Pope	45.664	-95.515	4	2000-2011	48	0.125	37.28	1.52	0.05

61-0130-00	Non-Metro (MN)	Pope	45.617	-95.442	3	2000-2011	36	0.028	3260.30	9.75	-0.30
61-0149-00	Non-Metro (MN)	Pope	45.541	-95.522	4	2000-2011	48	0.024	16.63	4.27	-0.35
61-0162-00	Non-Metro (MN)	Pope	45.672	-95.532	4	2000-2011	48	0.124	80.42	3.05	-0.03
61-0180-00	Non-Metro (MN)	Pope	45.516	-95.651	1	2000-2009	10	0.070	1300.46	2.13	0.07
73-0086-00	Non-Metro (MN)	Stearns	45.439	-94.450	5	2000-2011	60	0.126	83.03	6.10	-0.01
73-0087-00	Non-Metro (MN)	Stearns	45.439	-94.458	3	2003-2011	27	0.165	34.43	12.19	-0.20
73-0089-00	Non-Metro (MN)	Stearns	45.436	-94.488	5	2002-2011	50	0.143	42.93	7.01	0.04
73-0133-01	Non-Metro (MN)	Stearns	45.423	-94.505	2	2003-2011	18	0.189	13.37	6.10	-0.33
73-0157-00	Non-Metro (MN)	Stearns	45.431	-94.531	3	2003-2011	27	0.115	254.04	17.37	0.00
80-0030-00	Non-Metro (MN)	Wadena	46.799	-95.038	3	2000-2011	36	0.037	102.02	7.92	-0.01
80-0037-00	Non-Metro (MN)	Wadena	46.763	-95.066	4	2001-2011	44	0.046	144.56	6.71	0.01
80-0039-00	Non-Metro (MN)	Wadena	46.750	-95.103	5	2001-2011	55	0.019	46.13	13.72	-0.02
86-0001-00	Non-Metro (MN)	Wright	45.229	-93.577	5	2003-2011	45	0.191	49.01	3.05	-0.29
86-0023-00	Non-Metro (MN)	Wright	45.173	-93.743	4	2002-2011	40	0.056	120.01	8.23	-0.44

86-0066-00	Non-Metro (MN)	Wright	45.296	-93.882	5	2003-2011	45	0.018	40.34	15.85	0.03
86-0114-00	Non-Metro (MN)	Wright	45.074	-93.971	4	2001-2011	44	0.048	196.43	21.49	-0.18
86-0134-01	Non-Metro (MN)	Wright	45.234	-93.965	4	2001-2011	44	0.022	261.38	23.16	-0.08
86-0168-00	Non-Metro (MN)	Wright	45.360	-93.959	5	2001-2011	55	0.065	54.01	14.94	-0.23
86-0183-00	Non-Metro (MN)	Wright	45.383	-94.016	5	2002-2011	50	0.058	39.69	11.58	0.10
86-0190-00	Non-Metro (MN)	Wright	45.027	-94.049	1	2002-2011	10	0.304	152.03	5.64	-0.20
86-0193-00	Non-Metro (MN)	Wright	44.996	-94.023	4	2001-2011	44	0.043	76.94	14.02	-0.31
86-0199-00	Non-Metro (MN)	Wright	45.073	-94.068	5	2002-2011	50	0.094	297.99	11.89	-0.24
86-0217-00	Non-Metro (MN)	Wright	45.185	-94.110	5	2002-2011	50	0.059	142.99	10.36	-0.24
86-0221-00	Non-Metro (MN)	Wright	45.162	-94.094	4	2002-2011	40	0.097	43.74	15.85	-0.07
86-0227-00	Non-Metro (MN)	Wright	45.273	-94.065	4	2003-2011	36	0.052	317.19	32.92	-0.08
86-0229-00	Non-Metro (MN)	Wright	45.274	-94.023	1	2002-2011	10	0.146	113.29	11.89	-0.23
86-0230-00	Non-Metro (MN)	Wright	45.264	-94.027	4	2002-2011	40	0.084	61.30	6.40	-0.13
86-0233-00	Non-Metro (MN)	Wright	45.316	-94.043	5	2003-2011	45	0.020	413.09	21.03	0.04

86-0273-00	Non-Metro (MN)	Wright	45.209	-94.163	5	2003-2011	45	0.051	140.28	15.24	-0.32
86-0288-00	Non-Metro (MN)	Wright	45.259	-94.163	5	2003-2011	45	0.023	158.38	8.53	-0.27
86-0293-00	Non-Metro (MN)	Wright	45.052	-94.255	3	2002-2010	27	0.072	257.52	8.53	-0.13
33100	Non-Metro (WI)	Barron	45.584	-91.921	4	2002-2011	40	0.012	133.93	27.74	-0.25
33144	Non-Metro (WI)	Barron	45.345	-91.670	3	2000-2011	36	0.183	570.40	4.88	0.17
33177	Non-Metro (WI)	Barron	45.584	-92.006	4	2003-2011	36	0.098	62.75	10.36	-0.29
43035	Non-Metro (WI)	Bayfield	46.305	-91.513	2	2002-2010	18	0.025	356.29	20.12	-0.23
43092	Non-Metro (WI)	Bayfield	46.305	-91.513	3	2003-2011	27	0.015	59.87	5.49	0.01
43113	Non-Metro (WI)	Bayfield	46.305	-91.513	3	2003-2011	27	0.032	1173.26	15.24	-0.03
43126	Non-Metro (WI)	Bayfield	46.262	-91.144	3	2001-2010	30	0.005	130.56	25.30	-0.15
43159	Non-Metro (WI)	Bayfield	46.376	-91.539	1	2003-2011	9	0.022	49.60	3.66	0.00
73041	Non-Metro (WI)	Burnett	45.962	-92.074	4	2001-2009	36	0.008	133.44	9.14	0.26
73046	Non-Metro (WI)	Burnett	45.779	-92.484	6	2003-2011	54	0.011	230.57	20.12	0.46
73049	Non-Metro (WI)	Burnett	45.747	-92.538	1	2000-2009	10	0.041	79.19	7.01	0.00

73054	Non-Metro (WI)	Burnett	45.943	-92.314	1	2001-2011	11	0.015	161.54	7.01	-0.07
73079	Non-Metro (WI)	Burnett	45.943	-92.314	2	2003-2011	18	0.038	924.80	9.45	0.24
73080	Non-Metro (WI)	Burnett	45.918	-92.168	3	2000-2011	36	0.013	364.63	22.25	-0.22
73082	Non-Metro (WI)	Burnett	46.030	-92.129	3	2000-2009	30	0.032	306.21	9.45	0.04
73083	Non-Metro (WI)	Burnett	46.039	-92.142	3	2000-2009	30	0.016	306.21	9.45	0.28
73086	Non-Metro (WI)	Burnett	46.042	-92.180	1	2000-2011	12	0.005	61.88	7.01	0.34
73093	Non-Metro (WI)	Burnett	45.992	-92.318	3	2002-2011	30	0.020	26.89	7.92	0.08
73094	Non-Metro (WI)	Burnett	45.876	-92.049	3	2000-2011	36	0.023	159.01	7.32	-0.03
73095	Non-Metro (WI)	Burnett	45.985	-92.324	3	2002-2011	30	0.025	89.72	7.92	-0.10
73099	Non-Metro (WI)	Burnett	45.950	-92.151	4	2000-2011	48	0.010	311.05	3.96	-0.03
73124	Non-Metro (WI)	Burnett	45.960	-92.146	3	2003-2011	27	0.011	311.05	3.96	-0.12
93053	Non-Metro (WI)	Chippewa	45.276	-91.478	2	2000-2010	22	0.005	34.87	22.25	0.00
93070	Non-Metro (WI)	Chippewa	45.254	-91.450	2	2001-2010	20	0.010	87.39	5.49	0.17
93123	Non-Metro (WI)	Chippewa	45.248	-91.411	4	2001-2010	40	0.012	378.96	30.78	0.19

113076	Non-Metro (WI)	Columbia	43.544	-89.377	1	2001-2011	11	0.054	165.03	24.99	-0.32
163237	Non-Metro (WI)	Douglas	46.176	-91.881	4	2000-2009	40	0.004	112.93	20.42	0.24
163238	Non-Metro (WI)	Douglas	46.193	-91.859	1	2001-2011	11	0.004	69.28	17.07	0.17
163376	Non-Metro (WI)	Douglas	46.153	-91.936	1	2000-2008	9	0.029	335.45	6.71	0.32
163389	Non-Metro (WI)	Douglas	46.203	-91.876	2	2003-2011	18	0.005	343.60	31.09	0.06
163393	Non-Metro (WI)	Douglas	46.203	-91.876	4	2003-2011	36	0.019	70.53	3.66	0.19
173215	Non-Metro (WI)	Dunn	44.982	-91.860	1	2000-2011	12	0.118	649.85	11.28	-0.06
193006	Non-Metro (WI)	Florence	45.894	-88.306	3	2003-2011	27	0.018	78.90	23.47	-0.20
213017	Non-Metro (WI)	Forest	45.557	-88.708	3	2000-2011	36	0.010	128.22	6.10	0.19
213040	Non-Metro (WI)	Forest	45.721	-88.675	3	2000-2011	36	0.017	31.69	5.18	-0.26
213123	Non-Metro (WI)	Forest	45.531	-88.849	1	2000-2011	12	0.005	420.65	22.25	0.21
213124	Non-Metro (WI)	Forest	45.540	-88.904	3	2002-2011	30	0.005	825.59	24.08	0.24
213128	Non-Metro (WI)	Forest	45.397	-88.918	3	2002-2011	30	0.024	515.30	4.27	-0.26
213131	Non-Metro (WI)	Forest	45.397	-88.918	1	2003-2011	9	0.019	677.39	4.27	0.54

213137	Non-Metro (WI)	Forest	45.916	-88.983	1	2000-2011	12	0.012	504.77	12.80	0.04
213138	Non-Metro (WI)	Forest	45.937	-88.999	3	2000-2011	36	0.009	339.95	14.02	NaN
243021	Non-Metro (WI)	Green Lake	43.820	-88.976	4	2001-2010	40	0.040	3207.60	71.93	-0.20
263056	Non-Metro (WI)	Iron	46.279	-89.932	2	2001-2010	20	0.014	83.81	8.23	0.06
263059	Non-Metro (WI)	Iron	46.083	-90.174	2	2002-2011	20	0.020	5241.62	15.24	0.52
303050	Non-Metro (WI)	Kenosha	42.547	-88.298	2	2002-2011	20	0.007	182.80	10.06	0.31
303121	Non-Metro (WI)	Kenosha	42.523	-88.257	1	2003-2011	9	0.024	132.59	10.06	0.03
303122	Non-Metro (WI)	Kenosha	42.573	-88.101	2	2002-2010	18	0.021	51.84	9.75	0.29
343126	Non-Metro (WI)	Langlade	45.438	-88.949	2	2000-2011	24	0.036	276.27	3.66	-0.26
343151	Non-Metro (WI)	Langlade	45.163	-88.767	2	2000-2008	18	0.007	62.11	12.80	0.24
353077	Non-Metro (WI)	Lincoln	45.429	-89.489	4	2001-2011	44	0.008	42.83	13.11	-0.02
383054	Non-Metro (WI)	Marinette	45.543	-88.065	1	2000-2009	10	0.013	73.76	2.74	-0.04
433035	Non-Metro (WI)	Oconto	45.283	-88.581	1	2001-2011	11	0.008	158.80	15.24	NaN
433072	Non-Metro (WI)	Oconto	45.242	-88.354	1	2002-2011	10	0.008	65.55	11.28	0.15

433074	Non-Metro (WI)	Oconto	45.242	-88.354	3	2003-2011	27	0.007	112.66	15.85	-0.21
443053	Non-Metro (WI)	Oneida	45.710	-89.592	4	2000-2010	44	0.006	80.64	10.97	-0.06
443078	Non-Metro (WI)	Oneida	45.596	-89.514	3	2003-2011	27	0.011	249.49	9.75	0.00
443092	Non-Metro (WI)	Oneida	45.699	-89.612	3	2000-2011	36	0.020	77.54	7.92	-0.13
443111	Non-Metro (WI)	Oneida	45.782	-89.586	2	2002-2010	18	0.050	152.76	3.35	-0.07
443132	Non-Metro (WI)	Oneida	45.782	-89.586	2	2003-2011	18	0.028	74.55	8.23	-0.36
443134	Non-Metro (WI)	Oneida	45.872	-89.692	3	2000-2009	30	0.019	542.47	18.29	0.13
443142	Non-Metro (WI)	Oneida	45.806	-89.314	4	2000-2011	48	0.004	210.25	11.58	0.11
443147	Non-Metro (WI)	Oneida	45.771	-89.519	4	2002-2011	40	0.008	291.23	19.20	-0.19
443253	Non-Metro (WI)	Oneida	45.875	-89.064	1	2000-2010	11	0.015	209.87	13.11	0.26
443332	Non-Metro (WI)	Oneida	45.785	-89.720	1	2002-2011	10	0.005	26.42	11.89	0.00
443368	Non-Metro (WI)	Oneida	45.819	-89.584	1	2003-2011	9	0.005	38.99	10.67	0.39
443386	Non-Metro (WI)	Oneida	45.840	-89.578	2	2000-2011	24	0.004	124.48	15.24	NaN
443391	Non-Metro (WI)	Oneida	45.840	-89.578	4	2003-2011	36	0.007	291.23	19.20	-0.41

443413	Non-Metro (WI)	Oneida	45.614	-89.430	4	2001-2011	44	0.005	97.47	5.79	0.20
493063	Non-Metro (WI)	Polk	45.405	-92.513	1	2000-2008	9	0.026	318.13	14.02	-0.09
493064	Non-Metro (WI)	Polk	45.404	-92.542	2	2000-2008	18	0.029	318.13	14.02	-0.15
493097	Non-Metro (WI)	Polk	45.519	-92.209	3	2000-2011	36	0.011	118.78	20.73	-0.17
493099	Non-Metro (WI)	Polk	45.489	-92.412	1	2000-2008	9	0.012	222.88	18.29	0.13
493103	Non-Metro (WI)	Polk	45.439	-92.495	3	2000-2011	36	0.054	53.26	6.10	0.07
493104	Non-Metro (WI)	Polk	45.317	-92.356	4	2000-2011	48	0.049	244.82	5.49	0.25
493105	Non-Metro (WI)	Polk	45.533	-92.199	3	2002-2011	30	0.056	26.11	11.28	-0.11
493106	Non-Metro (WI)	Polk	45.571	-92.461	2	2000-2011	24	0.054	155.71	5.79	0.09
493107	Non-Metro (WI)	Polk	45.571	-92.461	3	2000-2008	27	0.039	99.11	7.32	0.07
493108	Non-Metro (WI)	Polk	45.571	-92.461	3	2000-2008	27	0.005	35.27	13.72	NaN
493116	Non-Metro (WI)	Polk	45.571	-92.461	3	2000-2008	27	0.019	15.78	2.13	0.38
493122	Non-Metro (WI)	Polk	45.314	-92.410	1	2000-2010	11	0.020	100.22	7.62	-0.24
493131	Non-Metro (WI)	Polk	45.319	-92.426	2	2000-2011	24	0.025	481.47	9.75	0.27

513079	Non-Metro (WI)	Price	45.388	-90.158	4	2003-2011	36	0.055	90.86	6.71	0.25
513087	Non-Metro (WI)	Price	45.701	-90.565	4	2000-2011	48	0.054	243.33	6.40	0.03
513097	Non-Metro (WI)	Taylor	45.379	-90.134	4	2002-2011	40	0.081	55.40	2.74	0.27
513121	Non-Metro (WI)	Price	45.968	-90.519	3	2002-2011	30	0.040	398.20	9.75	0.14
513126	Non-Metro (WI)	Price	45.921	-90.074	3	2000-2010	33	0.032	302.96	7.32	-0.09
513137	Non-Metro (WI)	Price	45.921	-90.074	3	2000-2008	27	0.057	140.95	3.35	-0.08
543247	Non-Metro (WI)	Rock	42.799	-88.980	1	2000-2011	12	0.011	31.35	6.10	0.43
553068	Non-Metro (WI)	Rusk	45.396	-91.318	2	2000-2009	20	0.051	114.42	6.10	0.25
563056	Non-Metro (WI)	Saint Croix	45.187	-92.615	2	2000-2011	24	0.168	44.53	9.75	-0.05
563057	Non-Metro (WI)	Polk	45.213	-92.572	3	2000-2008	27	0.084	453.74	8.53	0.57
563058	Non-Metro (WI)	Saint Croix	45.069	-92.649	3	2000-2008	27	0.010	149.84	10.67	0.19
573121	Non-Metro (WI)	Sauk	43.417	-89.733	6	2003-2011	54	0.021	151.50	14.33	-0.11
583046	Non-Metro (WI)	Sawyer	43.417	-89.733	1	2003-2011	9	0.005	2081.47	27.43	0.24
583047	Non-Metro (WI)	Sawyer	45.848	-91.486	4	2000-2008	36	0.031	384.54	15.24	0.17

583055	Non-Metro (WI)	Sawyer	46.089	-91.105	3	2000-2011	36	0.025	414.87	9.45	0.16
583056	Non-Metro (WI)	Sawyer	46.109	-91.143	1	2002-2011	10	0.021	511.83	6.40	-0.63
583065	Non-Metro (WI)	Sawyer	46.094	-91.226	2	2000-2008	18	0.008	1286.41	18.29	0.00
583088	Non-Metro (WI)	Sawyer	45.864	-91.446	3	2001-2011	33	0.008	323.83	32.00	0.12
583149	Non-Metro (WI)	Sawyer	45.864	-91.446	1	2003-2011	9	0.126	86.56	6.71	-0.26
583170	Non-Metro (WI)	Sawyer	45.864	-91.446	4	2003-2011	36	0.029	1099.95	10.06	0.01
583171	Non-Metro (WI)	Sawyer	46.079	-91.244	1	2002-2011	10	0.005	483.69	19.51	-0.35
593003	Non-Metro (WI)	Shawano	44.697	-88.641	4	2001-2011	44	0.036	35.09	10.67	0.11
593072	Non-Metro (WI)	Shawano	44.809	-88.518	4	2001-2011	44	0.029	2517.22	12.80	0.00
603312	Non-Metro (WI)	Sheboygan	43.550	-87.955	3	2002-2011	30	0.018	85.75	6.40	0.09
613187	Non-Metro (WI)	Taylor	43.550	-87.955	3	2003-2011	27	0.013	19.25	10.97	0.11
643042	Non-Metro (WI)	Vilas	46.172	-89.343	3	2000-2011	36	0.005	14.09	19.20	-0.01
643047	Non-Metro (WI)	Vilas	45.908	-89.427	3	2000-2011	36	0.005	23.38	5.49	0.13
643055	Non-Metro (WI)	Vilas	45.942	-89.148	3	2000-2011	36	0.009	137.34	4.88	0.24

643058	Non-Metro (WI)	Vilas	45.981	-89.165	3	2000-2011	36	0.009	121.96	5.49	0.34
643077	Non-Metro (WI)	Vilas	45.971	-89.708	3	2000-2011	36	0.011	90.17	7.01	0.05
643084	Non-Metro (WI)	Vilas	45.906	-89.398	4	2001-2011	44	0.009	16.74	9.14	-0.07
643088	Non-Metro (WI)	Vilas	45.918	-89.435	3	2000-2011	36	0.005	52.86	11.58	0.03
643089	Non-Metro (WI)	Vilas	46.080	-89.333	2	2000-2010	22	0.014	11.49	8.84	0.24
643095	Non-Metro (WI)	Vilas	45.968	-89.774	4	2002-2011	40	0.005	88.53	19.81	0.19
643113	Non-Metro (WI)	Vilas	45.941	-89.711	1	2001-2011	11	0.008	56.35	8.23	-0.07
643126	Non-Metro (WI)	Vilas	46.162	-89.309	3	2002-2011	30	0.005	228.34	25.91	-0.18
643165	Non-Metro (WI)	Vilas	46.162	-89.309	2	2000-2008	18	0.005	237.46	12.19	NaN
643170	Non-Metro (WI)	Vilas	45.929	-89.440	1	2002-2011	10	0.068	393.53	16.15	0.00
643171	Non-Metro (WI)	Vilas	45.908	-89.473	1	2000-2011	12	0.005	393.53	16.15	0.17
643172	Non-Metro (WI)	Vilas	45.910	-89.452	1	2000-2011	12	0.025	393.53	16.15	-0.33
643195	Non-Metro (WI)	Vilas	45.910	-89.452	2	2003-2011	18	0.005	62.70	10.97	0.00
643197	Non-Metro (WI)	Vilas	46.231	-89.716	2	2000-2009	20	0.019	101.25	7.32	0.29

643220	Non-Metro (WI)	Vilas	45.932	-90.034	3	2000-2010	33	0.032	57.03	2.44	-0.13
643237	Non-Metro (WI)	Vilas	46.150	-89.695	1	2000-2010	11	0.026	62.24	6.10	0.51
643239	Non-Metro (WI)	Vilas	45.927	-89.897	1	2001-2011	11	0.005	45.89	13.41	NaN
643245	Non-Metro (WI)	Vilas	46.188	-89.583	2	2003-2011	18	0.029	66.68	8.84	-0.20
643249	Non-Metro (WI)	Vilas	46.234	-89.885	4	2000-2009	40	0.013	145.46	17.68	0.01
643252	Non-Metro (WI)	Vilas	46.183	-89.800	2	2003-2011	18	0.004	171.07	19.81	0.35
643268	Non-Metro (WI)	Vilas	46.068	-89.737	4	2000-2011	48	0.011	146.66	9.75	0.11
643407	Non-Metro (WI)	Vilas	46.197	-89.726	2	2000-2008	18	0.005	368.09	18.29	-0.22
643411	Non-Metro (WI)	Vilas	46.197	-89.726	2	2003-2011	18	0.020	93.15	3.96	0.40
643421	Non-Metro (WI)	Vilas	46.197	-89.726	1	2003-2011	9	0.005	471.87	31.39	NaN
643444	Non-Metro (WI)	Vilas	46.212	-89.683	4	2002-2011	40	0.008	78.76	9.14	0.08
643446	Non-Metro (WI)	Vilas	45.997	-89.828	2	2000-2010	22	0.007	18.91	10.06	-0.16
643451	Non-Metro (WI)	Vilas	45.992	-88.987	3	2001-2011	33	0.017	405.46	12.19	0.14
643467	Non-Metro (WI)	Vilas	46.216	-89.838	1	2003-2011	9	0.016	205.02	13.72	0.09

643478	Non-Metro (WI)	Vilas	45.939	-89.981	2	2002-2011	20	0.005	28.42	7.62	0.11
643482	Non-Metro (WI)	Vilas	45.951	-89.446	2	2000-2011	24	0.027	136.22	6.40	0.02
643488	Non-Metro (WI)	Vilas	46.191	-89.830	4	2000-2009	40	0.010	14.69	17.68	0.05
643512	Non-Metro (WI)	Vilas	46.260	-89.835	1	2003-2011	9	0.010	216.24	17.37	-0.50
643515	Non-Metro (WI)	Vilas	45.899	-89.817	1	2002-2011	10	0.017	283.47	12.80	0.52
643557	Non-Metro (WI)	Vilas	45.926	-89.428	2	2002-2011	20	0.060	393.53	16.15	0.02
653122	Non-Metro (WI)	Walworth	42.560	-88.542	3	2000-2009	30	0.005	2187.40	41.15	0.05
653126	Non-Metro (WI)	Walworth	42.760	-88.700	1	2001-2011	11	0.026	253.20	11.58	0.07
663050	Non-Metro (WI)	Washburn	45.915	-91.998	2	2002-2011	20	0.007	53.65	9.45	0.34
663088	Non-Metro (WI)	Washburn	45.758	-91.648	4	2001-2011	44	0.028	1408.56	22.56	0.07
663099	Non-Metro (WI)	Washburn	46.123	-91.933	2	2002-2011	20	0.033	642.88	6.40	0.18
663104	Non-Metro (WI)	Washburn	46.062	-91.961	3	2000-2011	36	0.009	42.97	8.84	-0.01
663118	Non-Metro (WI)	Washburn	45.754	-91.673	2	2000-2008	18	0.024	1408.56	22.56	-0.18
663151	Non-Metro (WI)	Washburn	45.754	-91.673	4	2003-2011	36	0.007	306.69	11.89	0.09

Blanks indicate no lake data was available.

NaN indicates a tau score could not be calculated with the data available for that lake.

Table 9. Individual lake information for all lakes analyzed for Total Kjeldahl Nitrogen trends.

Lake ID	Lake Group	County	Latitude	Longitude	Months	Years	Total Values	Surface Area (hectares)	Maximum Depth (m)	Tau Value Description
02-0003-00	Metro TKN	Anoka	45.124	-93.041	5	2000-2010	55	122.40	6.40	0.32
02-0005-00	Metro TKN	Anoka	45.176	-93.091	2	2001-2011	22	358.83	2.13	0.03
02-0022-00	Metro TKN	Anoka	45.368	-93.096	6	2003-2011	54	27.01	6.71	0.31
02-0045-00	Metro TKN	Anoka	45.139	-93.153	5	2000-2010	55	23.53	7.62	-0.11
02-0654-00	Metro TKN	Anoka	45.140	-93.300	7	2001-2011	77	11.58	10.97	0.27
10-0002-00	Metro TKN	Carver	44.836	-93.522	6	2002-2011	60	119.97	14.94	-0.01
10-0005-00	Metro TKN	Carver	44.789	-93.590	7	2000-2011	84	4.05	17.37	0.09
10-0006-00	Metro TKN	Carver	44.878	-93.531	2	2003-2011	18	99.28	8.84	0.24
10-0010-00	Metro TKN	Carver	44.874	-93.635	5	2001-2009	45	9.88	24.99	0.18
10-0019-00	Metro TKN	Carver	44.837	-93.639	6	2000-2011	72	67.41	20.12	0.27
10-0029-00	Metro TKN	Carver	44.786	-93.742	6	2000-2011	72	57.62	4.27	0.15
10-0052-00	Metro TKN	Carver	44.839	-93.745	5	2000-2011	60	37.43	10.97	-0.31
10-0059-00	Metro TKN	Carver	44.872	-93.782	5	2000-2011	60	1247.52	11.28	-0.04
10-0088-00	Metro TKN	Carver	44.816	-93.876	6	2002-2011	60	90.27	5.49	0.02
10-0089-00	Metro TKN	Carver	44.891	-93.844	6	2001-2011	66	159.57	3.05	0.29
10-0095-00	Metro TKN	Carver	44.930	-93.820	7	2002-2011	70	175.30	3.66	0.43
10-0121-00	Metro TKN	Carver	44.809	-93.934	6	2000-2011	72	74.20	4.27	0.19

10-0225-00	Metro TKN	Carver	44.794	-93.600	7	2002-2011	70	6.89	13.11	0.34
10-0226-00	Metro TKN	Carver	44.791	-93.604	7	2002-2011	70	3.44	7.01	0.17
19-0021-00	Metro TKN	Dakota	44.748	-93.248	6	2001-2011	66	36.13	3.51	0.00
19-0022-00	Metro TKN	Dakota	44.756	-93.174	6	2003-2011	54	15.80		-0.05
19-0023-00	Metro TKN	Dakota	44.759	-93.164	6	2000-2011	72	27.14	3.05	-0.02
19-0024-00	Metro TKN	Dakota	44.741	-93.266	7	2000-2010	77	3.65	4.27	0.29
19-0025-00	Metro TKN	Dakota	44.727	-93.252	3	2000-2011	36	20.66	2.13	0.23
19-0026-01	Metro TKN	Dakota	44.666	-93.281	7	2000-2010	77	214.77	6.40	0.59
19-0027-00	Metro TKN	Dakota	44.723	-93.266	7	2000-2011	84	116.90	11.28	0.29
19-0028-00	Metro TKN	Dakota	44.735	-93.277	2	2001-2011	22	7.29		0.16
19-0029-00	Metro TKN	Dakota	44.712	-93.288	5	2000-2010	55	8.91	4.27	-0.04
19-0030-00	Metro TKN	Dakota	44.707	-93.299	7	2000-2010	77	30.38		0.26
19-0031-00	Metro TKN	Dakota	44.701	-93.309	6	2003-2011	54	95.28	10.06	-0.17
19-0033-00	Metro TKN	Dakota	44.739	-93.297	4	2000-2011	48	11.34		-0.19
19-0095-00	Metro TKN	Dakota	44.883	-93.054	4	2000-2008	36	1.62		0.56
19-0348-00	Metro TKN	Dakota	44.715	-93.209	7	2000-2010	77	2.84	3.35	0.38
19-0446-00	Metro TKN	Dakota	44.721	-93.245	6	2002-2011	60	22.28	9.75	0.20
27-0035-01	Metro TKN	Hennepin	44.993	-93.339	5	2000-2011	60	26.73	8.53	0.22
27-0070-00	Metro TKN	Hennepin	44.859	-93.498	6	2003-2011	54	46.14	5.79	-0.14
27-0107-00	Metro TKN	Hennepin	44.994	-93.472	6	2002-2010	54	40.57	11.28	0.21
27-0627-00	Metro TKN	Hennepin	45.028	-93.394	6	2000-2011	72	6.08		0.15
27-0645-00	Metro TKN	Hennepin	0.000	0.000	4	2000-2008	36	3.65		0.03
27-0656-00	Metro TKN	Hennepin	44.959	-93.337	6	2002-2011	60	5.27		0.02
27-0711-00	Metro TKN	Hennepin	44.970	-93.389	4	2000-2011	48	45.77		0.11
62-0001-00	Metro TKN	Ramsey	45.027	-93.988	5	2001-2010	50	29.16	5.49	0.41

62-0002-00	Metro TKN	Ramsey	45.115	-93.017	5	2000-2010	55	423.88	10.97	0.16
62-0006-00	Metro TKN	Ramsey	45.024	-93.058	5	2000-2010	55	29.97	2.74	0.08
62-0007-00	Metro TKN	Ramsey	45.021	-93.071	5	2000-2010	55	95.18	12.50	-0.10
62-0010-02	Metro TKN	Ramsey	45.008	-93.061	5	2000-2010	55	29.16	2.44	-0.25
62-0011-00	Metro TKN	Ramsey	44.995	-93.036	5	2000-2010	55	8.69	2.44	-0.31
62-0012-00	Metro TKN	Ramsey	44.994	-93.063	5	2000-2010	55	12.15		-0.02
62-0013-00	Metro TKN	Ramsey	44.988	-93.054	5	2000-2010	55	80.06	27.74	-0.01
62-0016-00	Metro TKN	Ramsey	44.973	-93.005	4	2000-2010	44	33.54	3.35	-0.17
62-0047-00	Metro TKN	Ramsey	44.904	-93.151	4	2002-2010	36	19.44	5.79	0.51
62-0048-00	Metro TKN	Ramsey	45.018	-93.141	4	2000-2010	44	11.52	2.74	0.02
62-0054-00	Metro TKN	Ramsey	44.998	-93.113	5	2000-2010	55	29.67	17.37	-0.31
62-0055-00	Metro TKN	Ramsey	44.979	-93.141	5	2000-2010	55	27.72	4.72	-0.12
62-0056-00	Metro TKN	Ramsey	45.038	-93.120	4	2000-2010	44	151.86	11.28	0.33
62-0057-00	Metro TKN	Ramsey	45.036	-93.153	5	2000-2010	55	47.05	13.41	0.10
62-0061-00	Metro TKN	Ramsey	45.099	-93.138	5	2000-2010	55	182.25	8.53	0.15
62-0067-00	Metro TKN	Ramsey	45.073	-93.201	4	2000-2010	44	69.91	9.14	-0.16
62-0069-00	Metro TKN	Ramsey	45.068	-93.208	3	2000-2008	27	14.18	4.88	0.45
62-0071-00	Metro TKN	Ramsey	45.060	-93.168	5	2001-2010	50	29.97	3.96	0.18
62-0073-00	Metro TKN	Ramsey	45.073	-93.125	5	2000-2010	55	63.28	9.14	0.31
62-0075-01	Metro TKN	Ramsey	45.054	-93.136	5	2000-2010	55		3.35	0.32
62-0075-02	Metro TKN	Ramsey	45.058	-93.134	3	2000-2010	33	7.13	3.35	0.14
62-0078-00	Metro TKN	Ramsey	45.044	-93.170	5	2000-2010	55	85.82	13.11	0.03
62-0082-00	Metro TKN	Ramsey	45.045	-93.116	5	2000-2010	55	18.79	20.12	0.26
62-0083-00	Metro TKN	Ramsey	45.044	-93.226	4	2000-2010	44		14.33	-0.23
70-0018-00	Metro TKN	Scott	44.727	-93.391	6	2002-2011	60	10.94		0.24

70-0026-00	Metro TKN	Scott	44.735	-93.415	5	2000-2011	60	387.44	18.29	0.18
70-0054-00	Metro TKN	Scott	44.701	-93.473	4	2000-2010	44	239.70	11.28	0.09
70-0069-00	Metro TKN	Scott	44.652	-93.460	5	2000-2011	60	70.04	8.53	-0.03
70-0072-00	Metro TKN	Scott	44.715	-93.444	4	2002-2011	40	156.43	15.24	-0.03
70-0074-00	Metro TKN	Scott	44.774	-93.444	5	2002-2010	45	90.32		0.10
70-0079-00	Metro TKN	Scott	44.737	-93.468	3	2002-2011	30			-0.34
70-0085-00	Metro TKN	Scott	44.720	-93.458	3	2002-2011	30			-0.15
82-0009-00	Metro TKN	Washington	45.019	-92.852	5	2001-2011	55	14.18	8.53	0.27
82-0010-00	Metro TKN	Washington	45.017	-92.844	5	2001-2009	45	16.20		0.10
82-0015-02	Metro TKN	Washington	45.113	-92.837	6	2000-2010	66		5.18	0.32
82-0019-00	Metro TKN	Washington	45.078	-92.848	6	2003-2011	54	21.47		0.11
82-0020-00	Metro TKN	Washington	45.062	-92.829	6	2000-2011	72	27.95	3.81	0.17
82-0021-00	Metro TKN	Washington	45.048	-92.853	6	2000-2011	72	44.55	6.71	-0.37
82-0023-00	Metro TKN	Washington	45.048	-92.824	5	2000-2010	55	17.25	15.54	0.14
82-0030-00	Metro TKN	Washington	45.191	-92.840	5	2000-2011	60	28.71	3.66	-0.10
82-0034-00	Metro TKN	Washington	45.165	-92.832	6	2000-2011	72	13.24	8.23	-0.19
82-0049-00	Metro TKN	Washington	45.135	-92.809	1	2000-2010	11	185.10	20.12	-0.38
82-0052-02	Metro TKN	Washington	45.224	-92.832	6	2000-2011	72	728.67	18.29	-0.61
82-0054-00	Metro TKN	Washington	45.286	-92.860	4	2001-2011	44	89.69	9.14	-0.43
82-0064-00	Metro TKN	Washington	45.239	-92.844	6	2001-2011	66	19.44	0.61	-0.59
82-0065-00	Metro TKN	Washington	45.234	-92.814	5	2003-2011	45	22.68		-0.28
82-0067-00	Metro TKN	Washington	45.230	-92.805	5	2002-2011	50	18.23	5.49	0.10
82-0068-00	Metro TKN	Washington	45.227	-92.820	6	2001-2011	66	16.61	2.13	-0.21
82-0077-00	Metro TKN	Washington	45.133	-92.893	6	2000-2011	72	17.82		0.47
82-0087-00	Metro TKN	Washington	44.806	-92.902	5	2000-2011	60	7.87	4.88	-0.28

82-0089-00	Metro TKN	Washington	44.938	-92.899	6	2000-2011	72	14.58	2.44	0.38
82-0090-00	Metro TKN	Washington	44.934	-92.917	6	2000-2010	66	13.37		0.12
82-0092-00	Metro TKN	Washington	44.926	-92.900	7	2003-2011	63	23.58	12.50	0.15
82-0094-00	Metro TKN	Washington	44.907	-92.910	1	2000-2008	9	27.89	3.35	0.06
82-0097-00	Metro TKN	Washington	44.888	-92.970	3	2000-2011	36	17.01	3.05	0.04
82-0101-00	Metro TKN	Washington	45.023	-92.940	5	2003-2011	45	63.61	7.32	-0.03
82-0103-00	Metro TKN	Washington	45.017	-92.944	5	2003-2011	45	35.29	4.57	0.12
82-0110-00	Metro TKN	Washington	44.982	-92.866	1	2001-2009	9	13.37		-0.06
82-0116-00	Metro TKN	Washington	44.964	-92.939	6	2000-2011	72			-0.02
82-0122-00	Metro TKN	Washington	45.101	-92.954	1	2000-2011	12	48.60	9.45	-0.11
82-0130-00	Metro TKN	Washington	45.080	-92.951	4	2003-2011	36	19.44	7.62	0.10
82-0133-00	Metro TKN	Washington	45.051	-92.911	6	2001-2011	66	6.08		0.04
82-0153-00	Metro TKN	Washington	45.133	-92.942	4	2000-2011	48	50.22	5.18	0.20
82-0159-01	Metro TKN	Washington	45.271	-92.948	6	2000-2011	72	919.71	11.28	0.02
82-0167-00	Metro TKN	Washington	45.076	-92.984	5	2000-2010	55	983.20	25.30	0.48
82-0313-00	Metro TKN	Washington	45.016	-92.866	3	2002-2010	27	4.46		0.19
82-0334-00	Metro TKN	Washington	45.095	-92.891	6	2000-2011	72	4.05		-0.17
82-0368-00	Metro TKN	Washington	45.033	-92.909	6	2002-2011	60	1.22		0.28

Blanks indicate no lake data was available.