LAKE CLASSIFICATION APPROACH

Buffalo River
Watershed

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INTRODUCTION

This report addresses the classification / grouping of lakes in the Buffalo River Watershed (BRW) as described in Task 9 of the Minnesota Pollution Control Agency (MPCA) contract #B55092: Buffalo River Watershed Approach Plan Phase 2. A main goal of the MPCA's Watershed Approach is to develop plans that are protective of waters where conditions are excellent and restorative of waters where conditions are impaired. These plans will include strategies to guide management activities, priorities and policies, including those activities as they pertain to lakes. The management strategies developed for the BRW Approach Plan will be informed by various findings from Phase 2 of the work, including results of modeling to be completed in future tasks. Creating models for each of the over 300 lakes in the BRW is not a realistic goal. An approach is, therefore, needed to develop more generalized models that are reflective of water quality processes in the lakes of the BRW, in general, and to use those models to inform management of the individual lakes of the area. Other information that may influence the management of these lakes is also sought.

Herein we provide select background information pertaining to lakes within the BRW, describe the information that was gathered or computed for the 300+ waterbodies to support lake management, discuss the methods that were used to group the lakes for statistical analysis, and summarize the results of these analyses. Overall results include the development of "example" lakes (one to represent each lake group) which will be used in future tasks to model anticipated eutrophication response. The product of this work is information to support lake management activities within the BRW, guidance on the anticipated response of BRW lakes to nutrient loading, and attributes of "example" lakes from each lake group for use in future modeling efforts.

LAKE CLASSIFICATION VARIABLES: DEFINITIONS AND METHODS

Background

Various classification variables were assigned to the lakes in the BRW to assist with lake management activities and also to inform the lake grouping exercise. The primary data sources used for this analysis were MPCA personnel, the Minnesota Department of Natural Resources (MnDNR) LakeFinder website (http://www.dnr.state.mn.us/lakefind/index.html), the MnDNR Geographic Information Systems (GIS) online data deli (http://deli.dnr.state.mn.us), the MPCA's lake water quality data website (http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/lake-water-quality/lake-water-quality-data-search.html), and the Multi-Resolution Land Characteristics Consortium (MRLC) website (http://www.mrlc.gov/nlcd06_data.php). Lake classification variables were chosen for attributing the lakes based on: 1) the information being widely available (creating an approach that could be applied in other watersheds); 2) the information is currently being used by the Buffalo-Red River Watershed District (BRRWD) to manage lakes – most specifically in their development of "priority lakes"

in their Watershed Management Plan; 3) the data being required for future modeling efforts (e.g., estimated lake mean depth); and 4) the information being required to assess the waters for impairment (e.g., ecoregion or land use data to determine which water quality standards are applicable).

Defining the Lakes

The BRW has numerous lakes and small ponds within its boundaries. The largest lakes (i.e., Tamarack Lake and Rock Lake) lie in the headwaters of the Buffalo River in the far eastern portion of the watershed (**Figure 1**). A large grouping of small lakes exists in the middle of the watershed, while relatively few lakes exist within the western portion. According to the MnDNR 24 k lakes GIS data layer, 303 lakes (defined as waterbodies with a surface area greater than 10 acres) and 1,870 smaller ponds exist within the watershed. Many of the lakes in the BRW are small, with fifty percent of the lakes having surface areas of less than thirty acres (**Figure 2**).

The MnDNR lake 24 k GIS data layer was used as the basis for classifying lakes in this work. Data were initially filtered to include only the 303 lakes with surface areas greater than 10 acres. Surface areas for all lakes were calculated in GIS according to the defined lake borders provided by the MnDNR lakes 24 k data layer. When available, each lake was attributed with data such as the MnDNR lake identification number, lake name, maximum and mean depths, percent of the lake that is littoral, number of public accesses, whether the lake is considered shallow (< 15 ft. or > 80% littoral) or deep, whether it has water quality data available, and the Level III ecoregion that the lake is located within. In addition to these variables, which mainly came directly from the MnDNR LakeFinder database, three additional variables (percent land use/land cover in surrounding area, mean eutrophication water quality condition, and trophic status index) were computed and assigned to each lake, as discussed below. A comprehensive listing of the 303 lakes in the BRW and their lake characteristic data is given in **Appendix A**.

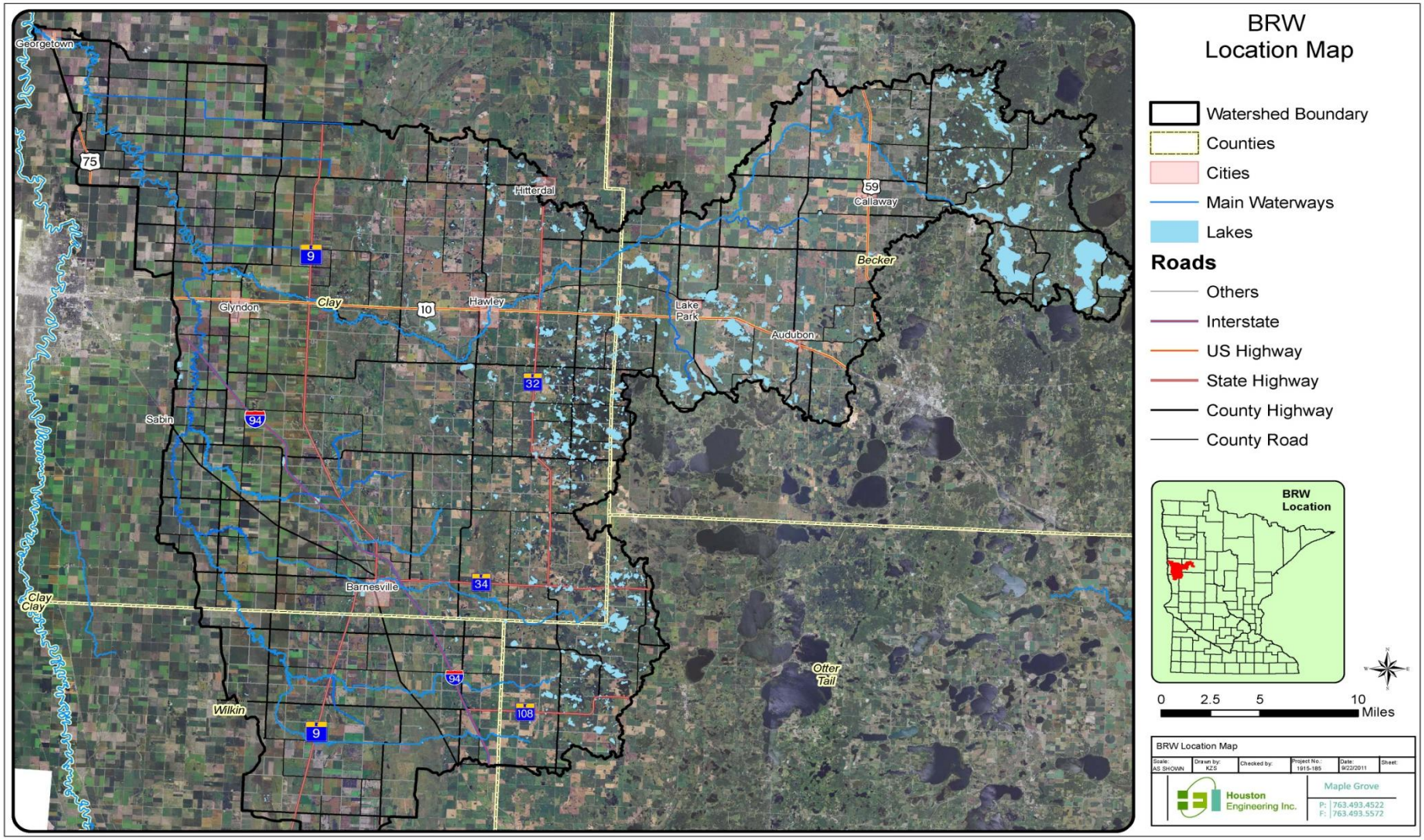


Figure 1. Location and Base Map of the Buffalo River Watershed.

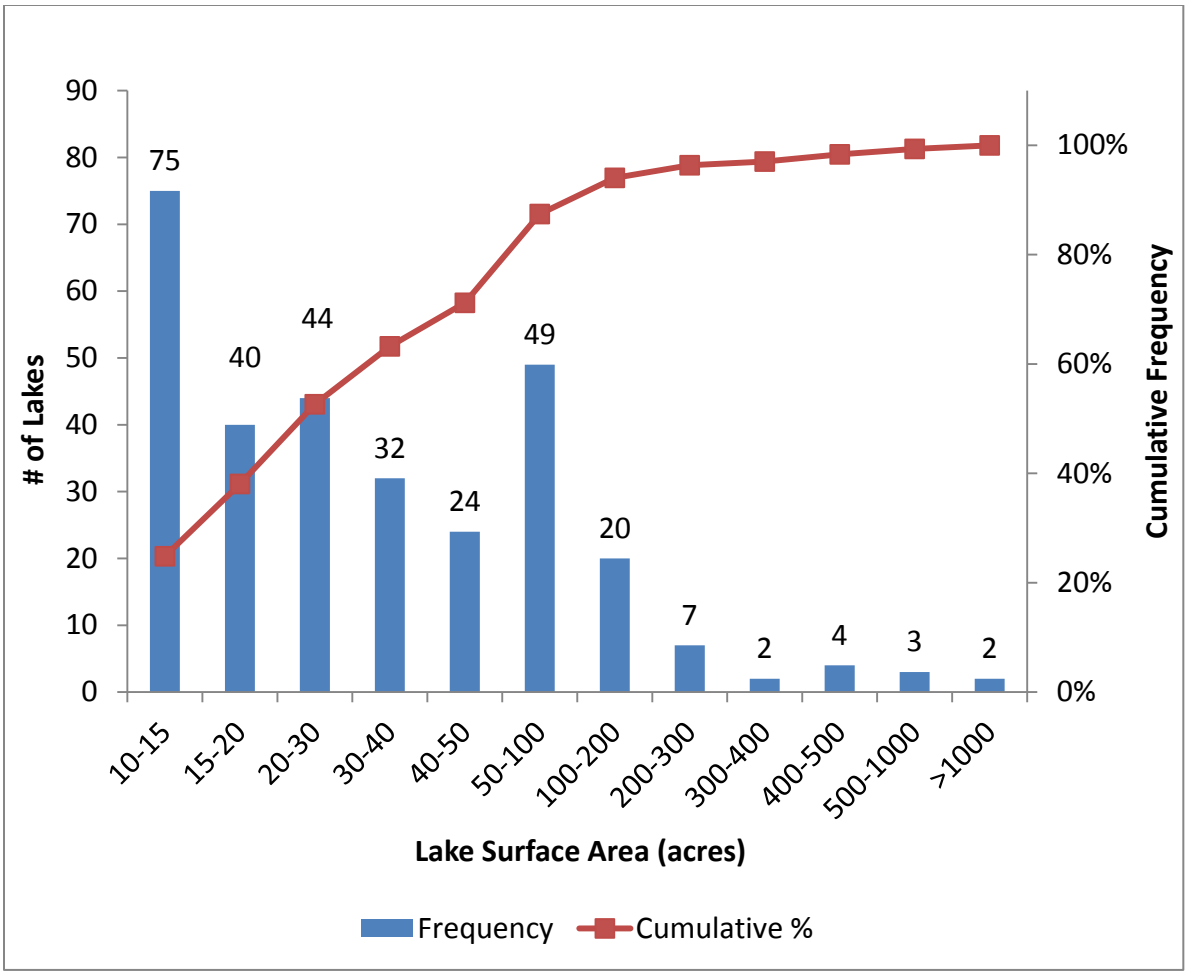


Figure 2. Histogram of Buffalo River Watershed Lake Surface Areas (acres).

Land Use/Land Cover

Lake water quality is highly dependent on the land use/land cover (LULC) of the surrounding area. Since shapefiles of direct contributing areas to the lakes in the BRW were not readily available, the MnDNR Level 8 Catchment (i.e., Catchment) layer was used to identify and quantify the type of LULC in the areas surrounding the study's lakes. This approach assumes that LULC is homogeneous throughout each Catchment and that the LULC characteristics of the MnDNR catchment containing a given lake are the same as that of the lake's actual lakeshed. Given the relative homogeneity of land use across the BRW, this is a safe assumption. Using the Level 8 Catchments is also consistent with the approach used by the MPCA when quantifying LULC surrounding lakes for purposes of water quality assessment (Anderson 2011) (i.e., computing the percent LULC surrounding lakes in the Lake Agassiz Ecoregion when determining which water quality standards should be applied).

Figure 3 shows the MnDNR Level 8 catchments and LULC data for the BRW. Catchments in the study area range in size from 290 to 28,427 acres. The 2006 version of the National Land Cover Dataset (NLCD) was used to define LULC. The ArcGIS zonal statistics command was used to compute the number of raster cells within each catchment for each NLCD LULC category. The fifteen NLCD LULC categories were then condensed into four more general categories (forest, water/wetland, cultivated, urban), using methods consistent with those of the MPCA (Anderson 2011). **Table 1** shows the approach. **Appendix A** shows the results of the LULC analysis for all 300+ lakes in the BRW.

Table 1. 2006 NLCD and Associated General LULC Categories.

NLCD Categories	MPCA Categories
Deciduous Forest Evergreen Forest Mixed Forest Shrub/scrub	Forest
Open Water Woody Wetlands Emergent Herbaceous Wetlands	Water/Wetland
Cultivated Crops	Cultivated
Grassland/herbaceous Pasture/hay Barren	Pasture and Open
Developed Open Space Developed Low Intensity Developed Medium Intensity Developed High Intensity	Urban

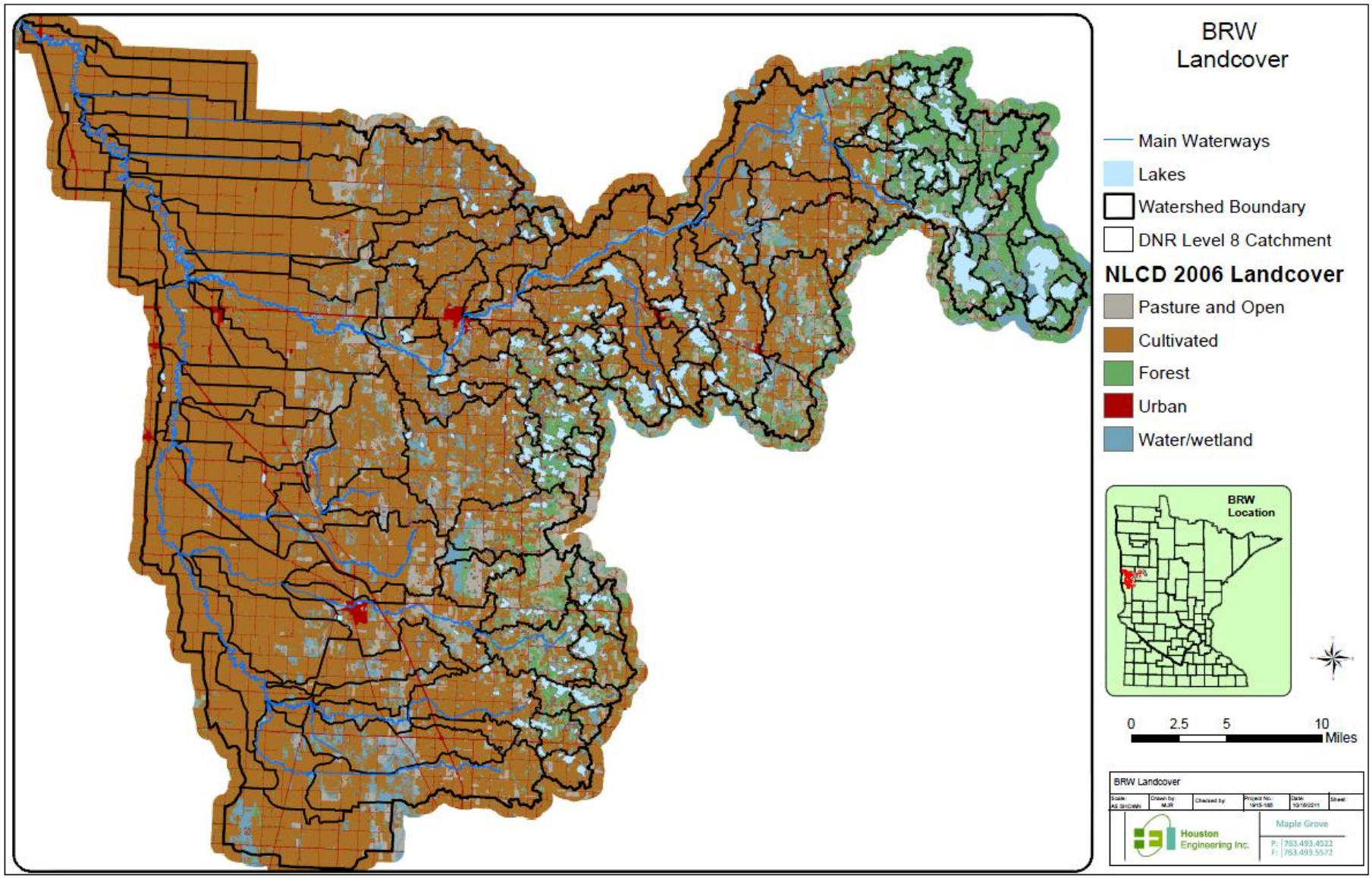


Figure 3. MnDNR Level 8 Catchments and 2006 NLCD Land Use/Land Cover in the Buffalo River Watershed.

The MPCA has defined typical (defined as 25th to 75th percentiles) LULC in reference lake lakesheds of four of the Level III Ecoregions of the State (Heiskary and Wilson 2005). **Table 2** shows those typical ranges, along with the ranges of LULC found in the BRW. The BRW transects three Level III Ecoregions: the Lake Agassiz Plain (LA), the North Central Hardwood Forests (NCHF), and the North Lakes and Forests (NLF). The majority of the watershed is located in the LA Ecoregion with a lesser area of NCHF. Less than 5% of the watershed is located in the NLF Ecoregion. Seven lakes are located in the NLF, 71 are located in the LA, and 224 are located within the NCHF. According to this analysis, BRW lakes have similar coverages as reference lakes within each Ecoregion (**Table 2**). Because landcover in the LA is most similar to the Western Cornbelt Plains (WCBP) and the Northern Glaciated Plains (NGP) ecoregions, MPCA commonly uses the water quality standards associated these ecoregions to apply to BRW LA ecoregion lakes (since the LA ecoregion does not have lake eutrophication standards developed).

Table 2. LULC Ranges (IQR) for Typical Ecoregion Lakes and Lakes within the Buffalo River Watershed.

General LULC Category	NCHF		NLF		WCBP	NGP	LA
	Typical ecoregion[1]	BRW	Typical ecoregion[1]	BRW	Typical ecoregion[1]	Typical ecoregion[1]	BRW
Forest	6-25 %	16-39 %	54-81 %	44-84 %	0-15 %	0-1 %	2-6 %
Water & Wetland	14-30 %	12-22 %	14-31 %	10-50 %	3-26 %	8-26 %	10-15 %
Cultivated	22-50 %	14-48 %	< 1 %	0-0 %	42-75 %	60-82 %	63-77 %
Pasture & Open	11-25 %	9-20 %	0-6 %	3-6 %	0-7 %	5-15 %	7-13 %
Developed	2-9 %	3-5 %	0-7 %	1-2 %	0-16 %	0-2 %	4-5 %

[1] Typical ecoregion values adapted from Heiskary and Wilson 2005.

Average Eutrophication Water Quality

Water quality data in the BRW was obtained from MPCA personnel, who downloaded the complete record of data available. This analysis focuses on the eutrophication of lakes, therefore, the three constituents (total phosphorus concentrations, chlorophyll-a concentrations, and Secchi disk depth) that address this phenomena were used. Since Minnesota water quality standards are written to address eutrophication during the summer months (defined as June through September), the analyses focused only on data collected during those times. To provide as comprehensive of a dataset as possible, all years of available data were included. **Table 3** summarizes the data available for analyzing the eutrophication water quality of the lakes in the BRW, including the years that observations were recorded and select other classification variables. As shown in **Table 3**, only 48 of the 303 lakes in the BRW have summertime eutrophication water quality data available.

Table 3. Select Characteristics for BRW Lakes with Summertime Eutrophication Water Quality Data Available.

Lake Name	Level III Ecoregion	"Shallow" vs. "Deep"	% Littoral	Impairment	Avg TSI	Avg Trophic Status	% of Land Use in MN DNR Catchment					Years of WQ Data		Summertime Total Phosphorus (ppb)				Summertime Chlorophyll-a (ppb)				Summertime Secchi Disk Depth (m)			
							Water/ Wetland	Urban	Forest	Pasture/ Open	Cultivated	Min	Max	n	Min	Max	Mean	n	Min	Max	Mean	n	Min	Max	Mean
ANFINSON	NCHF	Shallow	100	None	72	Hyper-	14.5	4.3	3.7	12.3	65.1	2006	2006	1	108	108	108								
AXBERG (MAIN BASIN)	NCHF	Shallow	100	None	77	Hyper-	22.0	3.3	28.9	9.2	36.6	1994	2000	15	168	325	232.9	11	65	188	143.4	15	0.30	0.76	0.46
AXBERG (WEST BASIN)	NCHF	Shallow	100	None	92	Hyper-	22.0	3.3	28.9	9.2	36.6	1994	1997	4	740	1440	1142.5	3	166	716	400.7	4	0.08	0.76	0.36
BIG SUGAR BUSH	NCHF	Deep	69	None	40	Mesotrophic	30.1	2.4	64.3	2.6	0.5	1975	2010	33	5	21	13.2	33	1	7	3.3	518	2.3	9.8	5.3
BIRCH	NCHF	Deep	72	None	53	Eutrophic	29.4	0.8	62.5	5.8	1.5	2009	2010	12	13	66	37.4	12	1	50	16	12	1.2	4.9	2.8
BOYER	NCHF	Deep	53	Nutrients	57	Eutrophic	25.9	3.6	22.8	7.6	40.1	2008	2009	11	30	93	54. 4	11	2	62	23.7	11	0.91	5	2.4
BUFFALO	NCHF	Shallow	47	None	48	Mesotrophic	23.0	4.7	46.5	19.9	6.0	1988	2009	32	14	38	22.4	31	2	17	8.1	341	1.5	5.2	2.9
CANARY	NCHF	Deep	66	None	55	Eutrophic	25.9	3.6	22.8	7.6	40.1	2007	2010									8	0.76	2.3	1.6
EAST LABELLE	Agassiz	Deep	42	None	54	Eutrophic	30.6	12.9	14.3	8.3	33.9	2009	2010	12	22	69	37.5	12	5	24	14.6	12	1.5	2.6	2.1
ELEVEN	NCHF	Deep	unknown	None	49	Mesotrophic	16.6	3.5	39.1	15.7	25.1	2009	2010	12	19	44	25.6	12	2	16	6.2	11	1.4	2.7	2.2
FIFTEEN	NCHF	Deep	74	None	53	Eutrophic	14.4	4.6	36.6	30.1	14.2	1977	2010	12	23	47	33	12	5	32	14.1	24	1.4	3.2	2.3
FORGET-ME-NOT	NCHF	Shallow	100	Nutrients	64	Eutrophic	16.1	3.9	14.5	6.8	58.7	2009	2010	12	34	159	82.4	12	3	59	27.4	12	0.61	1.7	0.94
GOTTENBERG	NCHF	Shallow	100	Nutrients	64	Eutrophic	21.9	3.4	31.3	14.4	28.9	2009	2010	12	48	103	68	12	12	68	33.8	12	0.6	1.2	0.81
GOURD	NCHF	Shallow	100	Nutrients	70	Hyper-	32.5	4.3	21.7	7.5	34.0	2009	2010	12	70	180	113.3	12	24	93	53.9	12	0.3	0.76	0.58
GROVE	NCHF	Shallow	92	None	52	Eutrophic	15.9	3.4	19.9	16.2	44.6	2009	2010	14	23	88	39.7	14	1	35	11.7	13	1.5	5.8	3.29
HARRISON (HELGESON)	NCHF	Shallow	100	None	61	Eutrophic	15.1	4.0	25.0	42.0	13.8	2009	2010	12	25	104	53.6	12	10	61	33.3	11	0.91	2.1	1.4
ISLAND	NCHF	Shallow	100	None	48	Mesotrophic	32.6	0.7	60.2	5.5	1.1	2009	2010	12	15	68	22.9	12	2	12	6.1	12	2	3.1	2.5
JACOBS	NCHF	Deep	unknown	Nutrients	62	Eutrophic	14.4	5.5	29.1	12.1	38.9	2009	2010	12	37	231	86.8	12	4	86	37.5	11	0.9	4.1	1.9
LEE	NCHF	Deep	64	None	59	Eutrophic	14.9	3.7	22.2	14.7	44.4	2010	2010	4	33	62	42.5	4	8.19	35	17.8	4	0.9	1.2	1.1
LIME	NCHF	Shallow	100	Nutrients	70	Hyper-	18.8	6.9	10.8	6.9	56.6	2009	2010	12	65	210	137. 7	12	13	112	63.4	12	0.3	1.7	0.85
LITTLE ROUND	NCHF	Shallow	100	None	51	Eutrophic	40.1	1.8	49.1	9.0	0.0	2003	2010	9	16	35	24.1	8	1.43	3.4	2.6	9	0.5	1.1	0.83
LITTLE SUGAR BUSH	NCHF	Shallow	45	None	49	Mesotrophic	21.8	2.6	59.9	15.7	0.0	2009	2010	12	10	36	22.2	12	3	48	10.8	12	1.5	4.3	3.0
LUND BROTHERS MARSH	NCHF	Shallow	100	None	76	Hyper-	11.7	5.8	3.4	2.9	76.2	2003	2003	1	133	133	133					1	0.3	0.3	0.3
MARIA	Agassiz	Shallow	100	Nutrients	70	Hyper-	10.3	6.7	1.6	8.0	73.4	2009	2010	12	109	330	199.2	12	6	112	55.5	11	0.3	2.4	1.1
MARSHALL	NCHF	Deep	66	Nutrients	56	Eutrophic	33.6	3.4	19.0	5.6	38.5	2008	2009	12	18	63	41.8	12	2	85	20.5	11	1.1	3.1	1.8
MISSION	NCHF	Shallow	100	Nutrients	71	Hyper-	31.1	2.5	44.0	6.5	15.9	2009	2010	12	102	139	120.3	12	58	120	75.6	12	0.3	1.1	0.58
NORTH TAMARACK	NLF	Shallow	97	Nutrients	55	Eutrophic	50.7	1.6	44.2	3.5	0.0	2005	2010	23	5	54	35.6	21	5	29	12.9	69	0.76	5.2	1.7
O-ME-MEE	NCHF	Shallow	100	None	59	Eutrophic	16.3	4.2	30.2	19.8	29.6	2009	2010	12	16	113	67.9	12	2	53	21.3	12	0.91	2.6	1.7
PETE	NCHF	Shallow	100	None	54	Eutrophic	14.8	5.7	33.8	20.7	25.2	2009	2010	12	33	79	54.3	12	4	30	12.4	11	1.2	5.2	3.0
PINE	NLF	Shallow	89	None	50	Mesotrophic	48.5	2.0	44.3	5.2	0.0	2005	2010	23	16	42	24.2	21	4	11.7	7.5	71	1.1	3.7	2.1
RICE	NCHF	Deep	74	None	49	Mesotrophic	40.7	2.9	33.8	22.6	0.0	1995	2009	16	16	41	27.6	16	1	21	6.7	33	1.68	3.8	2.5
ROCK	NCHF	Deep	83	None	51	Eutrophic	41.3	2.9	38.2	14.3	3.3	1994	2010	17	16	51	27.1	17	3	14	7.6	87	0.91	3.4	1.9
SAND (STUMP)	NCHF	Deep	52	Nutrients	62	Eutrophic	22.0	3.3	28.9	9.2	36.6	1994	2008	50	30	835	138.9	38	4	131	26.1	63	0.5	5.8	2.0
SAND (YORT)	NCHF	Shallow	100	None	60	Eutrophic	32.1	2.2	8.2	14.2	43.3	2002	2002	3	71	101	82.7	3	4	12	8.7	3	0.76	1.3	1.1
SILVER	Agassiz	Deep	33	None	57	Eutrophic	16.7	5.4	7.8	13.4	56.7	2008	2010	6	24	76	49.5	6	5	37.4	17.3	6	0.8	3.4	1.8
SORENSON	NCHF	Shallow	100	Nutrients	66	Eutrophic	15.9	3.1	19.3	14.6	47.1	1999	2008	54	51	397	175.1	45	1	266	40.2	44	0.53	4.7	1.7
SOUTH TAMARACK	NLF	Shallow	100	None	48	Mesotrophic	68.2	2.3	28.8	0.7	0.0	2005	2010	13	12	31	20.5	12	1.43	7	4.1	36	1.68	2.1	1.9

ST. CLAIR	NCHF	Deep	88	None	48	Mesotrophic	16.8	2.3	70.5	7.5	2.9	2009	2010	12	16	40	24.3	12	1	18	7.8	12	1.7	5	3.1
STAKKE	NCHF	Shallow	100	Nutrients	61	Eutrophic	23.9	2.7	25.3	12.2	35.8	2003	2009	10	33	92	64.2	9	2	61	29.8	9	0.5	3.2	1.5
STINKING	Agassiz	Shallow	100	Nutrients	76	Hyper-	11.7	5.8	3.4	2.9	76.2	2009	2010	12	92	596	308.6	12	2	214	95.8	12	0.2	0.91	0.66
SWEDE GROVE	Agassiz	Shallow	100	None	61	Eutrophic	31.9	3.7	6.3	1.6	56.4	2009	2010	12	36	115	76.8	12	4	58	29.5	11	0.6	3.7	1.6
TALAC	NCHF	Shallow	100	Nutrients	61	Eutrophic	15.9	3.1	19.3	14.6	47.1	1987	2010	35	32	622	88.7	31	4	87.8	26.0	282	0.61	5.0	1.6
TEN	NCHF	Deep	90	None	59	Eutrophic	25.4	3.5	29.1	17.3	24.7	2009	2010	12	25	98	57.2	12	9	61	27	11	0.9	2.9	1.7
TURTLE	NCHF	Deep	37	None	40	Mesotrophic	23.5	5.9	33.2	22.9	14.4	1947	2010	53	2	40	16.5	51	0.64	28	3.5	823	1.68	11. 9	6.3
UNNAMED	NCHF	Shallow	unknown	None	70	Hyper-	16.7	5.4	7.8	13.4	56.7	2003	2003	1	142	142	142					1	0.76	0.76	0.76
UNNAMED (NORTH MAYFIELD)	NCHF	Shallow	unknown	None	47	Mesotrophic	14.4	4.6	36.6	30.1	14.2	2007	2007									1	2.5	2.5	2.5
WEST LABELLE	Agassiz	Shallow	100	Nutrients	64	Eutrophic	32.8	10.1	8.0	1.7	47.4	2009	2010	12	40	124	89.3	12	7	89	41.1	12	0.76	2.6	1.3
WEST OLAF	NCHF	Deep	35	None	52	Eutrophic	15.5	4.3	36.6	15.1	28.6	2005	2010	15	17	48	29.9	14	8	20	11	19	1.4	3.5	2.4

Mean summer concentrations of total phosphorus (TP) and chlorophyll-a (chl-a) and mean Secchi disk depths were computed for each lake. In addition, the data were also used to develop water quality statistics for "example" lakes as discussed below and to develop stressor-response relationships (using "paired" data) for each lake class developed. More details on these analyses are provided below.

Trophic Status Index

Trophic status refers to how productive a lake is or the degree of nutrient enrichment in a water body. The trophic status index (TSI) was created by R.E. Carlson (Carlson 1977) as a method to characterize a lake's health or productivity. TSI scale ranges from zero to 100 in which zero indicates an oligotrophic lake with low nutrient concentrations and 100 is a hypereutrophic lake with very high nutrient concentrations. TSI scores examine the relationship between TP, chl-a, and Secchi disk depth and were calculated using the following equations:

Total phosphorus TSI (TSI-P) = 14.42*[ln(TP average)]+4.15
Chlorophyll-a TSI (TSI-C) = 9.81*[ln(Chlorophyll-a average)]+30.6
Secchi disk TSI (TSI-S) = 60 – (14.41*[ln(Secchi average)])
Average TSI = (TSI-P + TSIC + TSIS) / 3

TSI scores were calculated for all lakes with water quality data available. Mean summer TSI values for each lake are shown in **Table 3**.

LAKE GROUPING

Background

The main purpose of the lake grouping exercise is to understand the differences in how lakes within the BRW receive and respond to nutrient loading and to group them accordingly for future modeling/ management purposes. Minnesota lake eutrophication water quality standards were developed under the assumption that lakes respond differently to nutrient loading based on their Level III ecoregion and if they are "shallow" or "deep". One outcome of the grouping exercise performed here is to determine if that assumption holds true for lakes in the BRW, based on the water quality data available. Analyses were also performed to investigate other methods for grouping lakes to see if they showed different historic eutrophication water quality, potentially implying different expected responses to nutrient loads.

Since the outcomes of this analysis will be a grouping scheme for use in developing BATHTUB receiving water models (in future tasks), it is important to focus our efforts only on those lakes that have sufficient data to actually create a model. Data requirements for model development include: lake volume (computed, in this case, as a function of surface area and mean depth) and eutrophication water quality data. In addition, the analysis itself is reliant on the use of historic water quality data. **Table 4** summarizes the number of lakes in the BRW that have these data available by Level III ecoregion.

Table 4. Summary of lakes with available water quality and morphometric data.

Ecoregion	Total # of waterbodies	Total # of lakes	Lakes with water quality data	Lakes with maximum depth	Lakes with mean depth	Lakes with water quality data, maximum depth, and mean depth
LA	1107	71	7	10	0	0
NCHF	1031	225	38	77	12	9
NLF	35	7	3	4	0	0
Total	2173	303	48	91	12	9
Note: All lakes have a surface area as defined by the MN DNR lakes 24 k data layer.						

As shown in **Table 4**, relatively few lakes within the BRW have mean depth data available. A large number of them, however, do have maximum depths. Twelve lakes have both mean and maximum depths available. In an effort to fill data gaps and create more information for model development, a relationship was developed between mean and maximum depths and used to estimate mean depths for those lakes that lack the data. The resultant linear regression equation showed that

$$\text{Mean depth (m)} = 0.48 * \text{Maximum Depth (m)} + 0.58$$

and resulted in an r^2 value of 0.710. When possible, this relationship was used to estimate mean depths for all lakes that lacked the data (based on their reported maximum depth). Results are shown in **Appendix A**.

Comparing Historic Water Quality by Lake Classification Variables

One way to identify the expected response of a lake (or group of lakes) to nutrient loading is to view historic water quality data. If different lakes (or groups of lakes) show statistically different historic data, one can anticipate that they have different responses to nutrient loading or that they are receiving different types of nutrient loads. In either case, the management strategies associated with those lakes should be different. The purpose of this exercise is to investigate different approaches to grouping BRW lakes and see if historic eutrophication water quality data is statistically significantly different.

A qualitative analysis of the impact of grouping BRW lakes by classification variable can be done through the use of box and whisker plots. These plots show the distribution of the water quality parameters by group. **Figures 4 through 6** show the box and whisker plots created to compare historic BRW lake summer TP, chl-a, and Secchi disk depth data, grouping the lakes by Level III Ecoregion. **Figures 7 through 9** show a similar comparison grouping the lakes by relative depth (i.e., “deep” vs. “shallow” as defined by the State’s water quality standards).

Figure 4: Summer TP Concentrations in BRW Lakes When Grouped by Level III Ecoregion.

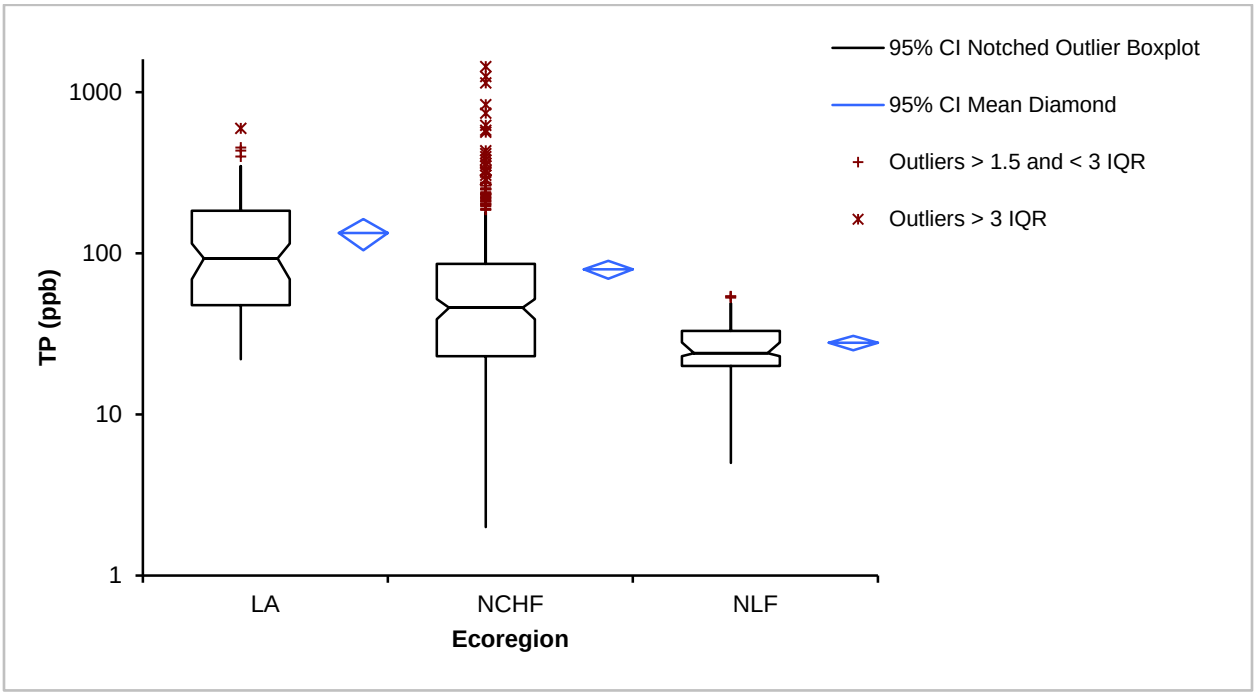


Table 5: Results of Kruskal-Wallis Test for Summer TP Concentrations by Level III Ecoregion.

n	707		
TP (ppb) by Ecoregion	n	Rank sum	Mean rank
LA	66	33244.0	503.70
NCHF	582	204624.5	351.59
NLF	59	12409.5	210.33
Kruskal-Wallis' statistic	64.74		
X^2 statistic	64.74		
DF	2		
p	<0.0001	(chisqr approximation, corrected for ties)	
Bonferroni Contrast	Difference	p	
LA v NCHF	152.1085	<0.0001	
LA v NLF	293.3665	<0.0001	
NCHF v NLF	141.2580	<0.0001	

Figure 5: Summer Chl-a Concentrations in BRW Lakes When Grouped by Level III Ecoregion.

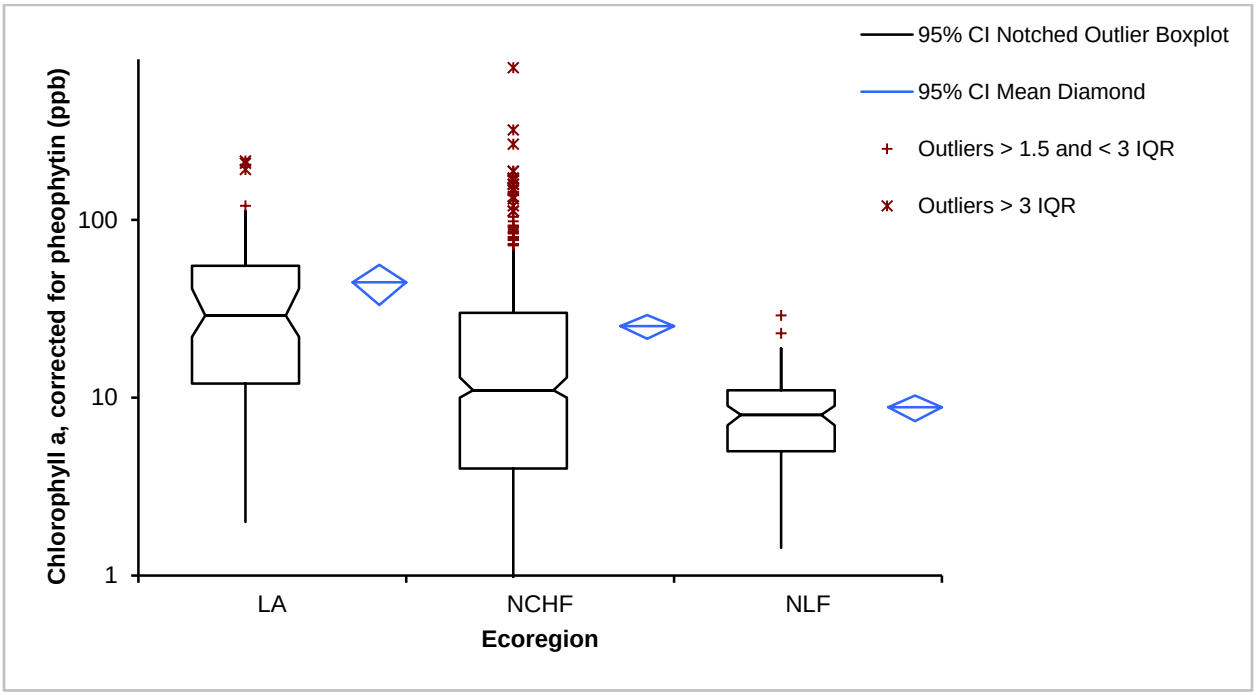


Table 6: Results of Kruskal-Wallis Test for Summer Chl-a Concentrations by Level III Ecoregion.

n	663		
Chlorophyll a, corrected for pheophytin (ppb) by Ecoregion	n	Rank sum	Mean rank
LA	66	30492.5	462.01
NCHF	543	176240.0	324.57
NLF	54	13383.5	247.84
Kruskal-Wallis' statistic	41.70		
X^2 statistic	41.70		
DF	2		
p	<0.0001	(chisqr approximation, corrected for ties)	
Bonferroni Contrast	Difference	p	
LA v NCHF	137.4404	<0.0001	
LA v NLF	214.1650	<0.0001	
NCHF v NLF	76.7246	0.0117	

Figure 6: Summer Secchi Disk Depths in BRW Lakes When Grouped by Level III Ecoregion.

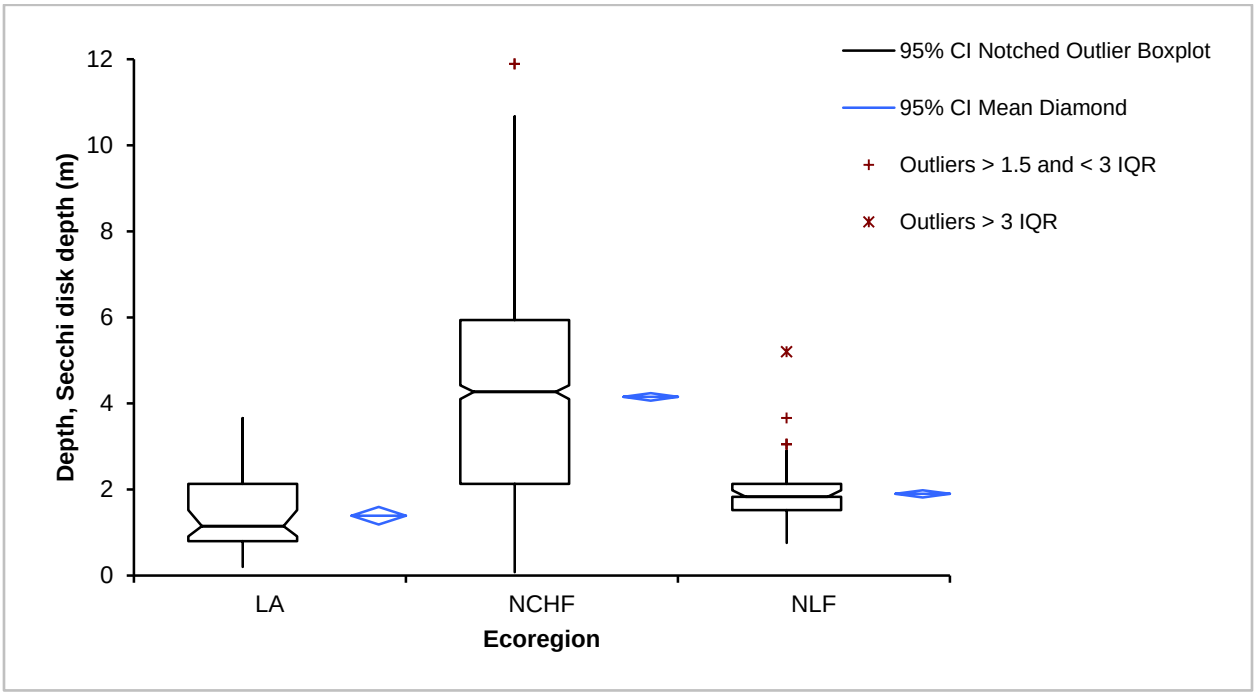


Table 7: Results of Kruskal-Wallis Test for Summer Secchi Disk Depths by Level III Ecoregion.

n	2739		
Depth, Secchi disk depth (m) by Ecoregion	n	Rank sum	Mean rank
LA	64	26137.5	408.40
NCHF	2499	3611163.5	1445.04
NLF	176	115129.0	654.14
Kruskal-Wallis' statistic	261.44		
X^2 statistic	261.44		
DF	2		
p	<0.0001	(chisqr approximation, corrected for ties)	
Bonferroni Contrast	Difference	p	
LA v NCHF	-1036.6450	<0.0001	
LA v NLF	-245.7436	0.0759	
NCHF v NLF	790.9014	<0.0001	

The box and whisker plots show a clear difference between eutrophication water quality in the BRW lakes when separated by Level III ecoregion. **Figures 4 and 6** show that the historical TP and chl-a concentrations in the lakes of the BRW are highest in the LA ecoregion and trend downward as you move east to the NCHF and the NLF. Secchi disk depths (**Figure 6**) follow a similar pattern in the LA and NCHF ecoregions (with greater observed depths in the NCHF than the LA ecoregion), but do not follow the expected trend in the NLF. Given that TP and chl-a concentrations in the NLF lakes are lower than those in the LA and NCHF ecoregions, we would expect their Secchi disk depths to be deeper (in comparison). The observed (shallow) Secchi disk depths in this ecoregion may be due to the relative depth of the lakes with water quality data, rather than the lakes' response to nutrient loading; the three lakes with water quality data in this area all have computed mean depths of less than 10 feet.

Figure 7: Summer TP Concentrations in BRW Lakes Grouped by Relative Depth.

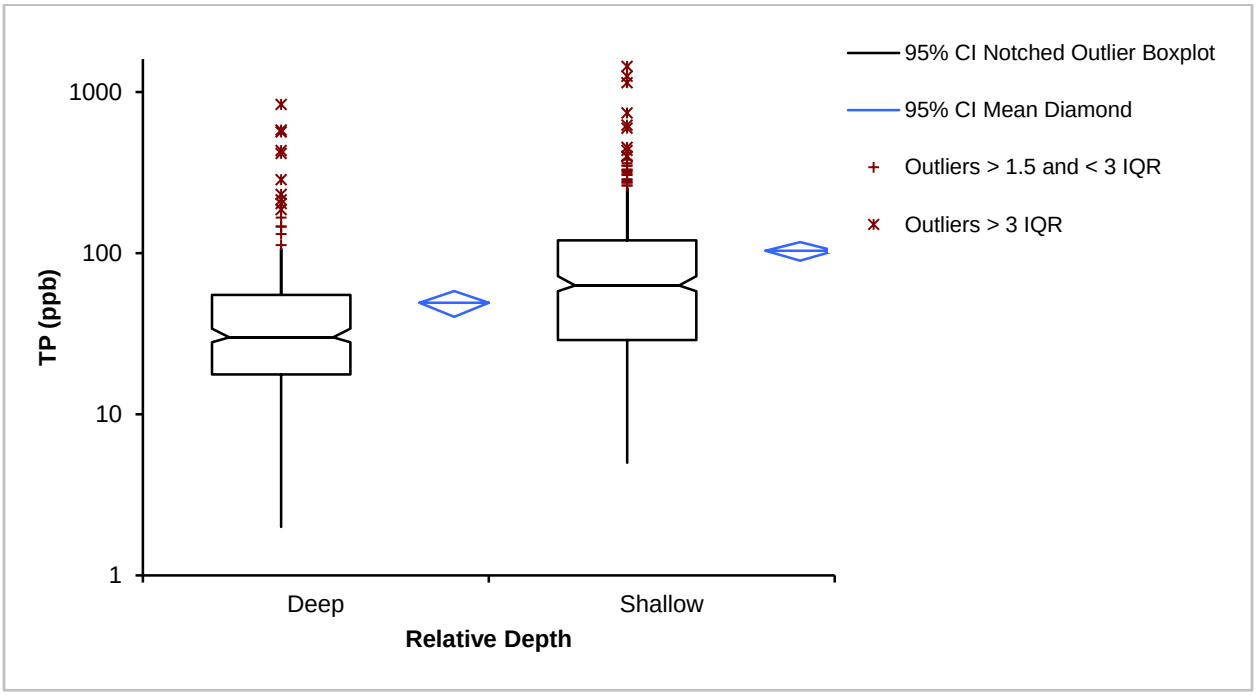


Table 8: Results of Kruskal-Wallis Test for Summer TP Concentrations Grouped by Relative Depth.

n	707		
TP (ppb) by Shallow v. Deep	n	Rank sum	Mean rank
Deep	301	80021.5	265.85
Shallow	406	170256.5	419.35
Kruskal-Wallis' statistic	97.65		
X^2 statistic	97.65		
DF	1		
p	<0.0001	(chisqr approximation, corrected for ties)	
Bonferroni Contrast	Difference	p	
Deep v Shallow	-153.4988	<0.0001	

Figure 8: Summer Chl-a Concentrations in BRW Lakes When Grouped by Relative Depth.

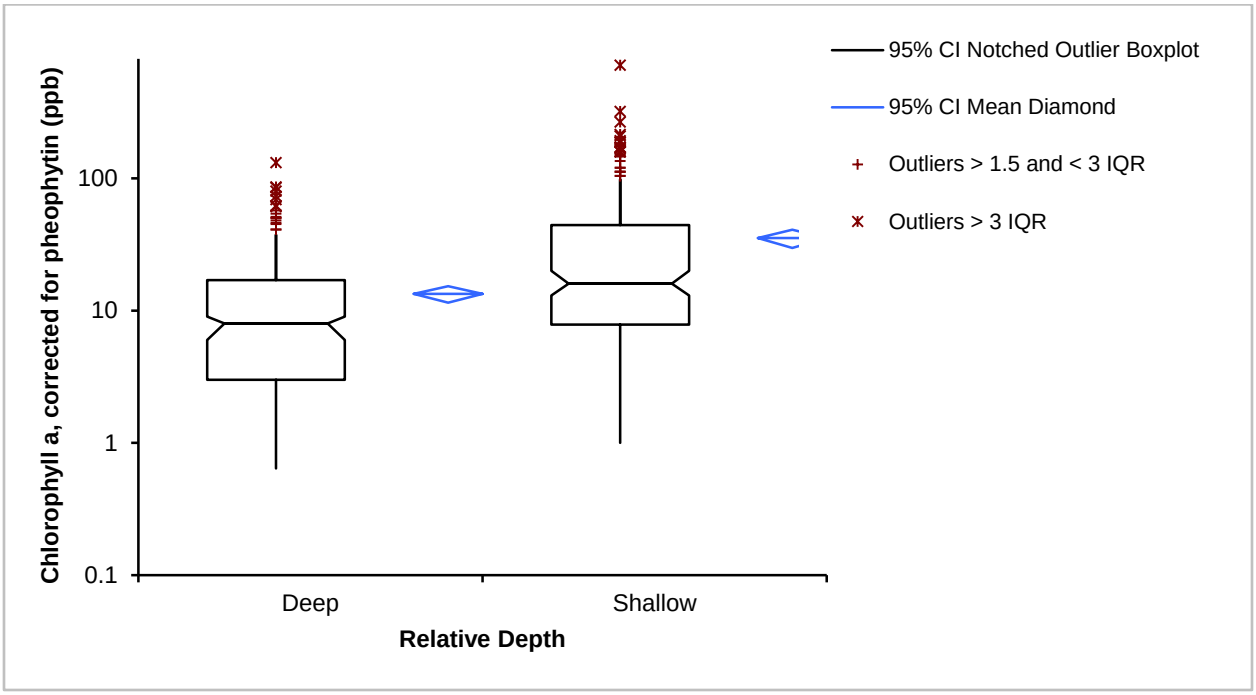


Table 9: Results of Kruskal-Wallis Test for Summer Chl-a Concentrations by Relative Depth.

n	663		
Chlorophyll a, corrected for pheophytin (ppb) by Shallow v. Deep	n	Rank sum	Mean rank
Deep	286	74298.5	259.78
Shallow	377	145817.5	386.78
Kruskal-Wallis' statistic	71.58		
X^2 statistic	71.58		
DF	1		
p	<0.0001	(chisqr approximation, corrected for ties)	
Bonferroni Contrast	Difference	p	
Deep v Shallow	-126.9989	<0.0001	

Figure 9: Summer Secchi Disk Depths in BRW lakes when grouped by Relative Depth.

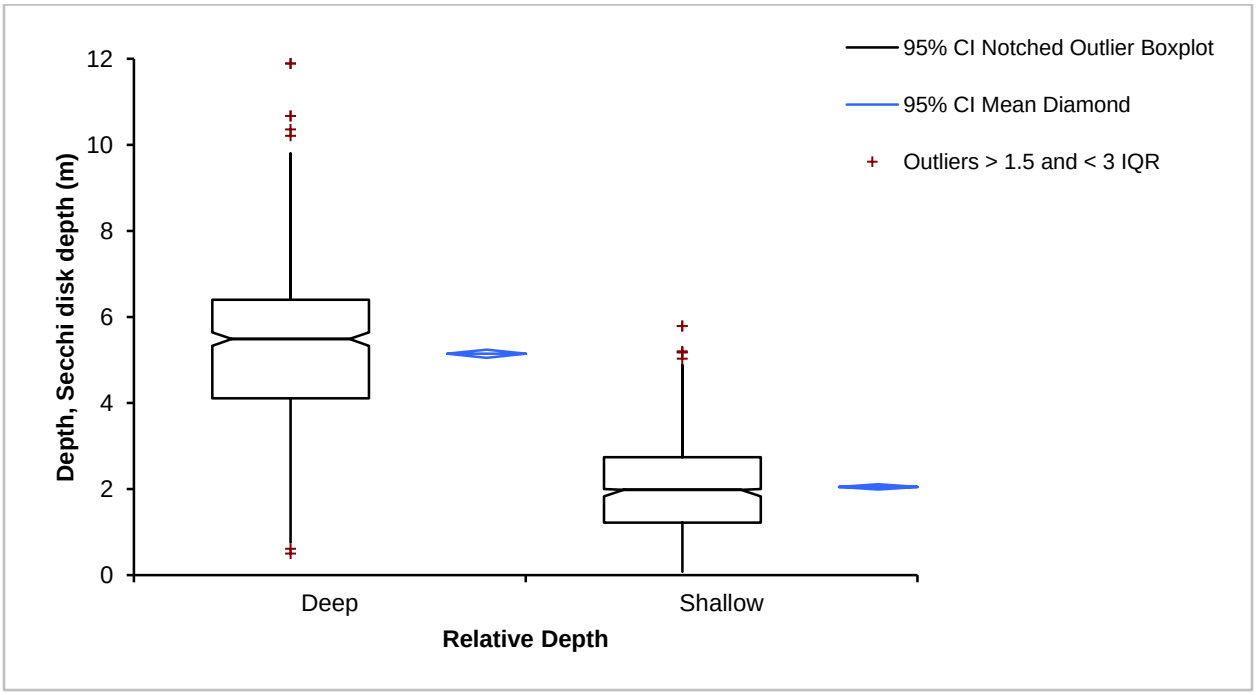


Table 10: Results of Kruskal-Wallis Test for Summer Secchi Disk Depths by Relative Depth

n	2739		
Depth, Secchi disk depth (m) by Shallow v. Deep	n	Rank sum	Mean rank
Deep	1676	3003683.0	1792.17
Shallow	1063	748747.0	704.37
Kruskal-Wallis' statistic	1231.19		
X^2 statistic	1231.19		
DF	1		
p	<0.0001	(chisqr approximation, corrected for ties)	
Bonferroni Contrast	Difference	p	
Deep v Shallow	1087.8020	<0.0001	

Clear differences are seen in the historic water quality data of the "deep" versus "shallow" lakes of the BRW. **Figures 7 and 8** show that the TP and chl-a concentrations are historically greater in shallow lakes. As expected, **Figure 9** shows Secchi disk depths are historically lower in the shallow lakes.

A more quantitative approach to viewing these differences in historic water quality data is through the use of statistical analysis. Analysis of variance is a statistical method that considers multiple data sets, categorized by group, and tests whether or not the statistical distributions of the data within each group are statistically significantly equal to one another (often by assuming that the variances are equivalent and testing the mean or median). As applied in this work, the analysis tests whether the distributions of TP, chl-a, and Secchi disk depth data amongst the lake groups are statistically significantly different from one another. To determine which analysis of variance test is most appropriate for this work, the data sets were first tested to see if they could be described using a Normal distribution. Normal probability plots and results of the Shapiro-Wilk Test indicate that the distributions of TP, chl-a, and Secchi depth are not Normal. A non-parametric statistical test is, therefore, preferred.

The Kruskal-Wallis test is a non-parametric statistical test that analyzes different groups of data to see if the median ranks of each group are statistically significantly different from one another. This test was used to compare TP, chl-a and Secchi disk depth data between the lake groups. Results of the analyses for grouping by Level III Ecorgeions and relative depth are shown in **Tables 4 through 10**.

Results of the Kruskal-Wallis test are summarized in the resultant p-value, which indicates the likelihood that the analyzed data would be observed by chance alone if the null hypothesis (in this case, that the distributions of data amongst the classifications are all equal) were true. When considering the historic TP concentrations amongst the various ecoregions, the Kruskal-Wallis test resulted in a p-value of <0.0001 (i.e., there is less than a 0.1% chance of observing the data that we have if the distributions amongst the three ecoregions are statistically equivalent), indicating that at least one of the distributions of TP is statistically significantly different from the remainder of the groups. Similar results are seen when considering chl-a and Secchi disk depths by ecoregion and also when considering the historic data by relative depth.

To determine if all of the distributions are different from one another, a series of pairwise Kruskal-Wallis tests were performed using the Bonferroni approach. Results of these analyses are also expressed through a p-value and shown in **Tables 4 through 10**. The pairwise analysis on the TP concentrations by ecoregion showed p-values of <0.0001, indicating that all the distributions are each statistically significantly different from one another when using a 95% confidence interval. Similar results are seen when considering chl-a by ecoregion. P-values for the Secchi disk depth comparison show a value of 0.076 when comparing the data in the LA and NLF ecoregions, indicating that these distributions are not statistically significantly different at a 95% confidence interval. All p-values are <0.0001 when comparing data by relative depth. Results of these analyses confirm that (for the most part) observed water quality in the lakes of the BRW differ when grouped by ecoregion or by relative depth.

State water quality standards are written to address lakes by both ecoregion and relative depth. To investigate this approach, based on historic water quality data in the BRW, the available data was grouped in this manner and the analyses were re-run. **Figures 10 through 12** and **Tables 11 through 13** show the results.

Figure 10: Summer TP Concentrations in BRW Lakes When Grouped by Ecoregion & Relative Depth.

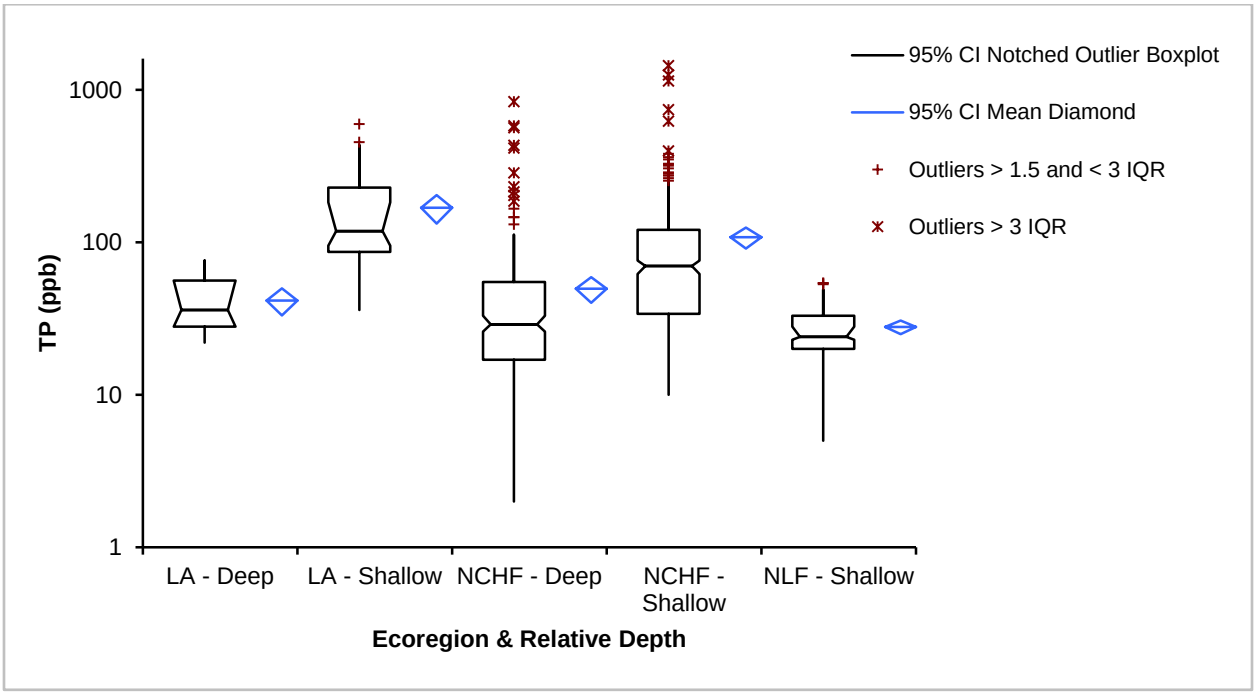


Table 11: Results of Kruskal-Wallis Test for Summer TP Concentrations by Ecoregion & Relative Depth.

n	707		
TP (ppb) by Eco & Depth	n	Rank sum	Mean rank
LA - Deep	18	5737.0	318.72
LA - Shallow	48	27507.0	573.06
NCHF - Deep	283	74284.5	262.49
NCHF - Shallow	299	130340.0	435.92
NLF - Shallow	59	12409.5	210.33
Kruskal-Wallis' statistic	189.90		
X^2 statistic	189.90		
DF	4		
p	<0.0001	(chisqr approximation, corrected for ties)	
Bonferroni Contrast	Difference	p	
LA - Deep v LA - Shallow	-254.3403	<0.0001	
LA - Deep v NCHF - Deep	56.2328	1.0000	
LA - Deep v NCHF - Shallow	-117.1975	0.0597	
LA - Deep v NLF - Shallow	108.3917	0.2180	
LA - Shallow v NCHF - Deep	310.5731	<0.0001	
LA - Shallow v NCHF - Shallow	137.1428	<0.0001	
LA - Shallow v NLF - Shallow	362.7320	<0.0001	
NCHF - Deep v NCHF - Shallow	-173.4303	<0.0001	
NCHF - Deep v NLF - Shallow	52.1589	0.3777	
NCHF - Shallow v NLF - Shallow	225.5892	<0.0001	

Figure 11: Summer Chl-a Concentrations in BRW lakes when grouped by Ecoregion & Relative Depth.

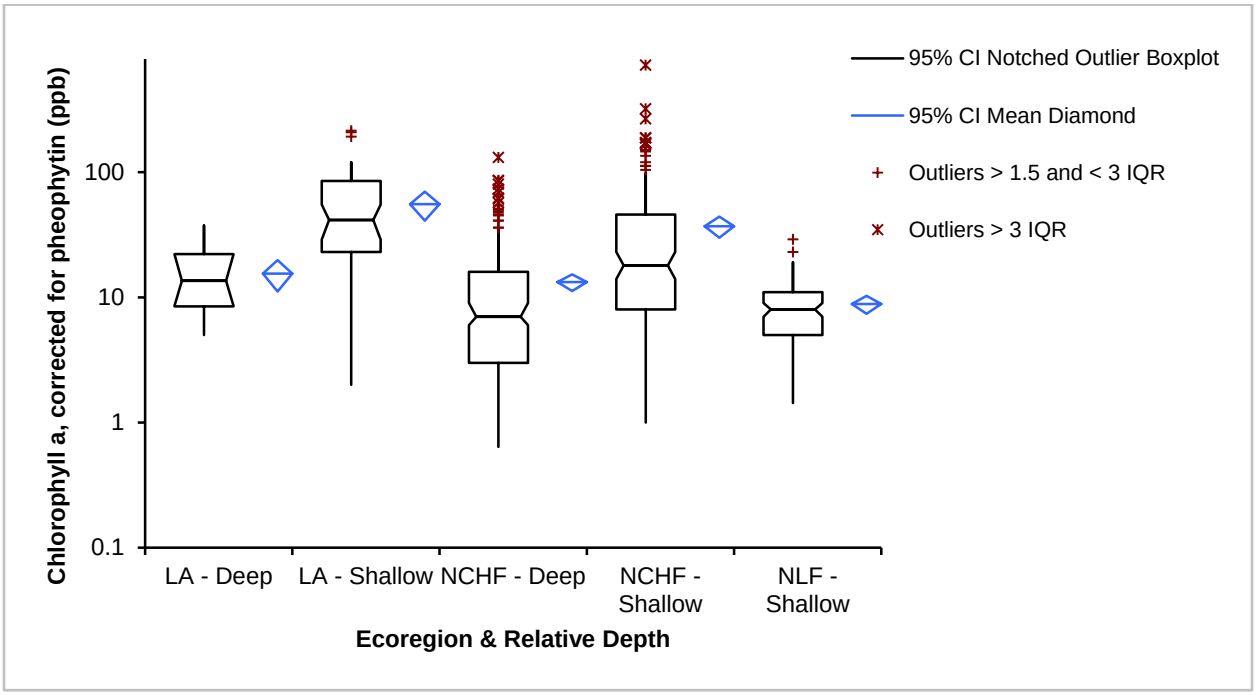


Table 12: Results of Kruskal-Wallis Test for Summer Chl-a Concentrations by Ecoregion & Relative Depth.

n	663		
Chl-a, corrected for pheophytin (ppb) by Eco & Depth	n	Rank sum	Mean rank
LA - Deep	18	6347.5	352.64
LA - Shallow	48	24145.0	503.02
NCHF - Deep	268	67951.0	253.55
NCHF - Shallow	275	108289.0	393.78
NLF - Shallow	54	13383.5	247.84
Kruskal-Wallis' statistic	122.61		
X^2 statistic	122.61		
DF	4		
p	<0.0001	(chisqr approximation, corrected for ties)	
Bonferroni Contrast	Difference	p	
LA - Deep v LA - Shallow	-150.3819	0.0177	
LA - Deep v NCHF - Deep	99.0904	0.1917	
LA - Deep v NCHF - Shallow	-41.1393	1.0000	
LA - Deep v NLF - Shallow	104.7963	0.2665	
LA - Shallow v NCHF - Deep	249.4723	<0.0001	
LA - Shallow v NCHF - Shallow	109.2427	0.0006	
LA - Shallow v NLF - Shallow	255.1782	<0.0001	
NCHF - Deep v NCHF - Shallow	-140.2297	<0.0001	
NCHF - Deep v NLF - Shallow	5.7059	1.0000	
NCHF - Shallow v NLF - Shallow	145.9356	<0.0001	

Figure 12: Summer Secchi Disk Depths in BRW lakes when grouped by Ecoregion & Relative Depth.

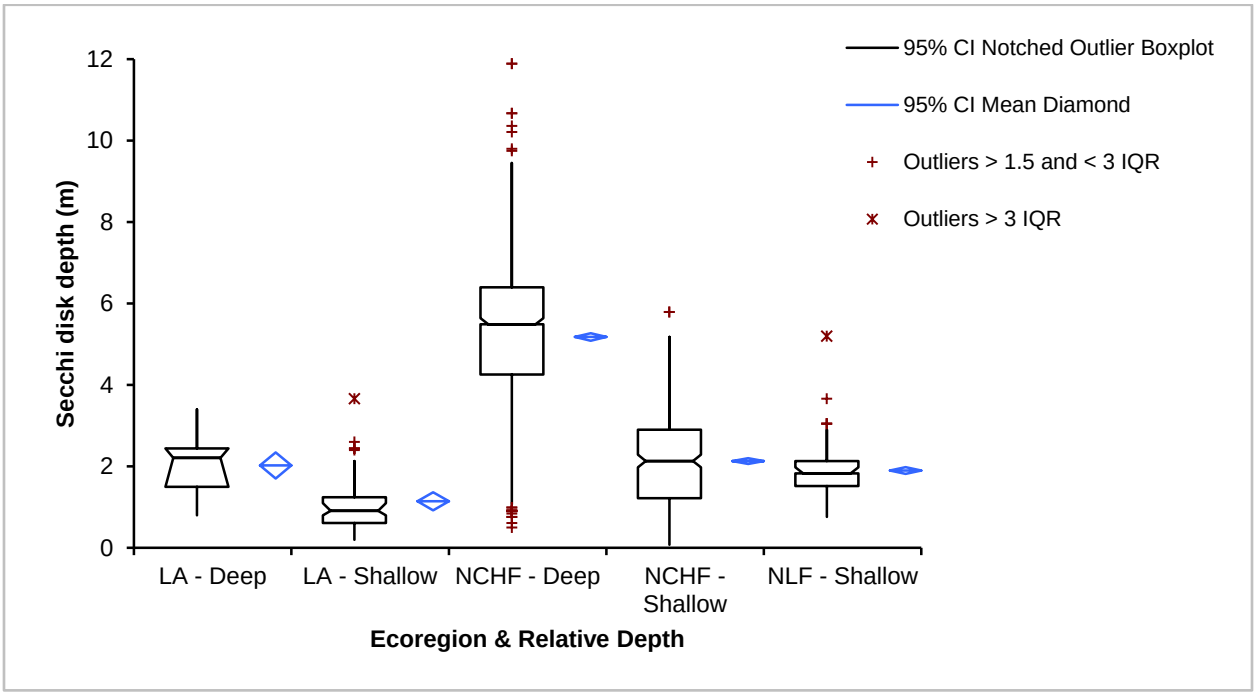


Table 13: Results of Kruskal-Wallis Test for Summer Secchi Disk Depths by Ecoregion & Relative Depth.

n	2739		
Depth, Secchi disk depth (m) by Eco & Depth	n	Rank sum	Mean rank
LA - Deep	18	12707.0	705.94
LA - Shallow	46	13430.5	291.97
NCHF - Deep	1658	2990976.0	1803.97
NCHF - Shallow	841	620187.5	737.44
NLF - Shallow	176	115129.0	654.14
Kruskal-Wallis' statistic	1280.22		
X^2 statistic	1280.22		
DF	4		
p	<0.0001	(chisqr approximation, corrected for ties)	
Bonferroni Contrast	Difference	p	
LA - Deep v LA - Shallow	413.9771	0.0996	
LA - Deep v NCHF - Deep	-1098.0218	<0.0001	
LA - Deep v NCHF - Shallow	-31.4961	1.0000	
LA - Deep v NLF - Shallow	51.8024	1.0000	
LA - Shallow v NCHF - Deep	-1511.9988	<0.0001	
LA - Shallow v NCHF - Shallow	-445.4732	<0.0001	
LA - Shallow v NLF - Shallow	-362.1747	0.0016	
NCHF - Deep v NCHF - Shallow	1066.5257	<0.0001	
NCHF - Deep v NLF - Shallow	1149.8242	<0.0001	
NCHF - Shallow v NLF - Shallow	83.2985	0.8187	

The results of grouping the data by both ecoregion and depth validate the State's methods of managing water quality by Level III ecoregion and relative depth. Results of the pairwise analyses show that TP and chl-a concentrations in "deep" versus "shallow" lakes within the same ecoregions are statistically significantly different (e.g., NCHF "deep" lakes are different than "shallow" lakes; **Figures 10 and 11** and **Tables 11 and 12**). However, the Secchi disk depth data is more variable and the distributions are not always statistically significantly different (**Figure 12** and **Table 13**). Results also show that "deep" vs. "shallow" lake data between ecoregions are not always statistically significantly different from one another (e.g., historic TP concentrations in NCHF "deep" lakes are not different from historic TP concentrations in NLF "shallow" lakes). These results are interesting, but not impactful in this work since we're concerned with the difference between "deep" and "shallow" lakes within the same ecoregions for our purposes.

Additional grouping analysis was performed on the BRW lakes to investigate the impact of considering the historic water quality by other lake characteristics. However, given that most of the other lake classification variables vary across the watershed by geography (e.g., land use) or by relative depth (e.g., % littoral), grouping the lakes by these variables provided a similar analysis to the groupings that were already performed. Also, some lake classification variables are useful for managing lakes (e.g., number of public access points), but are not expected to have a direct (i.e., no other confounding variables in play) impact on the lake's response to nutrient loading. Finally, a main purpose of grouping the lakes for

this work is to inform receiving water models that will provide information for managing water quality in the lakes of the BRW. Given that the State's water quality standards are a main motivator for managing lakes, aligning the lake grouping strategy with the water quality standards (if it makes sense, as the statistical analysis results have shown that it does) is an attractive approach. Given all of these considerations, the decision was made to develop the final grouping of BRW lakes (for future modeling purposes) by ecoregion and relative depth. "Example" lake characteristics were then computed to reflect those five groups (discussed below).

Although the analyses would not be used for developing "example" lakes or for future modeling purposes, additional lake grouping analyses were performed to inform lake management in the watershed. As mentioned earlier, land use surrounding lakes can have a major impact on the type of loading that the waters receive and, therefore, the observed water quality. To view these impacts in the BRW, box and whisker plots were created to analyze the differences in land use characteristics in the MnDNR catchments of impaired versus un-impaired lakes in the area. Results of the analysis show that, as expected, impaired waters in the BRW have significantly higher percentages of cultivated lands in their catchments. Unimpaired waters have more pasture/open lands and forests. The resultant box and whisker plots from this analysis are included in **Appendix B** of this report and may be helpful to the BRRWD and MPCA when managing the waters in the study area.

LAKE CHARACTERISTICS BY GROUP

Stressor-Response Relationships

Eutrophication is the process by which waters acquire an elevated amount of nutrients and results in excessive algal growth and a decrease in transparency. In the eutrophication process, nutrients (in this case, TP) are considered the stressing variable, with chl-a and Secchi disk depth showing a response to an increase or decrease in TP concentration. To view the eutrophication stressor-response dynamic within the lakes of the BRW, linear relationships were developed between the observed water quality data in each ecoregion/relative depth group. These relationships were developed via linear regression, using paired TP/chl-a and chl-a/Secchi disk depth data. Since the observed TP and chl-a concentrations were shown to not follow Normal distributions (discussed earlier) and are typically log-Normal in nature, they were log-transformed for the analysis. Results for the LA Ecoregion are shown in **Figures 13-16**, the NCHF Ecoregion in **Figures 17-20**, and the NLF Ecoregion in **Figures 21-22**.

Figure 13. Total Phosphorus v. Chlorophyll-a for "Shallow" Lakes in the LA Ecoregion.

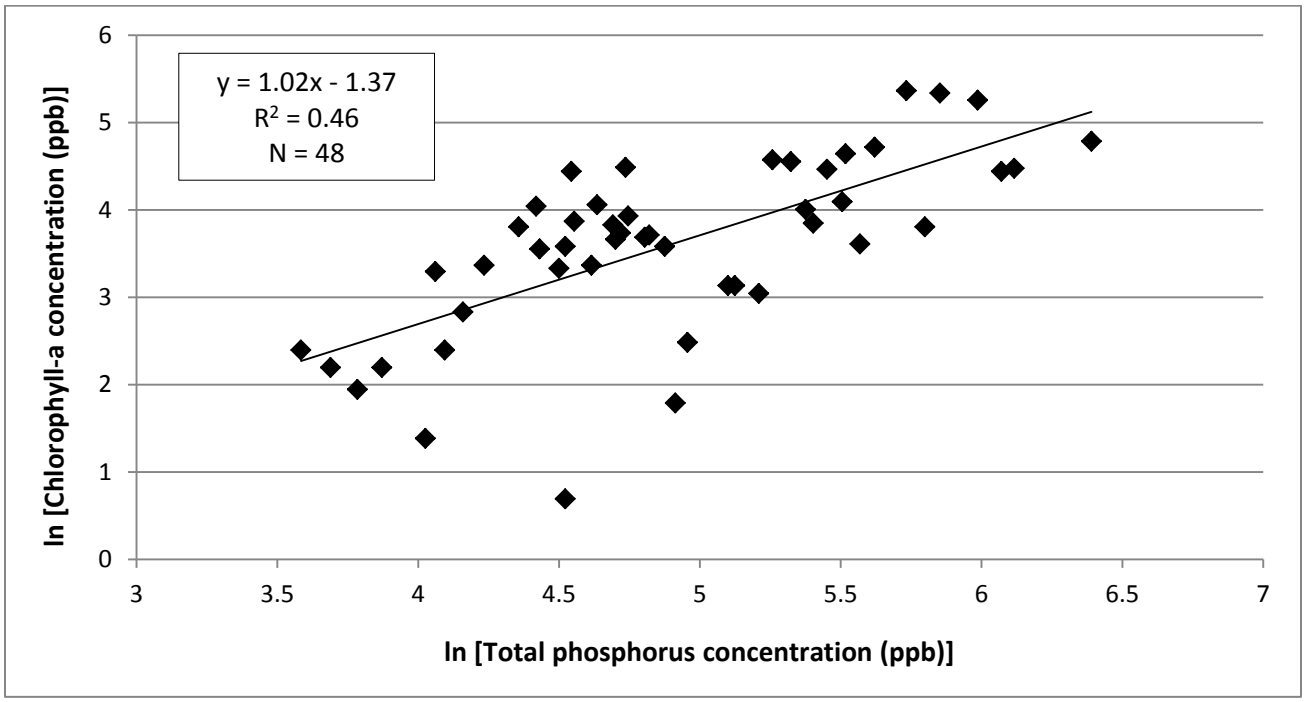


Figure 14. Chlorophyll-a v. Secchi Disk Depth for "Shallow" Lakes in the LA Ecoregion.

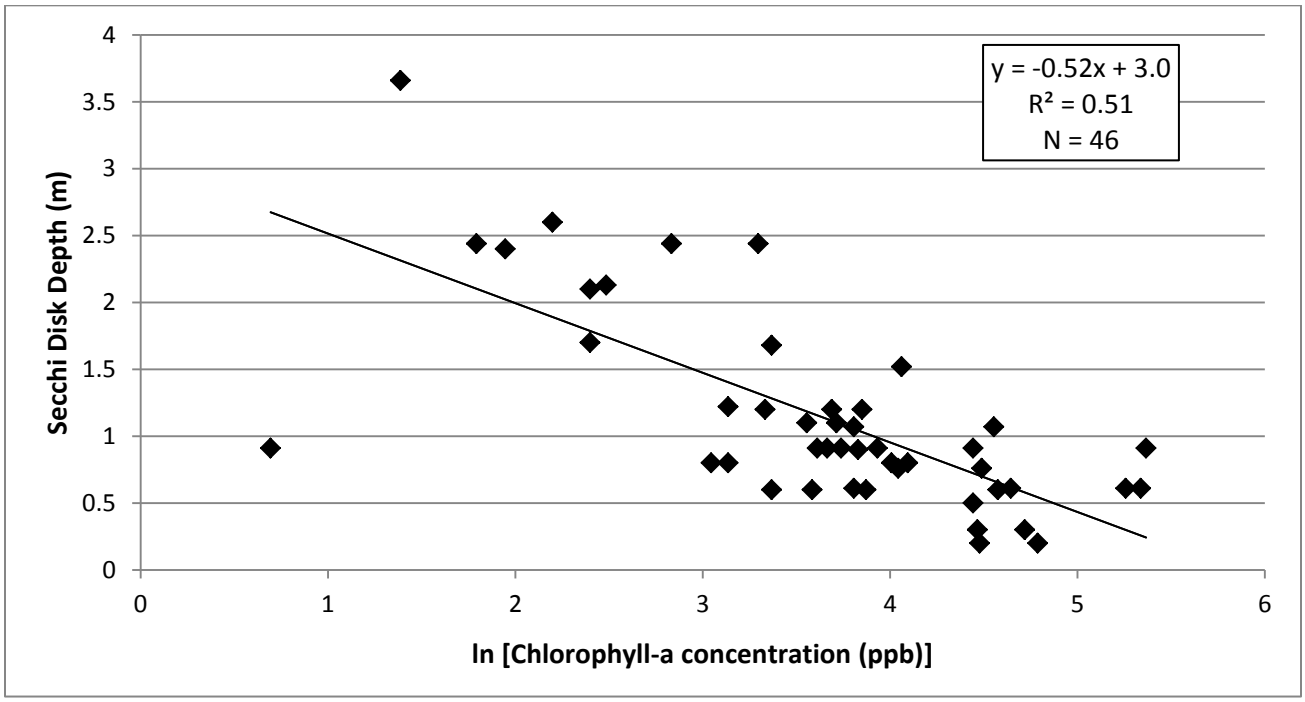


Figure 15. Total Phosphorus v. Chlorophyll-a for "Deep" Lakes in the LA Ecoregion.

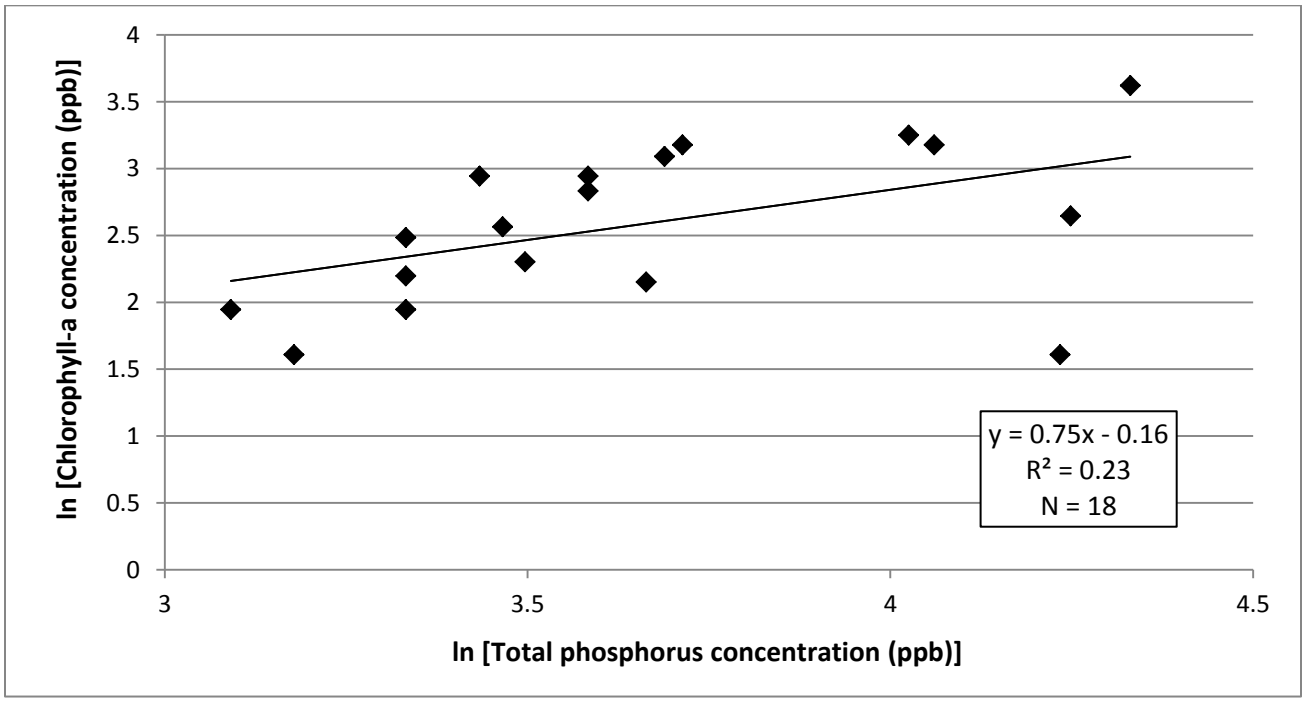


Figure 16. Chlorophyll-a v. Secchi Disk Depth for "Deep" Lakes in the LA Ecoregion.

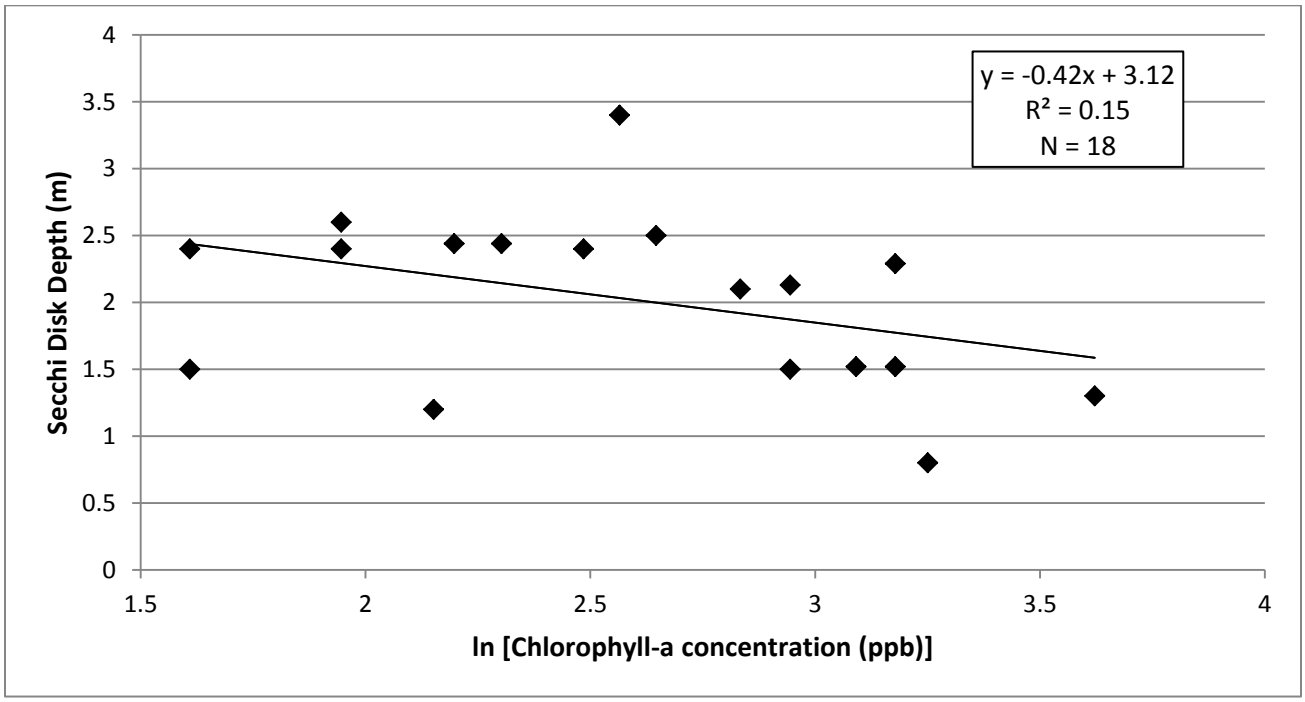


Figure 17. Total Phosphorus v. Chlorophyll-a for "Shallow" Lakes in the NCHF Ecoregion.

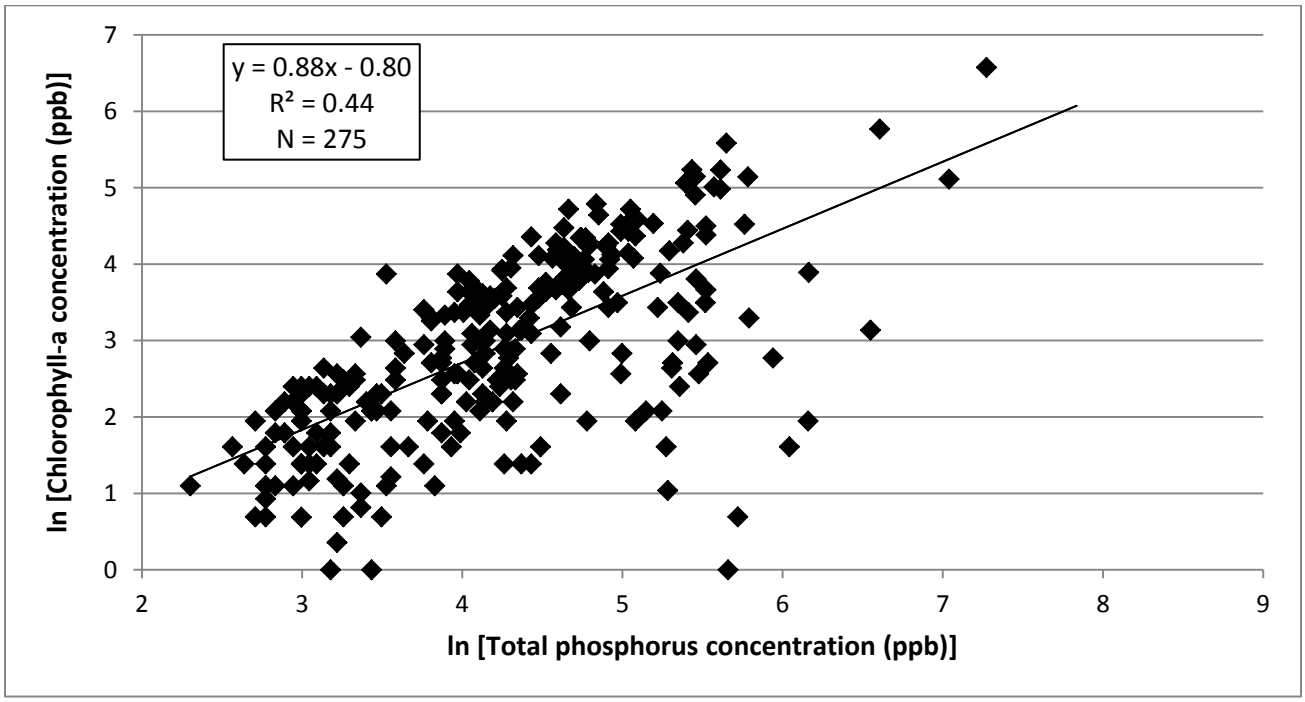


Figure 18. Chlorophyll-a v. Secchi Disk Depth for "Shallow" Lakes in the NCHF Ecoregion.

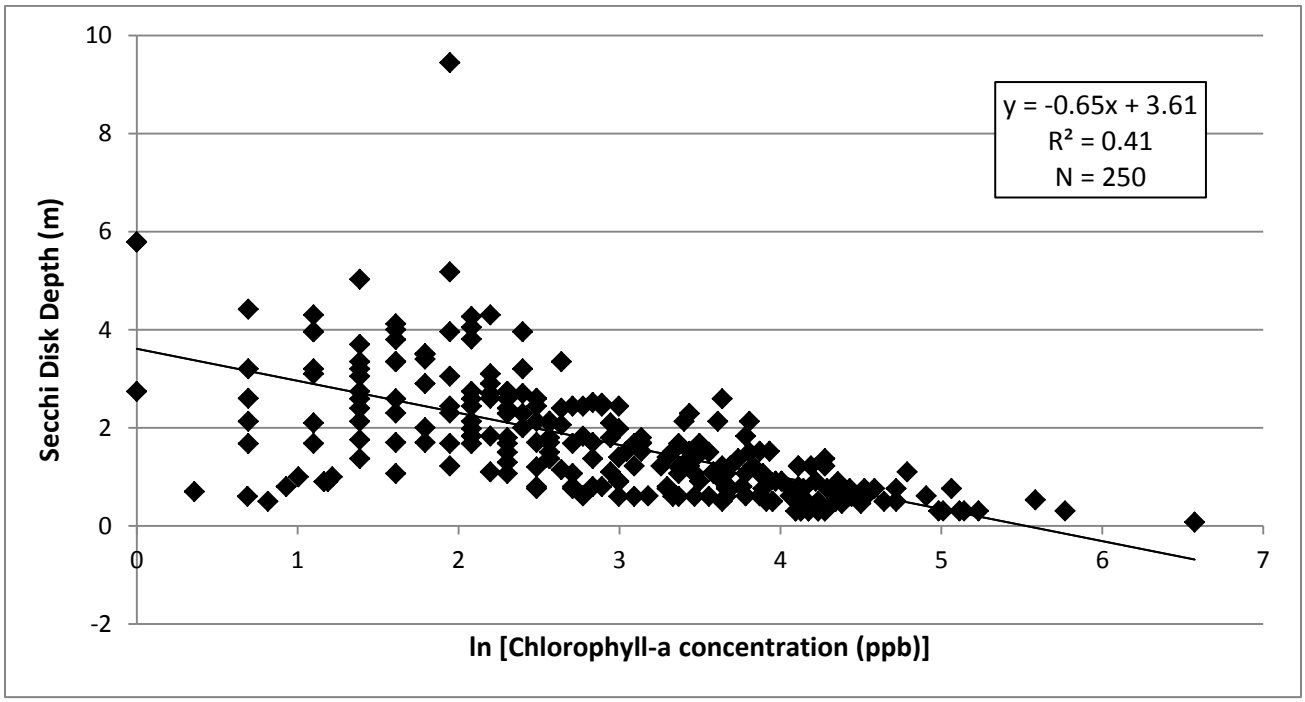


Figure 19. Total Phosphorus v. Chlorophyll-a for "Deep" Lakes in the NCHF Ecoregion.

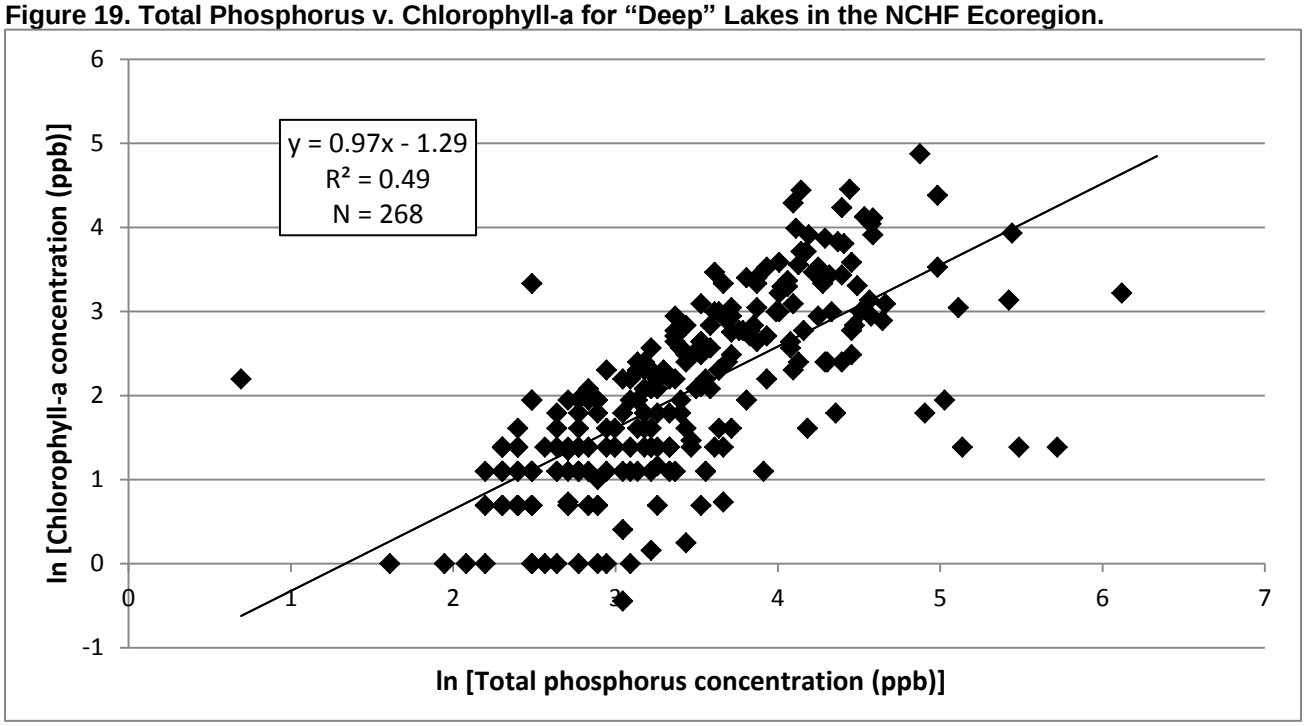


Figure 20. Chlorophyll-a v. Secchi Disk Depth for "Deep" Lakes in the NCHF Ecoregion.

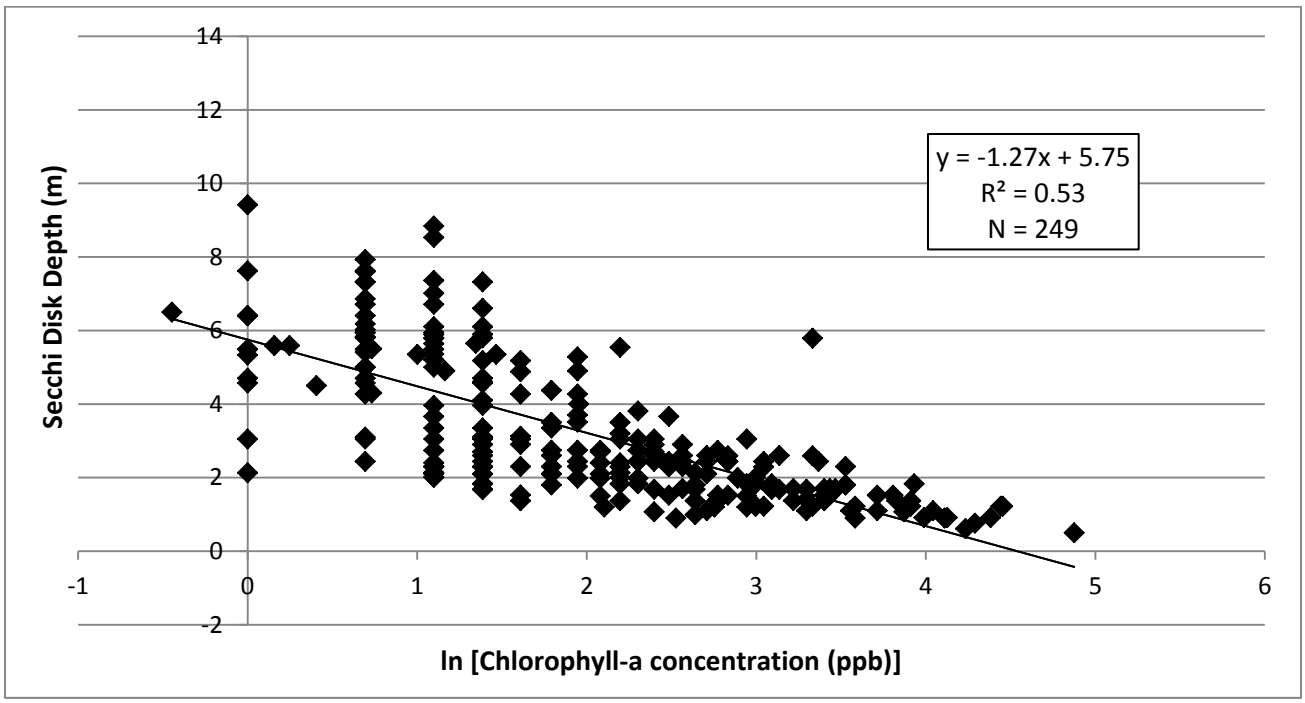


Figure 21. Total Phosphorus v. Chlorophyll-a for "Shallow" Lakes within the NLF Ecoregion.

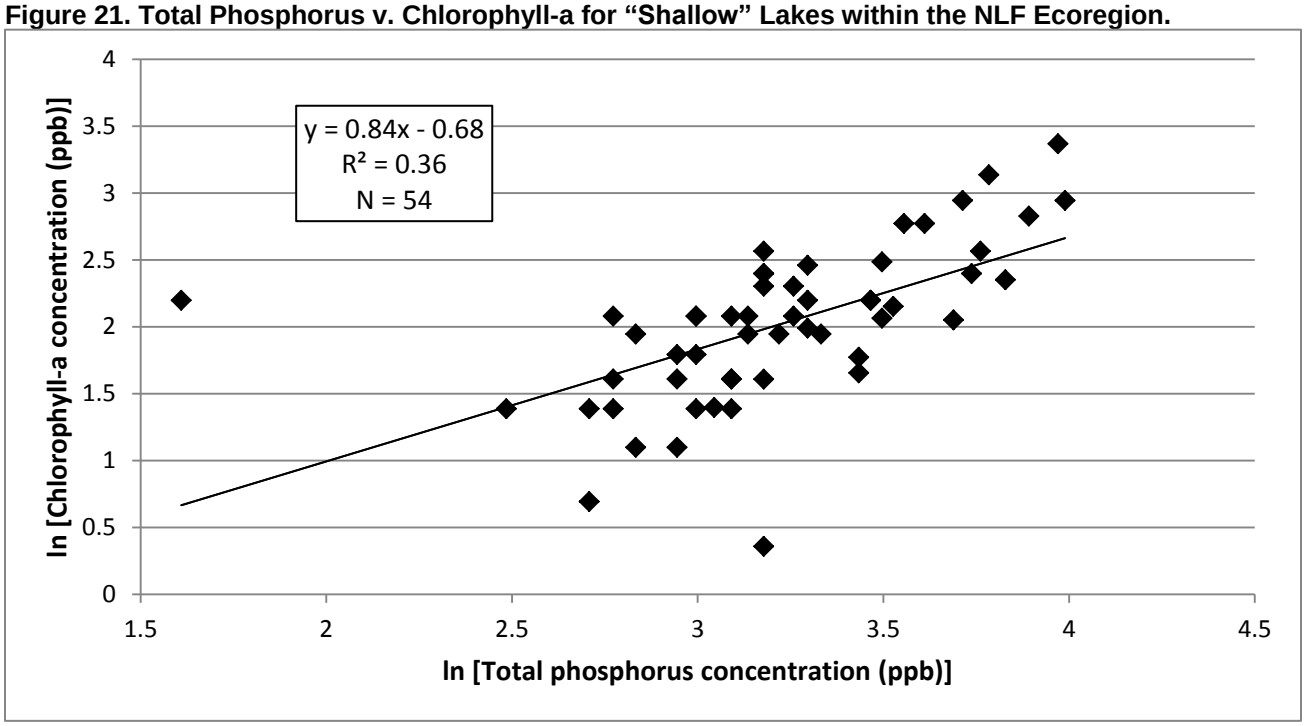
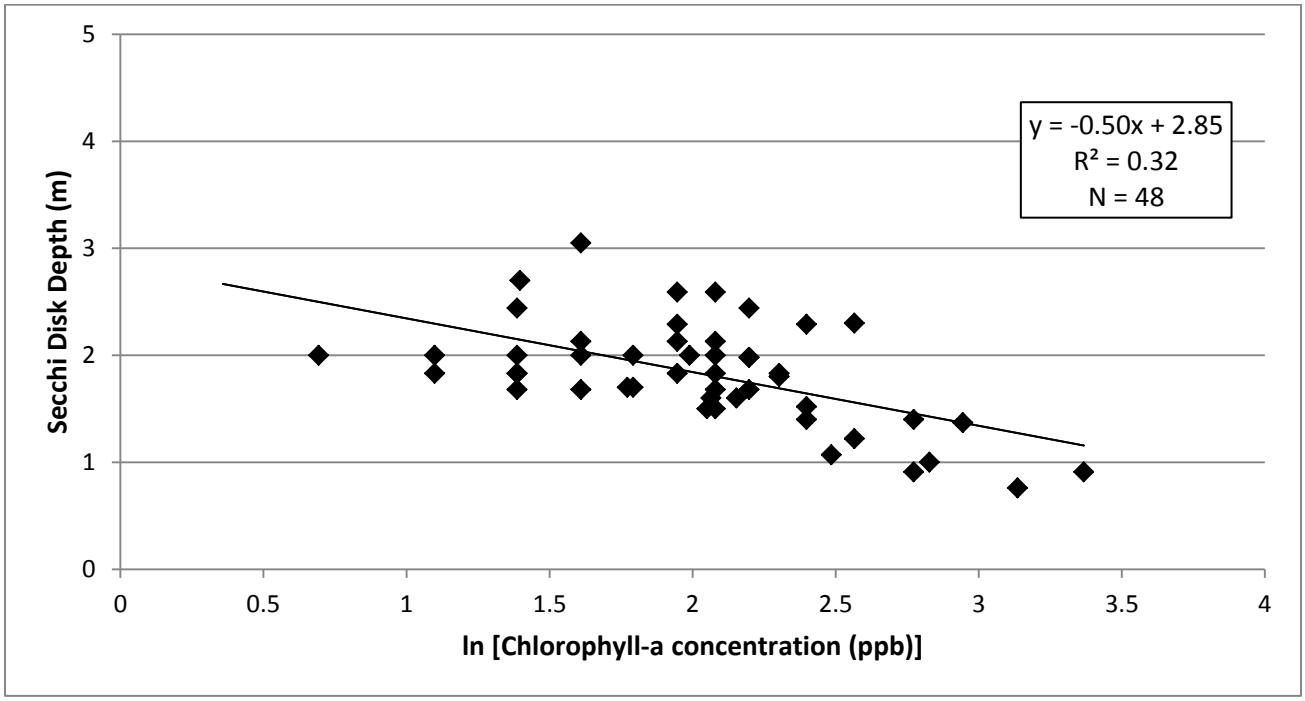


Figure 22. Chlorophyll-a v. Secchi Disk Depth for "Shallow" Lakes within the NLF Ecoregion.



All-in-all, the stressor-response relationships shown in **Figures 13 through 22** show the expected trend of increased chl-a with elevated TP concentration and decreased Secchi disk depth with increased chl-a. Results vary from group to group, but generally indicate much variability around the regression line; an expected result in natural systems. Shallow lakes (**Figures 13-14**) in the LA Ecoregion show moderately strong linear relationships (R^2 values around 0.5) for all variables. Deep LA lakes (**Figures 15-16**) show much weaker relationships (R^2 values of 0.15 – 0.23), perhaps due to a lack of paired data points (only 18) in this group. As the majority of the lakes within the BRW are located within the NCHF, these relationships (**Figures 17 through 20**) are built on the most data. Both shallow and deep lakes showed moderately strong stressor-response relationships for TP/chl-a and chl-a/Secchi disk depth (R^2= 0.41 – 0.53). NLF lakes have slightly weaker relationships, with R^2 values around 0.3 (**Figures 21-22)**.

The slopes of the stressor-response relationships can be used to gain a general appreciation for the sensitivity of the lakes in each group to an increase in TP and/or chl-a. A high slope in the TP/chl-a regression, for example, indicates that for each unit increase in TP concentration, a large increase in chl-a concentration is also expected. A low slope indicates that the same increase in TP concentration would cause a smaller increase in chl-a. Results of the linear regressions indicate that response within the waterbodies to increases in TP concentration of similar magnitudes, with "deep" lakes in the LA ecoregion being the least sensitive. "Shallow" lakes in the LA ecoregion are shown to be the most sensitive to TP loading (note, however, that limited data was available for the LA ecoregion). The analysis also shows that NCHF "deep" lakes are more sensitive to TP loads than "shallow".

"Example" Lakes

In future tasks of this project, BATHTUB receiving water models will be created to simulate eutrophication responses in the lakes of the BRW. BATHTUB requires a number of inputs, including lake volume, mean annual or season water quality TP, chl-a, and Secchi disk depth, and an estimate of watershed loading. The required information for the "example" lakes was computed by grouping the BRW lakes based on their ecoregion and relative depth. Representative values for mean depth, surface area, summer water quality, and catchment LULC were then computed for each "example" lake by averaging the individual values of the lakes within that group. The average of the individual values was then assumed reflective of the group, in general.

Morphometry

Comparing the available morphometric information for lakes with water quality data available versus those without water quality data shows that the State's sampling methods have tended toward sampling the larger lakes in the BRW lake groups. As shown in **Table 14**, the mean depth and surface area of lakes that have historically been sampled are larger than those of the non-sampled lakes. Given this fact, and the fact that the modeling will pair the morphometric data with the water quality data, the morphometric data for the "example" lakes will be computed only from information associated with those

lakes that have water quality data available (**Table 3**). This includes two "deep" lakes and four "shallow" lakes in the LA ecoregion, sixteen "deep" lakes and twenty-three "shallow" lakes in the NCHF ecoregion, and three "shallow" lakes in the NLF ecoregion. Using lakes without water quality data could potentially skew the results to show smaller lake volumes and the resultant (modeled) water quality relationships could be altered. The "example" lake morphometric data to be used for each ecoregion/relative depth group is shown in the upper part of **Table 14**.

Table 14. Average Lake Morphometric Data by Ecoregion & Relative Depth and Data Availability.

	LA – Deep	LA – Shallow	NCHF – Deep	NCHF – Shallow	NLF - Shallow
Lakes with Water Quality Data					
Mean Depth (m)[1]	4.42	1.49	4.76	1.83	2.25
Mean Surface Area (acres)	154	189	182	220	841
Lakes without Water Quality Data					
Mean Depth (m)[1]	n/a	1.13	5.05	1.74	1.20
Mean Surface Area (acres)	n/a	57	46	53	2.25

[1] The majority of mean depths in this dataset were estimated from maximum depths based on the maximum depth-mean depth relationship described herein.

Water Quality

Average summer season TP, chl-a, and Secchi disk depths for the "example" lakes are shown in **Table 15**. As stated earlier, these values were computed from data collected during the months of June through September. All years of available data (**Table 3**) were used. The information shown in **Table 5** will be used to calibrate the BATHTUB models. Results of additional statistical analyses on the water quality of the lakes in each group are contained in **Appendix C**.

Table 15. Average Water Quality in Lake Groups (by Ecoregion & Relative Depth).

	Mean Summer Season Values		
	Total Phosphorus (ppb)	**Chlorophyll-a (ppb)**	**Secchi Disk Depth (m)**
LA - Deep	41.50	15.49	2.02
LA - Shallow	168.44	55.46	1.14
NCHF - Deep	49.65	13.24	5.18
NCHF - Shallow	108.01	37.02	2.13
NLF - Shallow	27.85	8.84	1.90

Watershed LULC Characteristics

The final input need for the "example" lakes BATHTUB models is an estimate of watershed nutrient loading. The intention of this project is to eventually compute those loads through the use of watershed loading models (to be completed under future Objectives of this contract). A simple method for estimating watershed loading can also be completed, however, based on the land use within a lake's contributing watershed. **Table 16** shows the average LULC in the MnDNR catchments of the lakes within the various lake groups. In the absence of more detailed data from the watershed loading models, these values can be combined with a lake's lakeshed area (unfortunately not readily available at the time of this analysis) to estimate the area of each land use type contributing surface water runoff and nutrient load to a given lake. Using regional unit loading estimates the mean summer season TP load to the lakes can then be computed. Such regional unit loading values are available from a number of sources, including Wilson and Walker (1989).

Table 16: **Catchment LULC and Areas for "Example" Lakes by Group.**

Average Catchment Characteristics	LA – Deep	LA – Shallow	NCHF – Deep	NCHF – Shallow	NLF - Shallow
% Forest	14	5	43	29	39
% Water/Wetland	31	25	25	23	56
% Cultivated	34	59	15	31	0
% Pasture & Open	8	4	14	14	3
% Urban	13	7	3	4	2

Conclusion

A main goal of the MPCA's Watershed Approach is to develop plans that are protective of waters where conditions are excellent and restorative of waters where conditions are impaired. These plans will include strategies to guide management activities, priorities and policies, including those activities as they pertain to lakes. The BRW has over 300 lakes in its boundaries. Creating specific management strategies and receiving water models for each of these lakes is not a realistic goal. Therefore, the goal of this work was to gather information to support management of the lakes in the BRW, including developing an approach to (and inputs for) creating more generalized models that are reflective of water quality processes (in general) in the lakes of the BRW.

Appendix A contains a comprehensive list of the management data available for 300+ lakes within the BRW. Lake classification variables were chosen for attributing the lakes based on: 1) the information being widely available (creating an approach that could be applied in other watersheds); 2) the information currently being used by the BRRWD to manage lakes – most specifically in their development of "priority lakes" in their Watershed Management Plan; 3) the data being required for future modeling

efforts (e.g., estimated lake mean depth); and 4) the information being required to assess the waters for impairment. The information shown in **Appendix A** can be used to support future management of the water quality in the lakes of the BRW and should be considered in combination with the "priority lakes" that the BRRWD has already established (particularly given the finding in Objective 1 of this work that some of the lakes to be listed as impaired on the 2012 303(d) list are not currently considered "priority lakes").

Results of the lake grouping exercise confirmed the State of Minnesota's approach to managing lake eutrophication water quality by both Level III ecoregion and relative depth (i.e., "deep" vs. "shallow" lakes). Kruskal-Wallis statistical tests show that, for the most part, observed summer TP, chl-a, and Secchi disk depths are statically significantly different between ecoregion/relative depth groups at a 95% confidence interval.

Given the findings of the statistical analysis, "example" lakes were developed for each of the five ecoregion/relative depth lake groups. "Example" lake mean depth, surface area, mean summertime eutrophication water quality and catchment LULC characteristics were computed the individual lakes in each group. Characteristics of these "example" lakes will be used in future Objectives of this project to create BATHTUB models for simulating the expected eutrophication response in the lakes of the BRW.

Works Cited

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APPENDIX A

Comprehensive List of BRW Lakes & Associated Characteristics

Lake Name	DNR Lake ID #	County	Ecoregion	Surface Area (acres)	Mean Depth (ft.)	Calculated Mean depth (ft.)	Maximum Depth (ft.)	Volume (ac-ft)	Percent Littoral	"Shallow" v "Deep"	Public Access	Impairment	BRRWD Priority Lake	Catchment ID	Catchment Acres	Percent Land Use / Land Cover				
																Forest	Water / Wetland	Urban	Pasture & Open	Cultiv-ated
Alfred Lake		Otter Tail	NCHF	33								None	No	5800100	8927	24.4	12.5	3.7	20.9	38.4
Alfred Lake		Otter Tail	NCHF	21								None	No	5800100	8927	24.4	12.5	3.7	20.9	38.4
Anderson Lake - 1	14000200	Clay	NCHF	47		5.38	10	253.34	100	Shallow		None	No	5800900	5998	7.8	11.4	5.0	6.1	69.7
Anderson Lake - 2		Clay	LA	32								None	No	5804400	8240	1.8	11.6	4.3	1.1	81.3
Anderson Lake - 3	03043200	Becker	NCHF	38		2.98	5	113.0429	100	Shallow	1	None	No	5801700	6364	24.5	9.1	4.1	14.4	47.9
Anfinson	14004400	Clay	NCHF	25					100	Shallow	Unk	None	No	5800800	21713	3.7	14.5	4.3	12.3	65.1
Annie, Lake	56104000	Otter Tail	NCHF	14								None	No	5800302	3099	29.1	14.4	5.5	12.1	38.9
Audubon Lake		Becker	NCHF	78								None	No	5801200	10822	10.5	11.2	5.5	14.7	58.1
Axberg Lake (main and west basin)	03066000	Becker	NCHF	33	9	9	13	293.8381	100	Shallow	0	None	No	5800905	3664	28.9	22.0	3.3	9.2	36.6
Backman Lake	14004600	Clay	NCHF	14								None	No	5800900	5998	7.8	11.4	5.0	6.1	69.7
Balsam Lake	03029200	Becker	NLF	95		3.94	7	375.0306	100	Shallow	0	None	Yes	5801905	911	73.4	16.3	4.0	6.3	0.0
Bay Lake	03054200	Becker	LA	35								None	No	5801400	6490	2.8	15.4	3.6	6.7	71.5
Bear Lake		Becker	NCHF	29								None	No	5802101	2586	64.3	30.1	2.4	2.6	0.5
Becks Lake		Otter Tail	NCHF	18								None	No	5800300	11194	4.7	5.7	4.9	9.5	75.2
Beeber (Rose) Lake	03059100	Becker	NCHF	51	6	6	10	306.5	100	Shallow		None	No	5800805	1294	33.2	23.5	5.9	22.9	14.4
Berseth Lake	03053500	Becker	NCHF	22		7.3	14	160.2547	100	Shallow		None	No	5801201	6316	23.9	14.1	4.9	25.0	32.1
Big Sugar Bush Lake	03030400	Becker	NCHF	455		20.74	42	9430.119	69	Deep	1	None	Yes	5802101	2586	64.3	30.1	2.4	2.6	0.5
Birch Lake	03035200	Becker	NCHF	218		12.58	25	2740.974	72	Deep	0	None	Yes	5802204	924	62.5	29.4	0.8	5.8	1.5
Bjorndahl Lake		Clay	LA	14						Shallow		None	No	5800800	21713	3.7	14.5	4.3	12.3	65.1
Blackberry Lake	03031900	Becker	NCHF	62		3.94	7	245.3505	100	Shallow		None	No	5801703	446	49.3	26.3	6.3	16.2	1.9
Blue Eagle Lake		Clay	LA	12								None	No	5800200	13368	3.2	8.2	10.5	20.3	57.7
Bluebird Lake		Becker	LA	16								None	No	5801300	12968	14.3	11.5	5.0	18.9	50.3
Boe Lake		Becker	LA	20								None	No	5801100	5421	6.0	15.6	4.4	10.5	63.6
Bow-Dodge Lake		Becker	NCHF	35								None	No	5802101	2586	64.3	30.1	2.4	2.6	0.5
Boyer Lake	03057900	Becker	NCHF	328		13.06	26	4287.817	53	Deep	1	Excess Nutrients	Yes	5801101	2084	22.8	25.9	3.6	7.6	40.1
Brannigan (Frisk) Lake	03064300	Becker	NCHF	49		2.98	5	145.6596	100	Shallow	Unk	None	No	5800904	3039	25.3	23.9	2.7	12.2	35.8
Buffalo Lake	03035000	Becker	NCHF	406		4.9	9	1989.018	47	Shallow	1	None	No	5801800	3501	46.5	23.0	4.7	19.9	6.0
Bullhead Lake		Becker	NCHF	33								None	No	5802100	1326	78.0	11.6	3.2	7.3	0.0
Burk Lake	14006500	Clay	NCHF	36		4.42	8	160.2224	100	Shallow		None	No	5805902	4425	7.8	16.7	5.4	13.4	56.7
Businger Lake		Otter Tail	NCHF	45								None	No	5800102	2595	33.8	14.8	5.7	20.7	25.2
Canary (Felker) Lake	03051600	Becker	NCHF	66		12.58	25	824.3106	66	Deep	0	None	No	5801101	2084	22.8	25.9	3.6	7.6	40.1
Christ Olson Lake	14005300	Clay	NCHF	68		6.82	13	462.4959	100	Shallow		None	No	5805901	4704	22.2	14.9	3.7	14.7	44.4

Lake Name	DNR Lake ID #	County	Ecoregion	Surface Area (acres)	Mean Depth (ft.)	Calculated Mean depth (ft.)	Maximum Depth (ft.)	Volume (ac-ft)	Percent Littoral	"Shallow" v "Deep"	Public Access	Impairment	BRRWD Priority Lake	Catchment ID	Catchment Acres	Percent Land Use / Land Cover				
																Forest	Water / Wetland	Urban	Pasture & Open	Cultiv-ated
Colness Lake	56103700	Otter Tail	NCHF	85		3.46	6	293.4648	100	Shallow		None	No	5800300	11194	4.7	5.7	4.9	9.5	75.2
Cranberry (Island) Lake	03032500	Becker	NCHF	55						Shallow		None	No	5802101	2586	64.3	30.1	2.4	2.6	0.5
Cravath Lake		Becker	LA	88								None	No	5801500	11965	7.5	10.2	4.7	14.0	63.7
Cuba Lake - 1	03066200	Becker	NCHF	52						Shallow		None	No	5800900	5998	7.8	11.4	5.0	6.1	69.7
Deadman Lake	56095100	Otter Tail	NCHF	23						Shallow		None	No	5800105	1504	9.5	22.3	3.5	18.1	46.5
Dewey Lake	14004300	Clay	NCHF	14								None	No	5806600	10257	17.2	10.3	4.8	26.5	41.2
Doran Lake	14008900	Clay	LA	72		3.94	7	283.5059	100	Shallow	0	None	Yes	5805903	1153	1.0	14.6	4.6	7.7	72.1
Eagen Lake	03031800	Becker	NCHF	76								None	No	5801800	3501	46.5	23.0	4.7	19.9	6.0
East LaBelle Lake	03064800	Becker	LA	192		9.7	19	1864.662	42	Deep	1	None	Yes	5801003	1518	14.3	30.6	12.9	8.3	33.9
East Olaf Lake	56095002	Otter Tail	NCHF	230		3.46	6	795.7405	100	Shallow		None	No	5800106	1774	27.2	20.4	3.9	23.2	25.2
Eleven, Lake	14001800	Clay	NCHF	74		13.06	26	972.136		Deep	0	None	No	5800802	5247	39.1	16.6	3.5	15.7	25.1
Emma, Lake	14003700	Clay	NCHF	36						Shallow		None	No	5806600	10257	17.2	10.3	4.8	26.5	41.2
Engebretson Lake	03063600	Becker	NCHF	31								None	No	5800901	8059	3.4	11.7	5.8	2.9	76.2
Erickson Lake	14006100	Clay	NCHF	55								None	No	5800905	3664	28.9	22.0	3.3	9.2	36.6
Fairbank's Lake	03042900	Becker	NCHF	99						Shallow		None	No	5802202	904	40.8	15.7	2.7	9.5	31.3
Fifteen, Lake	14003000	Clay	NCHF	145		11.14	22	1611.838	74	Deep	1	None	Yes	5800801	3640	36.6	14.4	4.6	30.1	14.2
Fish Lake	03031400	Becker	NCHF	81		28.9	59	2341.805	43	Deep	1	None	Yes	5802002	3281	86.3	9.1	1.3	3.3	0.0
Forget-me-not	03062400	Becker	NCHF	225	4	4	7	901.935	100	Shallow	0	Excess Nutrients	Yes	5800909	2123	14.5	16.1	3.9	6.8	58.7
Fourteen, Lake		Clay	NCHF	42								None	No	5800801	3640	36.6	14.4	4.6	30.1	14.2
Gaards Lake		Otter Tail	NCHF	57		6.82	13	388.8026	100	Shallow		None	No	5800103	2225	36.6	15.5	4.3	15.1	28.6
Gandrud Lake		Becker	NCHF	25								None	No	5801500	11965	7.5	10.2	4.7	14.0	63.7
Gilbertson Lake		Becker	NCHF	44								None	No	5801200	10822	10.5	11.2	5.5	14.7	58.1
Gooseberry (Belcourt) Lake	03034300	Becker	NCHF	99						Shallow		None	No	5802102	736	82.4	16.0	0.7	0.9	0.0
Gottenberg Lake	03052800	Becker	NCHF	115		4.9	9	565.8108	100	Shallow	Unk	Excess Nutrients	Yes	5801202	709	31.3	21.9	3.4	14.4	28.9
Gourd Lake	03063500	Becker	NCHF	121		4.42	8	532.7137	100	Shallow	0	Excess Nutrients	Yes	5800906	362	21.7	32.5	4.3	7.5	34.0
Granrud Lake		Otter Tail	NCHF	81								None	No	5800301	2695	6.1	12.0	4.3	7.5	70.1
Grena Lake	56101900	Otter Tail	NCHF	95		3.94	7	373.0965	100	Shallow		None	No	5800301	2695	6.1	12.0	4.3	7.5	70.1
Grove Lake	56095200	Ottertail	NCHF	404	6	6	18	2424.864	92	Shallow	Unk	None	No	5800101	4163	19.9	15.9	3.4	16.2	44.6
Harrison (Helgeson) Lake	56093400	Otter Tail	NCHF	108		6.34	12	686.7169	100	Shallow	Unk	None	No	5800104	1857	25.0	15.1	4.0	42.0	13.8

Lake Name	DNR Lake ID #	County	Ecoregion	Surface Area (acres)	Mean Depth (ft.)	Calculated Mean depth (ft.)	Maximum Depth (ft.)	Volume (ac-ft)	Percent Littoral	"Shallow" v "Deep"	Public Access	Impairment	BRRWD Priority Lake	Catchment ID	Catchment Acres	Percent Land Use / Land Cover				
																Forest	Water / Wetland	Urban	Pasture & Open	Cultiv-ated
Hatchet Lake, Southern		Clay	LA	22								None	No	5803900	28427	1.9	9.7	4.4	6.8	77.1
Hoe (Thurston) Lake	14005400	Clay	NCHF	52		5.86	11	303.5112	100	Shallow		None	No	5800905	3664	28.9	22.0	3.3	9.2	36.6
Horan Lake	03063300	Becker	NCHF	76						Shallow		None	No	5800901	8059	3.4	11.7	5.8	2.9	76.2
Horseshoe Lake		Clay	LA	49								None	No	5804600	5298	2.2	9.9	3.3	2.1	82.5
Houg Lake	03040600	Becker	NCHF	45						Shallow		None	No	5801700	6364	24.5	9.1	4.1	14.4	47.9
Island Lake	03035100	Becker	NCHF	211	5	5	12	1057.245	100	Shallow	Unk	None	No	5801702	1379	60.2	32.6	0.7	5.5	1.1
Jacobs, Lake	56103900	Otter Tail	NCHF	134		8.74	17	1166.919		Deep	0	Excess Nutrients	Yes	5800302	3099	29.1	14.4	5.5	12.1	38.9
Jegtvig Lake		Clay	NCHF	20								None	No	5800800	21713	3.7	14.5	4.3	12.3	65.1
Jergenson Lake	14006200	Clay	NCHF	61		3.94	7	241.4139	100	Shallow		None	No	5805901	4704	22.2	14.9	3.7	14.7	44.4
John Lake		Otter Tail	NCHF	11								None	No	5800102	2595	33.8	14.8	5.7	20.7	25.2
Joy Lake		Becker	NCHF	24								None	No	5801200	10822	10.5	11.2	5.5	14.7	58.1
Knudson (Fifteen) Lake	14005600	Clay	NCHF	32		6.82	13	215.6246	100	Shallow		None	No	5805901	4704	22.2	14.9	3.7	14.7	44.4
Laura, Lake	14003800	Clay	NCHF	57		4.42	8	251.0515	100	Shallow	Unk	None	No	5806600	10257	17.2	10.3	4.8	26.5	41.2
Lee Lake	14004900	Clay	NCHF	137		17.86	36	2444.467	64	Deep	1	None	Yes	5805901	4704	22.2	14.9	3.7	14.7	44.4
Lee Marshes	03054500	Becker	LA	22						Shallow		None	No	5801100	5421	6.0	15.6	4.4	10.5	63.6
Lime Lake	03064600	Becker	NCHF	107		4.42	8	474.4397	100	Shallow	0	Excess Nutrients	Yes	5800902	1171	10.8	18.8	6.9	6.9	56.6
Little Boyer Lake, North	03061200	Becker	NCHF	17								None	No	5801003	1518	14.3	30.6	12.9	8.3	33.9
Little Boyer Lake, South	03061200	Becker	NCHF	17								None	No	5801003	1518	14.3	30.6	12.9	8.3	33.9
Little Cotton Lake		Becker	NCHF	41								None	No	5801901	1166	63.7	23.0	3.1	9.3	0.9
Little Round	03030200	Becker	NCHF	540	2	2	5.5	1079.09	100	Shallow	n/a	None	Yes	5801803	2212	49.1	40.1	1.8	9.0	0.0
Little Sugar Bush	03031300	Becker	NCHF	212		14.5	29	3071.436	45	Deep	1	None	Yes	5801705	1208	59.9	21.8	2.6	15.7	0.0
Long Lake	03065800	Becker	NCHF	99		6.82	13	674.3004	100	Shallow	Unk	None	No	5800806	467	23.2	23.1	6.8	39.6	7.4
Lund Brothers Marsh	03062100	Becker	NCHF	28					100	Shallow	Unk	None	No	5800901	8059	3.4	11.7	5.8	2.9	76.2
Lynn Flint Lake		Becker	NCHF	13								None	No	5800905	3664	28.9	22.0	3.3	9.2	36.6
Mansfield Lake	14003500	Clay	NCHF	34		5.38	10	183.4987	100	Shallow	Unk	None	No	5800801	3640	36.6	14.4	4.6	30.1	14.2
Maple Lake	14000100	Clay	NCHF	39	5	5	6	195.648	100	Shallow	Unk	None	No	5800100	8927	24.4	12.5	3.7	20.9	38.4
Maria Lake	14009900	Clay	LA	108		4.9	9	527.7357	100	Shallow	0	Excess Nutrients	Yes	5805905	1340	1.6	10.3	6.7	8.0	73.4
Marshall Lake	03052600	Becker	NCHF	185		10.66	21	1968.282	66	Deep	1	Excess Nutrients	Yes	5801203	531	19.0	33.6	3.4	5.6	38.5
Mary Yellowhead Lake	03024300	Becker	NLF	34						Shallow		None	No	5802002	3281	86.3	9.1	1.3	3.3	0.0

Lake Name	DNR Lake ID #	County	Ecoregion	Surface Area (acres)	Mean Depth (ft.)	Calculated Mean depth (ft.)	Maximum Depth (ft.)	Volume (ac-ft)	Percent Littoral	"Shallow" v "Deep"	Public Access	Impairment	BRRWD Priority Lake	Catchment ID	Catchment Acres	Percent Land Use / Land Cover				
																Forest	Water / Wetland	Urban	Pasture & Open	Cultiv-ated
McGurk Lake		Clay	NCHF	17		7.78	15	135.5942		Deep		None	No	5800905	3664	28.9	22.0	3.3	9.2	36.6
Meyer	14007900	Clay	LA	53		3.94	7	210.5823	10	Shallow	0	None	Yes	5804401	633	4.7	38.4	1.1	2.4	53.5
Mill Lake		Becker	NCHF	41								None	No	5802100	1326	78.0	11.6	3.2	7.3	0.0
Minnetonka Lake	03053100	Becker	NCHF	41		11.14	22	454.5756		Deep		None	No	5801201	6316	23.9	14.1	4.9	25.0	32.1
Mission Lake	03047100	Becker	NCHF	244	4	4	10	974.559	100	Shallow		Excess Nutrients	No	5802205	866	44.0	31.1	2.5	6.5	15.9
Moe Lake	14004700	Clay	NCHF	45		6.34	12	287.1181	100	Shallow	Unk	None	No	5800900	5998	7.8	11.4	5.0	6.1	69.7
Momb (Shake) Lake	03029400	Becker	NCHF	46		13.54	27	619.3091	63	Deep	Unk	None	No	5801900	5333	61.3	23.7	2.5	12.5	0.0
Mud Lake - 1	03031600	Becker	NCHF	50		4.42	8	220.0127	100	Shallow		None	No	5802001	4452	69.1	12.3	3.2	11.7	3.8
Mud Lake - 2		Becker	NLF	42								None	No	5801904	986	70.6	21.2	1.1	7.0	0.2
Mulgri Lake	03032000	Becker	NCHF	13								None	No	5801702	1379	60.2	32.6	0.7	5.5	1.1
Nelson Lake	14003300	Clay	NCHF	25								None	No	5800800	21713	3.7	14.5	4.3	12.3	65.1
Ness Lake		Clay	NCHF	51								None	No	5800802	5247	39.1	16.6	3.5	15.7	25.1
North Barnes Lake	03052400	Becker	NCHF	42		9.22	18	383.919	94	Shallow	Unk	None	No	5801200	10822	10.5	11.2	5.5	14.7	58.1
North Momb Lake		Becker	NCHF	29								None	No	5801900	5333	61.3	23.7	2.5	12.5	0.0
O-Me-Mee Lake	03042800	Becker	NCHF	120	5	5	10	599.8031	100	Shallow		None	No	5802201	1244	30.2	16.3	4.2	19.8	29.6
One Lake, North		Clay	NCHF	22								None	No	5800802	5247	39.1	16.6	3.5	15.7	25.1
One Lake, South		Clay	NCHF	23								None	No	5800802	5247	39.1	16.6	3.5	15.7	25.1
Orange Lake	03063400	Becker	NCHF	69								None	No	5800909	2123	14.5	16.1	3.9	6.8	58.7
Overson Lake	14006300	Clay	NCHF	54		6.34	12	341.3473		Shallow	Unk	None	No	5800802	5247	39.1	16.6	3.5	15.7	25.1
Perch Lake	14005800	Clay	NCHF	39		8.74	17	345.1042	10	deep	Unk	None	No	5805902	4425	7.8	16.7	5.4	13.4	56.7
Pete Lake	56094100	Otter Tail	NCHF	100		8.26	16	823.7642	100	Deep	Unk	None	No	5800102	2595	33.8	14.8	5.7	20.7	25.2
Pine Lake	03020000	Becker	NLF	515		9.22	18	4746.835	89	Shallow	Unk	None	No	5801903	1287	44.3	48.5	2.0	5.2	0.0
Pine Lake - 2		Becker	NLF	12								None	No	5802002	3281	86.3	9.1	1.3	3.3	0.0
Prestrude Lake		Becker	NCHF	40								None	No	5800904	3039	25.3	23.9	2.7	12.2	35.8
Prune (Roberg) Lake	03063200	Becker	NCHF	32						Shallow		None	No	5800901	8059	3.4	11.7	5.8	2.9	76.2
Pump (Boot) Lake	03066100	Becker	NCHF	54						Shallow		None	No	5800802	5247	39.1	16.6	3.5	15.7	25.1
Rankle (Randkler) Lake	56093500	Otter Tail	NCHF	32						Shallow		None	No	5800102	2595	33.8	14.8	5.7	20.7	25.2
Ranum Lake	14001100	Clay	NCHF	45		4.42	8	197.0257	100	Shallow	Unk	None	No	5806700	9183	25.2	5.9	4.3	33.0	31.6
Rat Lake	03055500	Becker	LA	33						Shallow		None	No	5801400	6490	2.8	15.4	3.6	6.7	71.5
Reep Lake	03051300	Becker	LA	48						Shallow		None	No	5801200	10822	10.5	11.2	5.5	14.7	58.1
Rice Lake	03029100	Becker	NCHF	226		11.62	23	2624.469	74	Deep	0	None	Yes	5801801	706	33.8	40.7	2.9	22.6	0.0
Rochert Lake		Becker	NCHF	20						Shallow		None	No	5801802	3902	38.2	41.3	2.9	14.3	3.3
Rock Lake	03029300	Becker	NCHF	1200		9.22	18	11064.63	83	Shallow	1	None	Yes	5801802	3902	38.2	41.3	2.9	14.3	3.3
Rushfieldt Lake	14009500	Clay	LA	40		3.94	7	157.3998	100	Shallow	0	None	No	5800800	21713	3.7	14.5	4.3	12.3	65.1
Sand (Stump) Lake	03065900	Becker	NCHF	199	15	15	28	2981.692	52	Deep	1	Excess Nutrients	Yes	5800905	3664	28.9	22.0	3.3	9.2	36.6

Lake Name	DNR Lake ID #	County	Ecoregion	Surface Area (acres)	Mean Depth (ft.)	Calculated Mean depth (ft.)	Maximum Depth (ft.)	Volume (ac-ft)	Percent Littoral	"Shallow" v "Deep"	Public Access	Impairment	BRRWD Priority Lake	Catchment ID	Catchment Acres	Percent Land Use / Land Cover				
																Forest	Water / Wetland	Urban	Pasture & Open	Cultiv-ated
Sand Pit - 1		Clay	LA	29								None	No	5805200	5188	0.5	6.3	6.2	0.4	86.7
Sand Pit - 2		Clay	LA	21								None	No	5805200	5188	0.5	6.3	6.2	0.4	86.7
Sands Lake	56102600	Otter Tail	NCHF	56						Shallow		None	No	5800300	11194	4.7	5.7	4.9	9.5	75.2
Seabold Lake	03055000	Becker	LA	98								None	No	5801200	10822	10.5	11.2	5.5	14.7	58.1
Seim Lake		Otter Tail	NCHF	32								None	No	5800102	2595	33.8	14.8	5.7	20.7	25.2
Sewage Pond - 2		Clay	LA	23								None	No	5800200	13368	3.2	8.2	10.5	20.3	57.7
Sewage pond -1		Clay	LA	11								None	No	5805904	7890	1.9	10.0	14.0	7.9	66.2
Shoe Lake	03063900	Becker	NCHF	54		6.34	12	345.2887	100	Shallow		None	No	5800802	5247	39.1	16.6	3.5	15.7	25.1
Silver Lake	14010000	Clay	LA	115		19.3	39	2217.324	33	Deep		None	Yes	5805902	4425	7.8	16.7	5.4	13.4	56.7
Skaeim Lake		Becker	NCHF	11						Shallow		None	No	5801201	6316	23.9	14.1	4.9	25.0	32.1
Solem Lake	14000900	clay	NCHF	69		5.38	10	370.7906	100	Shallow	Unk	None	No	5806700	9183	25.2	5.9	4.3	33.0	31.6
Solum Lake - Northern	14005200	Clay	NCHF	25								None	No	5800905	3664	28.9	22.0	3.3	9.2	36.6
Solum Lake - Southern	14005200	Clay	NCHF	25								None	No	5800905	3664	28.9	22.0	3.3	9.2	36.6
Solwald Lake	14009000	Clay	LA	61		2.98	5	181.5823	100	Shallow	Unk	None	No	5803900	28427	1.9	9.7	4.4	6.8	77.1
Somdahl Lake		Becker	NCHF	41								None	No	5801701	1951	60.7	18.7	3.0	11.8	5.9
Sorenson Lake	03062500	Becker	NCHF	78		4.42	8	343.2099	100	Shallow	Unk	Excess Nutrients	No	5800903	1757	19.3	15.9	3.1	14.6	47.1
South Barnes Lake	03052500	Becker	NCHF	80		5.38	10	431.3647	100	Shallow	Unk	None	No	5801200	10822	10.5	11.2	5.5	14.7	58.1
Spring Lake	03029000	Becker	NCHF	54		29.38	60	1586.12	35	Deep	Unk	None	No	5801800	3501	46.5	23.0	4.7	19.9	6.0
St. Clair Lake	03043000	Becker	NCHF	107		14.5	29	1545.216	88	Deep	0	None	Yes	5801704	2186	70.5	16.8	2.3	7.5	2.9
Stakke Lake	03063100	Becker	NCHF	482	7	7	15	3373.427	100	Shallow	1	Excess Nutrients	Yes	5800904	3039	25.3	23.9	2.7	12.2	35.8
Stinking Lake	03064700	Becker	LA	379		3.94	7	1495.08	100	Shallow	0	Excess Nutrients	Yes	5800901	8059	3.4	11.7	5.8	2.9	76.2
Swede Grove Lake	14007800	Clay	LA	156		4.42	8	687.7745	100	Shallow	0	None	Yes	5801001	1529	6.3	31.9	3.7	1.6	56.4
Talac Lake	03061900	Becker	NCHF	137	11	11	13	1502.619	100	Shallow	0	Excess Nutrients	Yes	5800903	1757	19.3	15.9	3.1	14.6	47.1
Tamarack, North Lake	03024102	Becker	NLF	1457		8.74	17	12730.61	97	Shallow	4	Excess Nutrients	Yes	5801902	4795	44.2	50.7	1.6	3.5	0.0
Tamarack, South Lake	03024101	Becker	NLF	551		4.18	7.5	2301.582	100	Shallow	n/a	None	Yes	5801906	1063	28.8	68.2	2.3	0.7	0.0
Tansem Lake	14001000	Clay	NCHF	30		4.42	8	133.3885	100	Shallow	Unk	None	No	5806700	9183	25.2	5.9	4.3	33.0	31.6
Tatley Lake		Clay	LA	50								None	No	5803900	28427	1.9	9.7	4.4	6.8	77.1
Ten, Lake	14002100	Clay	NCHF	135		8.74	17	1178.262	90	Shallow	0	None	Yes	5800803	932	29.1	25.4	3.5	17.3	24.7
Thirteen, Lake	14002600	Clay	NCHF	50		7.3	14	363.5632	100	Shallow	Unk	None	No	5800801	3640	36.6	14.4	4.6	30.1	14.2
Three, Lake	14001900	Clay	NCHF	93		7.3	14	681.9147	100	Shallow	0	None	Yes	5800804	519	25.1	26.5	1.8	23.7	23.0
Torgerson Lake		Becker	LA	35								None	No	5801200	10822	10.5	11.2	5.5	14.7	58.1

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																Forest	Water / Wetland	Urban	Pasture & Open	Cultiv-ated
Trotterchaud Lake		Becker	LA	91								None	No	5802300	22703	6.4	12.6	3.9	8.2	68.9
Turtle Lake	03065700	Becker	NCHF	184		35.62	73	6551.291	37	Deep	1	None	Yes	5800805	1294	33.2	23.5	5.9	22.9	14.4
Twin Lakes-2	03031100	Becker	NCHF	13								None	No	5801702	1379	60.2	32.6	0.7	5.5	1.1
Two, Lake		Clay	NCHF	74								None	No	5800802	5247	39.1	16.6	3.5	15.7	25.1
Unnamed		Becker	NCHF	12								None	No	5802205	866	44.0	31.1	2.5	6.5	15.9
Unnamed		Becker	NCHF	20								None	No	5802204	924	62.5	29.4	0.8	5.8	1.5
Unnamed		Becker	NCHF	18								None	No	5802300	22703	6.4	12.6	3.9	8.2	68.9
Unnamed		Becker	NCHF	39								None	No	5802300	22703	6.4	12.6	3.9	8.2	68.9
Unnamed		Becker	NCHF	16								None	No	5802101	2586	64.3	30.1	2.4	2.6	0.5
Unnamed		Becker	NCHF	10								None	No	5802101	2586	64.3	30.1	2.4	2.6	0.5
Unnamed		Becker	NCHF	13								None	No	5802203	1714	51.0	8.7	1.9	13.7	24.8
Unnamed		Becker	NCHF	15								None	No	5802201	1244	30.2	16.3	4.2	19.8	29.6
Unnamed		Becker	NCHF	12								None	No	5802001	4452	69.1	12.3	3.2	11.7	3.8
Unnamed		Becker	NCHF	11								None	No	5802001	4452	69.1	12.3	3.2	11.7	3.8
Unnamed		Becker	NCHF	12								None	No	5801704	2186	70.5	16.8	2.3	7.5	2.9
Unnamed		Becker	NCHF	35								None	No	5802200	862	17.5	9.7	6.1	28.5	38.1
Unnamed		Becker	NCHF	11								None	No	5801700	6364	24.5	9.1	4.1	14.4	47.9
Unnamed		Becker	NCHF	16								None	No	5801700	6364	24.5	9.1	4.1	14.4	47.9
Unnamed		Becker	NCHF	19								None	No	5801700	6364	24.5	9.1	4.1	14.4	47.9
Unnamed		Becker	NCHF	12								None	No	5801700	6364	24.5	9.1	4.1	14.4	47.9
Unnamed		Becker	NCHF	16								None	No	5801700	6364	24.5	9.1	4.1	14.4	47.9
Unnamed		Becker	NCHF	16								None	No	5801700	6364	24.5	9.1	4.1	14.4	47.9
Unnamed		Becker	NCHF	53								None	No	5801700	6364	24.5	9.1	4.1	14.4	47.9
Unnamed		Becker	NCHF	11								None	No	5801700	6364	24.5	9.1	4.1	14.4	47.9
Unnamed		Becker	NCHF	17								None	No	5801702	1379	60.2	32.6	0.7	5.5	1.1
Unnamed		Becker	NCHF	13								None	No	5801702	1379	60.2	32.6	0.7	5.5	1.1
Unnamed		Becker	NCHF	25								None	No	5801701	1951	60.7	18.7	3.0	11.8	5.9
Unnamed		Becker	NCHF	12								None	No	5801701	1951	60.7	18.7	3.0	11.8	5.9
Unnamed		Becker	NCHF	12								None	No	5801701	1951	60.7	18.7	3.0	11.8	5.9
Unnamed		Becker	NCHF	18								None	No	5801900	5333	61.3	23.7	2.5	12.5	0.0
Unnamed		Becker	NCHF	21								None	No	5801900	5333	61.3	23.7	2.5	12.5	0.0
Unnamed		Becker	NCHF	24								None	No	5801100	5421	6.0	15.6	4.4	10.5	63.6
Unnamed		Becker	NCHF	13								None	No	5801300	12968	14.3	11.5	5.0	18.9	50.3
Unnamed		Becker	NCHF	11								None	No	5801300	12968	14.3	11.5	5.0	18.9	50.3
Unnamed		Becker	NCHF	28								None	No	5800901	8059	3.4	11.7	5.8	2.9	76.2
Unnamed		Becker	NCHF	10								None	No	5800900	5998	7.8	11.4	5.0	6.1	69.7
Unnamed		Clay	NCHF	35								None	No	5800900	5998	7.8	11.4	5.0	6.1	69.7
Unnamed		Becker	NCHF	13								None	No	5800900	5998	7.8	11.4	5.0	6.1	69.7
Unnamed		Becker	NCHF	19								None	No	5801003	1518	14.3	30.6	12.9	8.3	33.9
Unnamed		Becker	NCHF	14								None	No	5800905	3664	28.9	22.0	3.3	9.2	36.6

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																Forest	Water / Wetland	Urban	Pasture & Open	Cultiv-ated
Unnamed		Becker	NCHF	19								None	No	5800905	3664	28.9	22.0	3.3	9.2	36.6
Unnamed		Becker	NCHF	17								None	No	5800905	3664	28.9	22.0	3.3	9.2	36.6
Unnamed		Becker	NCHF	19								None	No	5800907	290	8.2	32.1	2.2	14.2	43.3
Unnamed		Clay	NCHF	12								None	No	5805901	4704	22.2	14.9	3.7	14.7	44.4
Unnamed		Clay	NCHF	22								None	No	5805901	4704	22.2	14.9	3.7	14.7	44.4
Unnamed		Clay	NCHF	24								None	No	5805902	4425	7.8	16.7	5.4	13.4	56.7
Unnamed		Becker	NCHF	17								None	No	5801201	6316	23.9	14.1	4.9	25.0	32.1
Unnamed		Becker	NCHF	10								None	No	5801201	6316	23.9	14.1	4.9	25.0	32.1
Unnamed		Becker	NCHF	18								None	No	5801201	6316	23.9	14.1	4.9	25.0	32.1
Unnamed		Becker	NCHF	15								None	No	5800904	3039	25.3	23.9	2.7	12.2	35.8
Unnamed		Becker	NCHF	13								None	No	5800904	3039	25.3	23.9	2.7	12.2	35.8
Unnamed		Clay	NCHF	10								None	No	5800802	5247	39.1	16.6	3.5	15.7	25.1
Unnamed		Clay	NCHF	11								None	No	5800802	5247	39.1	16.6	3.5	15.7	25.1
Unnamed		Clay	NCHF	21								None	No	5800802	5247	39.1	16.6	3.5	15.7	25.1
Unnamed		Clay	NCHF	12								None	No	5800802	5247	39.1	16.6	3.5	15.7	25.1
Unnamed		Clay	NCHF	16								None	No	5800802	5247	39.1	16.6	3.5	15.7	25.1
Unnamed		Becker	NCHF	13								None	No	5800802	5247	39.1	16.6	3.5	15.7	25.1
Unnamed		Clay	NCHF	42								None	No	5800802	5247	39.1	16.6	3.5	15.7	25.1
Unnamed		Becker	NCHF	15								None	No	5801202	709	31.3	21.9	3.4	14.4	28.9
Unnamed		Becker	NCHF	14								None	No	5801202	709	31.3	21.9	3.4	14.4	28.9
Unnamed		Clay	NCHF	10								None	No	5800800	21713	3.7	14.5	4.3	12.3	65.1
Unnamed		Clay	NCHF	12								None	No	5800805	1294	33.2	23.5	5.9	22.9	14.4
Unnamed		Clay	NCHF	17								None	No	5800803	932	29.1	25.4	3.5	17.3	24.7
Unnamed		Clay	NCHF	19								None	No	5800803	932	29.1	25.4	3.5	17.3	24.7
Unnamed		Clay	NCHF	23								None	No	5800801	3640	36.6	14.4	4.6	30.1	14.2
Unnamed		Clay	NCHF	22								None	No	5800801	3640	36.6	14.4	4.6	30.1	14.2
Unnamed		Clay	NCHF	12								None	No	5800801	3640	36.6	14.4	4.6	30.1	14.2
Unnamed		Clay	NCHF	14								None	No	5800801	3640	36.6	14.4	4.6	30.1	14.2
Unnamed		Clay	NCHF	27								None	No	5806600	10257	17.2	10.3	4.8	26.5	41.2
Unnamed		Clay	NCHF	18								None	No	5806700	9183	25.2	5.9	4.3	33.0	31.6
Unnamed		Clay	NCHF	35								None	No	5806500	4637	13.1	16.2	2.9	29.8	38.0
Unnamed		Clay	NCHF	16								None	No	5806500	4637	13.1	16.2	2.9	29.8	38.0
Unnamed		Otter Tail	NCHF	14								None	No	5800104	1857	25.0	15.1	4.0	42.0	13.8
Unnamed		Otter Tail	NCHF	10								None	No	5800102	2595	33.8	14.8	5.7	20.7	25.2
Unnamed		Otter Tail	NCHF	15								None	No	5800102	2595	33.8	14.8	5.7	20.7	25.2
Unnamed		Otter Tail	NCHF	12								None	No	5800200	13368	3.2	8.2	10.5	20.3	57.7

Lake Name	DNR Lake ID #	County	Ecoregion	Surface Area (acres)	Mean Depth (ft.)	Calculated Mean depth (ft.)	Maximum Depth (ft.)	Volume (ac-ft)	Percent Littoral	"Shallow" v "Deep"	Public Access	Impairment	BRRWD Priority Lake	Catchment ID	Catchment Acres	Percent Land Use / Land Cover				
																Forest	Water / Wetland	Urban	Pasture & Open	Cultiv-ated
Unnamed		Otter Tail	NCHF	12								None	No	5800100	8927	24.4	12.5	3.7	20.9	38.4
Unnamed		Clay	NCHF	13								None	No	5800100	8927	24.4	12.5	3.7	20.9	38.4
Unnamed		Otter Tail	NCHF	12								None	No	5800100	8927	24.4	12.5	3.7	20.9	38.4
Unnamed		Otter Tail	NCHF	12								None	No	5800100	8927	24.4	12.5	3.7	20.9	38.4
Unnamed		Otter Tail	NCHF	31								None	No	5800100	8927	24.4	12.5	3.7	20.9	38.4
Unnamed		Otter Tail	NCHF	16								None	No	5800100	8927	24.4	12.5	3.7	20.9	38.4
Unnamed		Otter Tail	NCHF	10								None	No	5800101	4163	19.9	15.9	3.4	16.2	44.6
Unnamed		Otter Tail	NCHF	23								None	No	5800300	11194	4.7	5.7	4.9	9.5	75.2
Unnamed		Otter Tail	NCHF	10								None	No	5800300	11194	4.7	5.7	4.9	9.5	75.2
Unnamed		Otter Tail	NCHF	18								None	No	5800300	11194	4.7	5.7	4.9	9.5	75.2
Unnamed		Otter Tail	NCHF	15								None	No	5800103	2225	36.6	15.5	4.3	15.1	28.6
Unnamed		Otter Tail	NCHF	13								None	No	5800103	2225	36.6	15.5	4.3	15.1	28.6
Unnamed		Otter Tail	NCHF	24								None	No	5800302	3099	29.1	14.4	5.5	12.1	38.9
Unnamed		Otter Tail	NCHF	44								None	No	5800302	3099	29.1	14.4	5.5	12.1	38.9
Unnamed		Otter Tail	NCHF	10								None	No	5800301	2695	6.1	12.0	4.3	7.5	70.1
Unnamed		Becker	LA	16								None	No	5802300	22703	6.4	12.6	3.9	8.2	68.9
Unnamed		Becker	LA	18								None	No	5802300	22703	6.4	12.6	3.9	8.2	68.9
Unnamed		Becker	LA	12								None	No	5802300	22703	6.4	12.6	3.9	8.2	68.9
Unnamed		Becker	LA	22								None	No	5802300	22703	6.4	12.6	3.9	8.2	68.9
Unnamed		Becker	LA	20								None	No	5802300	22703	6.4	12.6	3.9	8.2	68.9
Unnamed		Becker	LA	10								None	No	5802300	22703	6.4	12.6	3.9	8.2	68.9
Unnamed		Becker	LA	14								None	No	5802300	22703	6.4	12.6	3.9	8.2	68.9
Unnamed		Clay	LA	31								None	No	5803900	28427	1.9	9.7	4.4	6.8	77.1
Unnamed		Clay	LA	23								None	No	5803900	28427	1.9	9.7	4.4	6.8	77.1
Unnamed		Clay	LA	17								None	No	5803900	28427	1.9	9.7	4.4	6.8	77.1
Unnamed		Clay	LA	15								None	No	5803900	28427	1.9	9.7	4.4	6.8	77.1
Unnamed		Clay	LA	25								None	No	5803900	28427	1.9	9.7	4.4	6.8	77.1
Unnamed		Clay	LA	29								None	No	5803900	28427	1.9	9.7	4.4	6.8	77.1

Lake Name	DNR Lake ID #	County	Ecoregion	Surface Area (acres)	Mean Depth (ft.)	Calculated Mean depth (ft.)	Maximum Depth (ft.)	Volume (ac-ft)	Percent Littoral	"Shallow" v "Deep"	Public Access	Impairment	BRRWD Priority Lake	Catchment ID	Catchment Acres	Percent Land Use / Land Cover				
																Forest	Water / Wetland	Urban	Pasture & Open	Cultiv-ated
Unnamed		Clay	LA	13								None	No	5803900	28427	1.9	9.7	4.4	6.8	77.1
Unnamed		Becker	LA	12								None	No	5801600	6226	1.1	11.0	5.9	8.9	73.1
Unnamed		Becker	LA	14								None	No	5801000	15895	1.6	10.3	4.6	6.6	76.9
Unnamed		Becker	LA	15								None	No	5801500	11965	7.5	10.2	4.7	14.0	63.7
Unnamed		Becker	LA	22								None	No	5801500	11965	7.5	10.2	4.7	14.0	63.7
Unnamed		Becker	LA	10								None	No	5801500	11965	7.5	10.2	4.7	14.0	63.7
Unnamed		Becker	LA	24								None	No	5801500	11965	7.5	10.2	4.7	14.0	63.7
Unnamed		Clay	LA	12								None	No	5804400	8240	1.8	11.6	4.3	1.1	81.3
Unnamed		Clay	LA	14								None	No	5804401	633	4.7	38.4	1.1	2.4	53.5
Unnamed		Becker	LA	14								None	No	5801100	5421	6.0	15.6	4.4	10.5	63.6
Unnamed		Becker	LA	42								None	No	5801100	5421	6.0	15.6	4.4	10.5	63.6
Unnamed		Becker	LA	19								None	No	5801100	5421	6.0	15.6	4.4	10.5	63.6
Unnamed		Becker	LA	10								None	No	5801100	5421	6.0	15.6	4.4	10.5	63.6
Unnamed		Becker	LA	11								None	No	5801200	10822	10.5	11.2	5.5	14.7	58.1
Unnamed		Becker	LA	31								None	No	5801300	12968	14.3	11.5	5.0	18.9	50.3
Unnamed		Becker	LA	13								None	No	5801300	12968	14.3	11.5	5.0	18.9	50.3
Unnamed		Clay	LA	11								None	No	5806000	4531	2.3	9.8	9.4	15.3	63.2
Unnamed		Clay	LA	15								None	No	5805000	7416	0.6	4.1	6.1	0.0	89.2
Unnamed		Clay	LA	14								None	No	5806800	18424	1.7	8.9	3.9	11.2	74.2
Unnamed		Clay	LA	23								None	No	5800800	21713	3.7	14.5	4.3	12.3	65.1
Unnamed		Clay	LA	13								None	No	5800800	21713	3.7	14.5	4.3	12.3	65.1
Unnamed		Clay	LA	13								None	No	5800800	21713	3.7	14.5	4.3	12.3	65.1
Unnamed		Clay	LA	16								None	No	5800800	21713	3.7	14.5	4.3	12.3	65.1
Unnamed		Clay	LA	31								None	No	5805700	12186	0.7	2.3	6.8	0.7	89.5
Unnamed		Clay	LA	11								None	No	5806600	10257	17.2	10.3	4.8	26.5	41.2
Unnamed		Clay	LA	19								None	No	5800200	13368	3.2	8.2	10.5	20.3	57.7
Unnamed		Wilkin	LA	17								None	No	5802700	9575	1.2	12.2	5.8	9.4	71.5
Unnamed	14005000	Clay	NCHF	16		4.42	8	71.00079	100	Shallow		None	No	5800900	5998	7.8	11.4	5.0	6.1	69.7
Unnamed	14005100	Clay	NCHF	21		4.9	9	102.9384	100	Shallow		None	No	5800900	5998	7.8	11.4	5.0	6.1	69.7
Unnamed	14005500	Clay	NCHF	19		2.98	5	56.13419	100	Shallow		None	No	5805901	4704	22.2	14.9	3.7	14.7	44.4
Unnamed	14006400	Clay	NCHF	12								None	No	5805902	4425	7.8	16.7	5.4	13.4	56.7
Unnamed	14006600	Clay	NCHF	19		4.42	8	83.77515	100	Shallow		None	No	5805902	4425	7.8	16.7	5.4	13.4	56.7
Unnamed (North Mayfield), Lake	14002900	Clay	NCHF	36						Shallow	0	None	No	5800801	3640	36.6	14.4	4.6	30.1	14.2
Unnamed (Wangensteen) Lake	03064900	Becker	LA	89						Shallow		None	No	5801000	15895	1.6	10.3	4.6	6.6	76.9
Unnamed Lake - 1	03065000	Becker	LA	53						Shallow	Unk	None	No	5801000	15895	1.6	10.3	4.6	6.6	76.9
Vale Lake	14006000	Clay	NCHF	20		4.42	8	86.99294	100	Shallow		None	No	5805901	4704	22.2	14.9	3.7	14.7	44.4
Vizenor Lake		Becker	NCHF	41								None	No	5801702	1379	60.2	32.6	0.7	5.5	1.1

Lake Name	DNR Lake ID #	County	Ecoregion	Surface Area (acres)	Mean Depth (ft.)	Calculated Mean depth (ft.)	Maximum Depth (ft.)	Volume (ac-ft)	Percent Littoral	"Shallow" v "Deep"	Public Access	Impairment	BRRWD Priority Lake	Catchment ID	Catchment Acres	Percent Land Use / Land Cover				
																Forest	Water / Wetland	Urban	Pasture & Open	Cultiv-ated
Werk Lake, North	03029800	Becker	NCHF	67								None	No	5801901	1166	63.7	23.0	3.1	9.3	0.9
Werk Lake, South	03029802	Becker	NCHF	30								None	No	5801901	1166	63.7	23.0	3.1	9.3	0.9
West Labelle (Duck) Lake	03064500	Becker	LA	112		6.34	12	708.4352	100	Shallow	Unk	Excess Nutrients	No	5801002	410	8.0	32.8	10.1	1.7	47.4
West Olaf Lake	56095001	Otter Tail	NCHF	144		29.86	61	4290.432	35	Deep	1	None	No	5800103	2225	36.6	15.5	4.3	15.1	28.6
Wheeler Lake	03039000	Becker	NCHF	62		21.22	43	1312.223	80	Shallow	0	None	No	5801300	12968	14.3	11.5	5.0	18.9	50.3
Whisky Lake		Clay	NCHF	34								None	No	5800100	8927	24.4	12.5	3.7	20.9	38.4
Yort (Sand) Lake	03061800	Becker	NCHF	58		4.9	9	286.1444	100	Shallow		None	No	5800907	290	8.2	32.1	2.2	14.2	43.3

APPENDIX B

Additional Statistical Analysis

Table B.1. Impairment Status vs. % Cultivated LULC in Catchment.

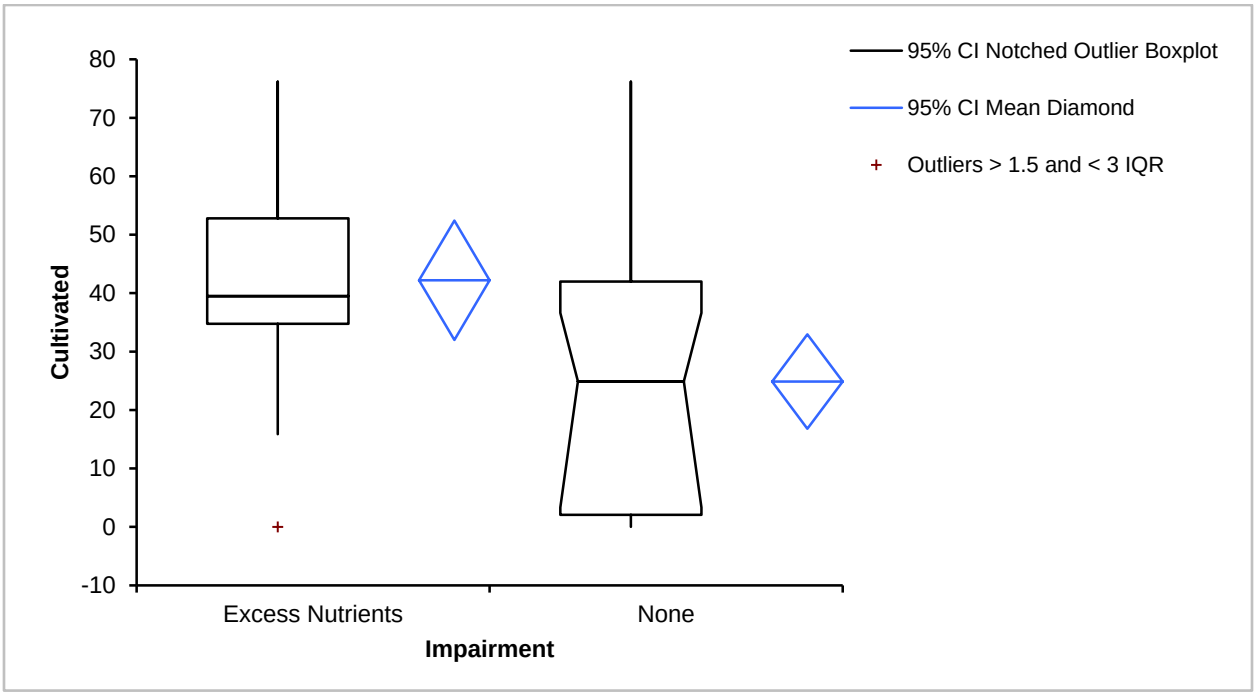


Table B.2. Impairment Status vs. % Pasture/Open LULC in Catchment.

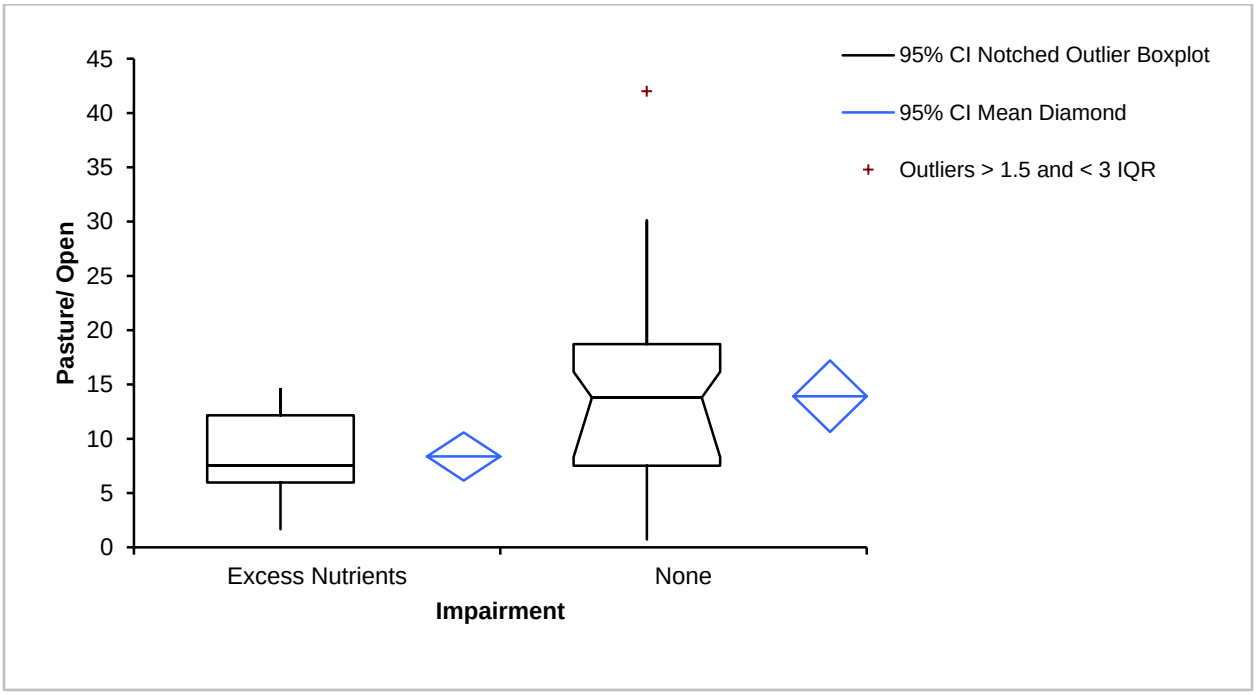


Table B.3. Impairment Status vs. % Forest LULC in Catchment.

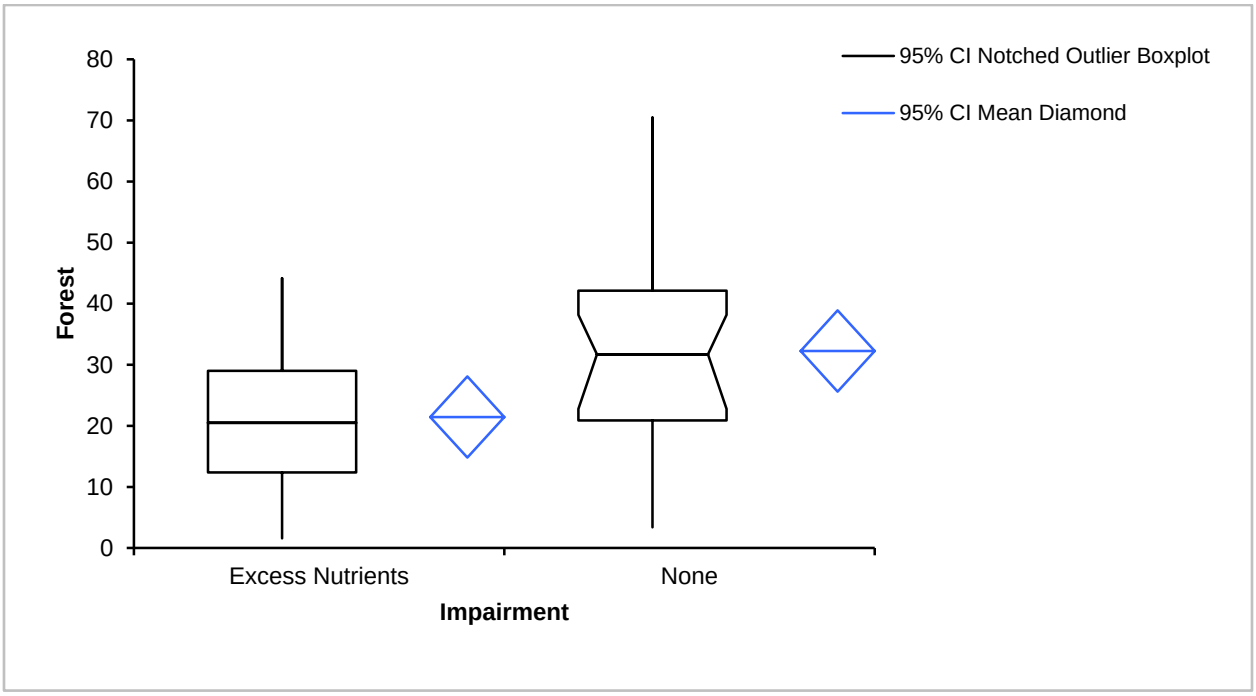


Table B.4. Impairment Status vs. % Urban LULC in Catchment

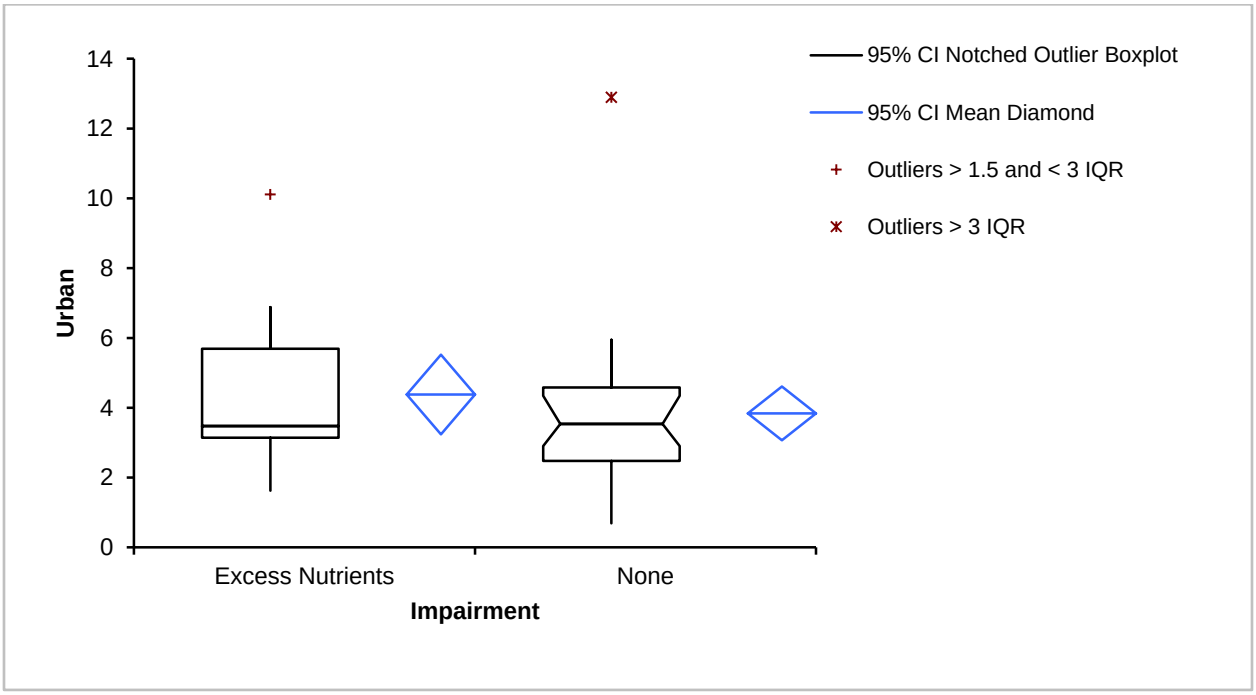
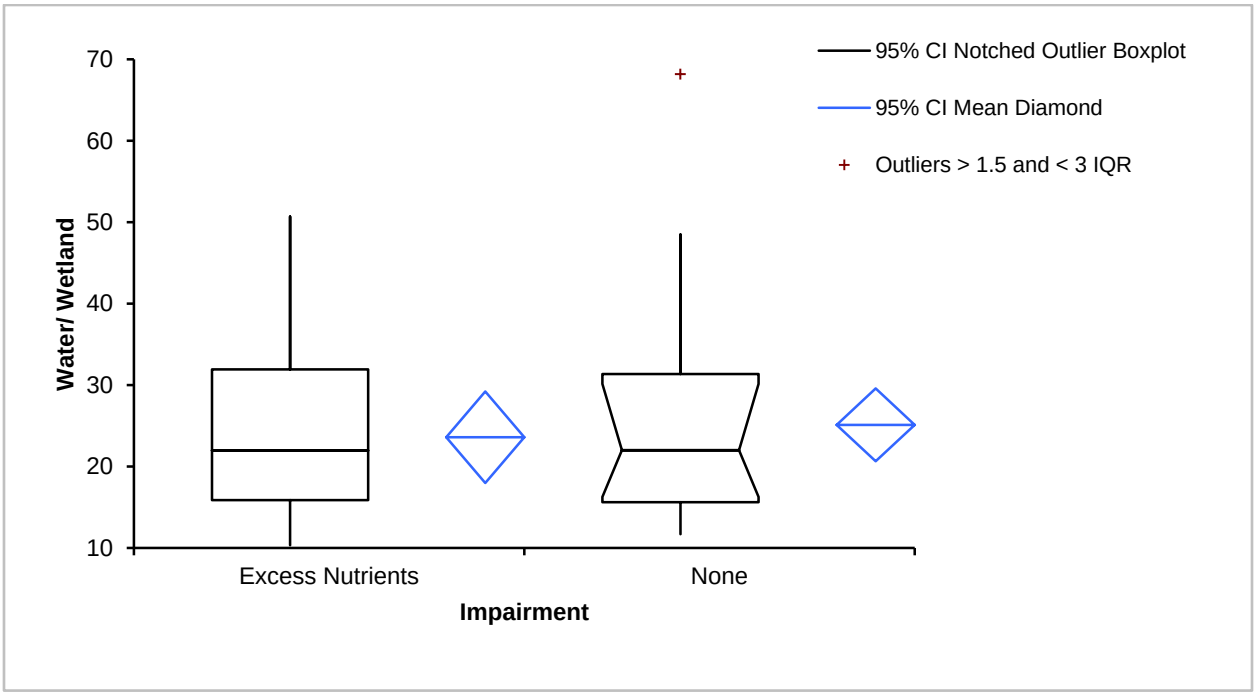


Table B.5. Impairment Status vs. % Water/Wetland LULC in Catchment



APPENDIX C

Summary Statistics for Lake Groups (by Ecoregion and Relative Depth)

Table C.1: Summary Statistics of BRW Lake TP Data by Level III Ecoregion and Relative Depth

	n			Mean TP (ppb)			Median TP (ppb)			1st Quartile TP (ppb)			3rd Quartile TP (ppb)		
	Agassiz	NCHF	NLF	Agassiz	NCHF	NLF	Agassiz	NCHF	NLF	Agassiz	NCHF	NLF	Agassiz	NCHF	NLF
All	66	582	59	133.8	79.6	27.8	93.0	46.0	20.0	47.7	23.0	20.0	183.8	86.0	33.0
Shallow	48	299	59	168.4	108.0	27.8	118.5	70.0	24.0	86.5	34.0	20.0	228.4	120.8	33.0
Deep	18	283	0	41.5	49.7	---	36.0	29.0	---	28.0	17.0	---	56.2	55.0	---

Table C.2: Summary Statistics of BRW Lake Chl-a Data by Level III Ecoregion and Relative Depth

	n			Mean Chl-a (ppb)			Median Chl-a (ppb)			1st Quartile Chl-a (ppb)			3rd Quartile Chl-a (ppb)		
	Agassiz	NCHF	NLF	Agassiz	NCHF	NLF	Agassiz	NCHF	NLF	Agassiz	NCHF	NLF	Agassiz	NCHF	NLF
All	66	543	54	44.6	25.3	8.8	29.0	11.0	8.0	12.0	4.0	5.0	55.2	30.0	11.0
Shallow	48	275	54	55.5	37.0	8.8	41.5	18.0	8.0	23.0	8.0	5.0	85.0	45.8	11.0
Deep	18	268	---	15.5	13.2	---	13.6	7.0	---	8.5	3.0	---	22.2	16.0	---

Table C.3: Summary Statistics of BRW Lake Secchi Disk Depth Data by Level III Ecoregion and Relative Depth

	n			Mean Secchi Disk Depth (m)			Median Secchi Disk Depth (m)			1st Quartile Secchi Disk Depth (m)			3rd Quartile Secchi Disk Depth (m)		
	Agassiz	NCHF	NLF	Agassiz	NCHF	NLF	Agassiz	NCHF	NLF	Agassiz	NCHF	NLF	Agassiz	NCHF	NLF
All	64	2499	176	1.4	4.2	1.9	1.2	4.3	1.8	0.8	2.1	1.5	2.1	5.9	2.1
Shallow	46	841	176	1.1	2.1	1.9	0.9	2.1	1.8	0.6	2.1	1.5	1.2	2.9	2.1
Deep	18	1658	---	2.0	5.2	---	2.2	5.5	---	1.5	4.3	---	2.4	6.4	---