Lake Cowdry (21-0103)
Stony Lake (21-0101)
North Union Lake (21-0095)
Taylor Lake (21-0105)
Douglas County:
2010 Lake Assessment

Minnesota Pollution Control Agency
Water Monitoring Section
Lakes and Streams Monitoring Unit
May 2010

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Lake Assessment Program 2010
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Minnesota Pollution Control Agency
Water Monitoring Section
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Executive Summary

The Minnesota Pollution Control Agency (MPCA) conducts and supports lake monitoring for a variety of objectives. Staff within the MPCA's Lakes and Streams Monitoring Unit samples approximately 100 lakes per year, coordinates citizen volunteer monitoring through the Citizen Lake Monitoring Program, and manages Surface Water Assessment Grants given to local groups to monitor lake water quality. All of the data from these activities are used to assess the condition of Minnesota lakes. Water quality data are compared to state water quality standards to determine if a given lake is fully supporting or not supporting standards set for recreational use (e.g., swimming, wading, etc.). Lakes not supporting aquatic recreational use are termed 'impaired' and are placed on a list biennially. This list is formally termed the 303(d) list (referencing the section within the federal Clean Water Act that requires us to assess for condition); it is also commonly called the "Impaired Waters List". A lake placed on the Impaired Waters List is required to be intensively researched through a Total Maximum Daily Load (TMDL) study to determine the source and extent of the pollution problem. The study also requires the development of a restoration plan. The water quality data and the results of the condition assessment are incorporated into a variety of products, including lake assessment reports, status and trend/update reports, and fact sheets. Lastly, it should be noted that a great deal of additional lake monitoring is carried out by various other MPCA staff and local groups who are undertaking TMDL studies or other, special projects.

Lake Cowdry is a 243-acre lake in central Douglas County within the Long Prairie River Hydrological Unit Code 8 (HUC-8) watershed. The lake has a maximum depth of 15.9 meters (52 feet) and 36% of the lake is littoral. There is one public access on the northeastern shore. The total catchment watershed for Lake Cowdry is 45,478 hectares (112,569 acres).

Stony Lake is an 87-acre lake in central Douglas County, within the Long Prairie River HUC-8 watershed. The lake has a maximum depth of 17.7 meters (58 feet) and 55% of the lake is littoral. Stony Lake can be accessed via Taylor Lake through a culvert on the southwest shore of Lake Cowdry. The total catchment watershed for Stony Lake is 43,986 hectares (108,875 acres).

North Union Lake is a 113-acre lake in central Douglas County within the Long Prairie River HUC-8 watershed. The lake has a maximum depth of 12.8 meters (42 feet) and 81% of the lake is littoral. Access can be obtained via a culvert from Stony Lake. The total catchment watershed for North Union Lake is 43,914 hectares (108,699 acres).

Taylor Lake is a 46-acre lake in central Douglas County within the Long Prairie River HUC-8 watershed. The lake has a maximum depth of 9.5 meters (31 feet) and 89% of the lake is littoral. Access can be obtained via Lake Cowdry. The total catchment watershed for Taylor Lake is 44,055 hectares (109,048 acres).

Based on the basin characteristics alone, Lake Cowdry, Stony Lake, North Union Lake, and Taylor Lake are all deep dimictic lakes that turn over in the spring and fall and develop two distinct temperature layers during the summer. Based on water quality data presented in this report, all four lakes are considered mesotrophic. The lakes are all moderately clear with the probability of anoxic conditions developing in the hypolimnion during the summer. Additionally, all four lakes are located within the North Central Hardwood Forest (NCHF) ecoregion.

Introduction

This report details the analysis of monitoring on Lake Cowdry, Stony Lake, North Union Lake, and Taylor Lake in Douglas County during the 2009 season. Data collected in 2009 were combined with data from previous sample seasons for the assessment of each lake. For data-poor lakes, monitoring establishes a baseline data. In the selection of lakes, a focus is typically placed on large lakes with surface areas of 500 acres or more. Data analyzed included all available data in STORET, the national repository for water quality data. Further detail on concepts and terms in this report can be found in the Guide to Lake Protection and Management (http://www.pca.state.mn.us/water/lakeprotection.html).

Background

Lake Morphometric & Catchment Watershed Characteristics

Lake Cowdry, Stony Lake, North Union Lake, and Taylor Lake are all located in central/south central Douglas County within the Long Prairie River HUC-8 watershed (Figure 1). These lakes are all to the west of Alexandria, Minnesota. Table 1 illustrates the morphometric and watershed characteristics of each of the lakes within this report. Percent littoral refers to that portion of the lake that is 4.6 meters (15 feet) or less in depth, which often represents the depth at which rooted plants may grow in the lake. Lakes with a high percentage of littoral area often have extensive macrophyte (rooted plant) beds. These plant beds are a natural part of the ecology of these lakes and are important to protect (EPA 2007).

Lake Cowdry, Stony Lake, North Union Lake, and Taylor Lake are a part of a very large watershed resulting in very high watershed: lake area ratios (Table 1). North Union Lake receives input from the south via Lake Louise and the northeast via Lake Brophy, flows on to Stony Lake and then finally to Lake Cowdry through Taylor Lake. Additionally, Cowdry Lake receives flow from the Lake Latoka catchment watershed. The characteristics of each of the lake catchment watershed are also described in Table 1. The entire catchment watershed for the three lakes drains from the northern shore of Lake Cowdry and into the southern shore of Lake Darling. Watershed areas were estimated based on data from the University of Minnesota Remote and Geospatial Analysis Lab.

Table 1. Lake Cowdry, Stony Lake, North Union Lake and Taylor Lake Morphometric and watershed characteristics

Lake Name	Lake ID	Lake Basin	Littoral Area	Total Watershed Area	Watershed: Lake	Max. Depth	Mean Depth
		Hectares (Acres)	%	Hectares (Acres)	Ratio	Meters (Feet)	Meters (Feet)
Cowdry	21-0103	98 243	36	45,478 112,569	463:1	15.9 52	6.7 22.1
Stony	21-0101	35 87	55	43,986 108,875	1,251:1	17.7 58	3.9 12.8
North Union	21-0095	46 113	81	43,914 108,699	962:1	12.8 42	2.8 9.1
Taylor	21-0105	19 46	89	44,055 109,048	2,371:1	9.5 31	2.4 7.8

Soils within the Long Prairie River major watershed are defined as medium to fine prairie and prairie border soils of Western Minnesota from the Waukon-Barnes series. The area is undulating to rolling and the soils are dark colored and well drained. The major land use is cash grain farming. (Arneman 1963). These lakes are an ice-block basins that were likely formed in the outwash localized preglacial valleys (Zumberge, 1952).

Land Use Characteristics and Ecoregion

Since land use affects water quality, it has proven helpful to divide the state into regions where land use and water resources are similar. Land use in the catchment watershed for all four lakes is fairly typical for this ecoregion. Cropland is the predominant land use and falls within the expected range for the North Central Hardwood Forest (NCHF) ecoregion (Table 2 & Figure 1).

Minnesota is divided into seven regions, referred to as ecoregions, as defined by soils, land surface form, natural vegetation, and current land use. Lake Cowdry, Stony Lake, North Union Lake, and Taylor Lake lie within the NCHF ecoregion (Figure 2). Assessment criteria values for the NCHF ecoregion (Table 3) were used for comparing the water quality characteristics of these lakes. NCHF ecoregion values were also used for land use comparisons (Table 2). Finally, NCHF ecoregional characteristics were used for the MINLEAP model application.

Table 2. Lake Cowdry, Stony Lake, North Union Lake, and Taylor Lake ecoregional land use comparisons

Land Use (%)	Lake Cowdry	Stony Lake	North Union Lake	Taylor Lake	NCHF Ecoregion
Developed	6	6	6	6	2-9
Cropland	30	30	30	30	22-50
Rangeland	24	24	24	24	11-25
Forest	17	17	17	17	6-25
Water & Wetland	23	23	23	23	14-30

Land Use data generated from The National Land Cover Database 2001 Multi-Resolution Land Characteristics (MRLC) Consortium

Figure 1. Lake Cowdry, Stony Lake, North Union Lake, and Taylor Lake contributing watershed and land use

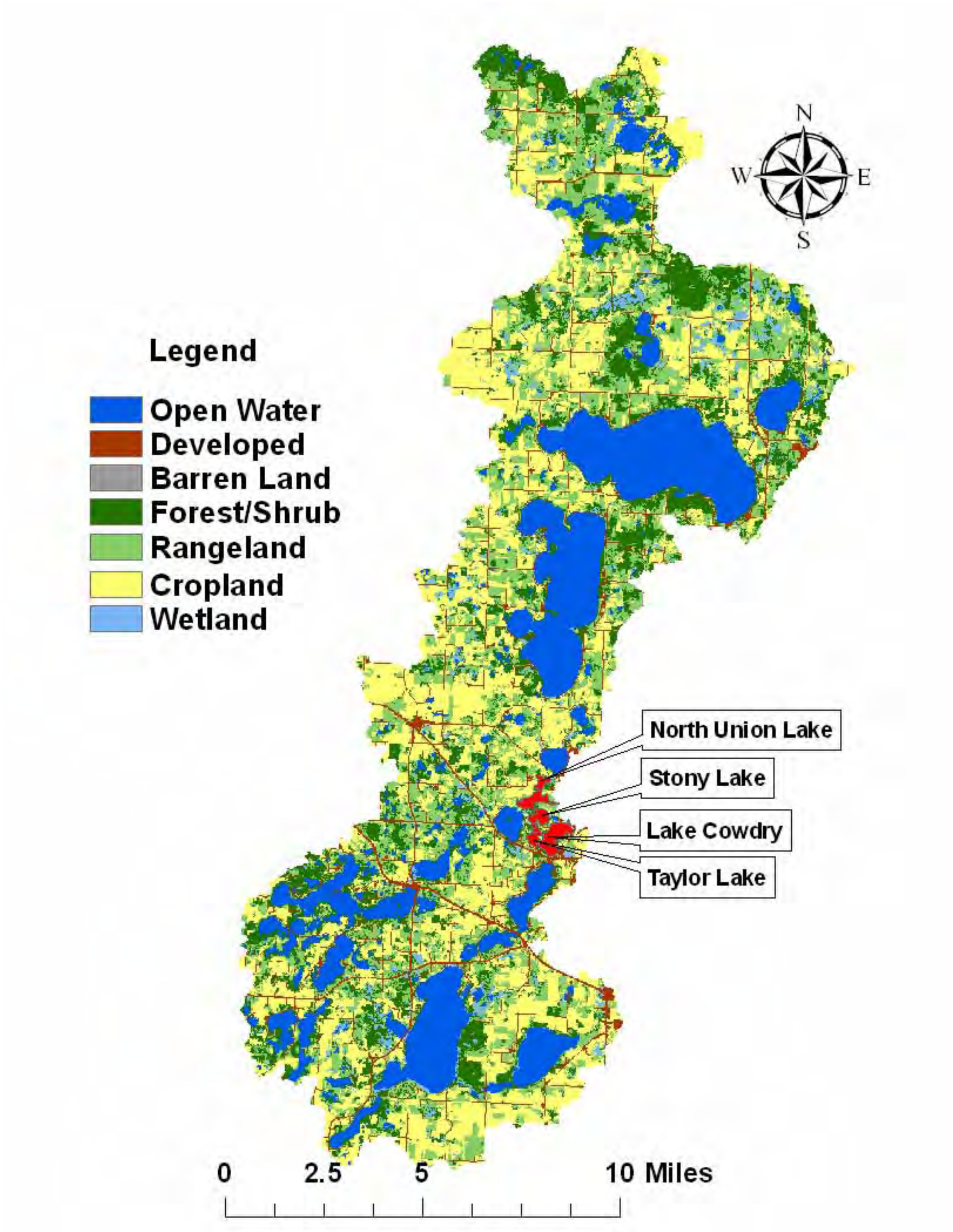
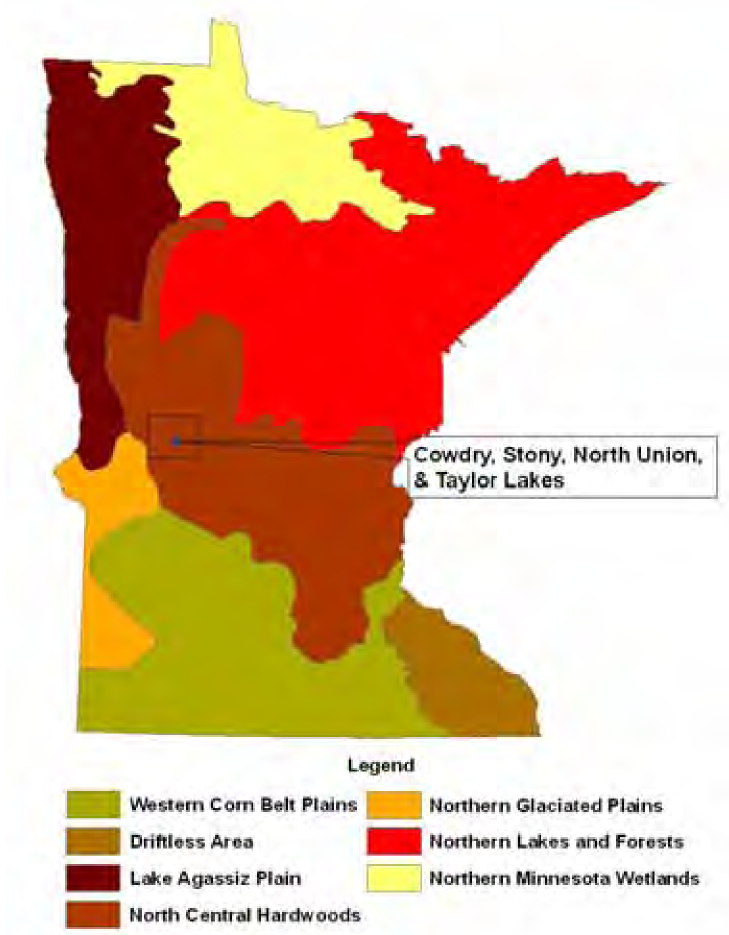


Figure 2. Minnesota's seven ecoregions as mapped by U.S. Environmental Protection Agency (EPA)



Lake Mixing

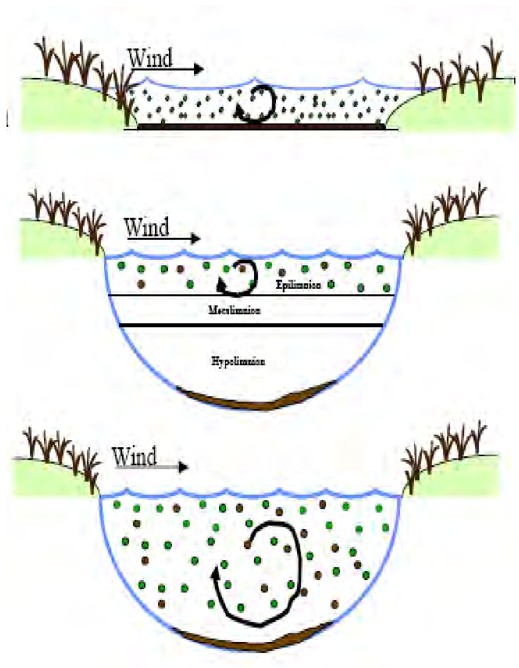
Lake depth can have a significant influence on lake processes and water quality. One such process is *thermal stratification* (formation of distinct temperature layers), in which deep lakes (maximum depths of 9.1 – 12.1 meters (30 - 40 feet) or more) often stratify (form layers) during the summer months and are referred to as *dimictic* (Figure 3). These lakes fully mix or turn over twice per year; typically in spring and fall. Shallow lakes (maximum depths of 4.6 meters (15 feet) or less) in contrast, typically do not stratify and are often referred to as *polymictic*. Lakes with moderate depths may stratify intermittently during calm periods, but mix during heavy winds, and during spring and fall. Measurement of temperature throughout the water column (surface to bottom) at selected intervals (e.g. every meter) can be used to determine whether the lake is well mixed or stratified. It can also identify the depth of the thermocline (zone of maximum change in temperature over the depth interval). In general, dimictic lakes have an upper, well-mixed layer (epilimnion) that is warm and has high oxygen concentrations. In contrast, the lower layer (hypolimnion) is much cooler and often has little or no oxygen. This low oxygen environment in the hypolimnion is conducive to the release of phosphorus (P) from the lake sediments. During stratification, dense colder hypolimnetic waters are separated from the warmer algae-rich surface waters in the epilimnion. Mixing events allow for the nutrient-rich water to mix with the surface water and available to algae. Most of the fish in the lake are usually found in the epilimnion or near the thermocline. Consistent profile data was not collected in 2009 for Lake Cowdry, Stony Lake, North Union Lake, or Taylor Lake; however, based on the bathymetry of each lake, it is likely that all three are dimictic. Additional profile data will be required to make this determination.

Figure 3. Lake stratification

Polymictic Lake
Shallow, no layers,
Mixes continuously
Spring, Summer & Fall

Dimictic Lake
Deep, form layers,
Mixes Spring/Fall

Intermittently Stratified
Moderately deep
Mixes during high winds
Spring, Summer, & Fall



Lake Level Trends

The Minnesota Department of Natural Resources (DNR) Division of Waters has measured water levels on Lake Cowdry since 1977. During the period of record (1977 – 2009), the lake had varied by 2.5 feet, based on 142 readings. The highest and lowest recorded elevations are 1,358.9 feet on 7/16/2003 and 1,356.5 feet on 9/15/2007, respectively. The ordinary high-water mark for Lake Cowdry is 1,359.3 feet. Lake level measurements have not been recorded for Stony Lake, North Union Lake, and Taylor Lake.

Precipitation

Rain gauge records from Alexandria, Minnesota show two one-inch plus rain events during summer 2009 (Figure 4). These rain events will increase runoff into the lakes and may influence in-lake water quality and lake levels; however, despite the higher levels of precipitation occurring in mid- to late-August, nutrient levels showed no measurable increases during this period. Precipitation records for the 2009 water year (October 2008 through September 2009) indicated normal average rainfall for the Alexandria area (Figure 5).

Figure 4. Summer 2009 rainfall based on records for Alexandria, Minnesota

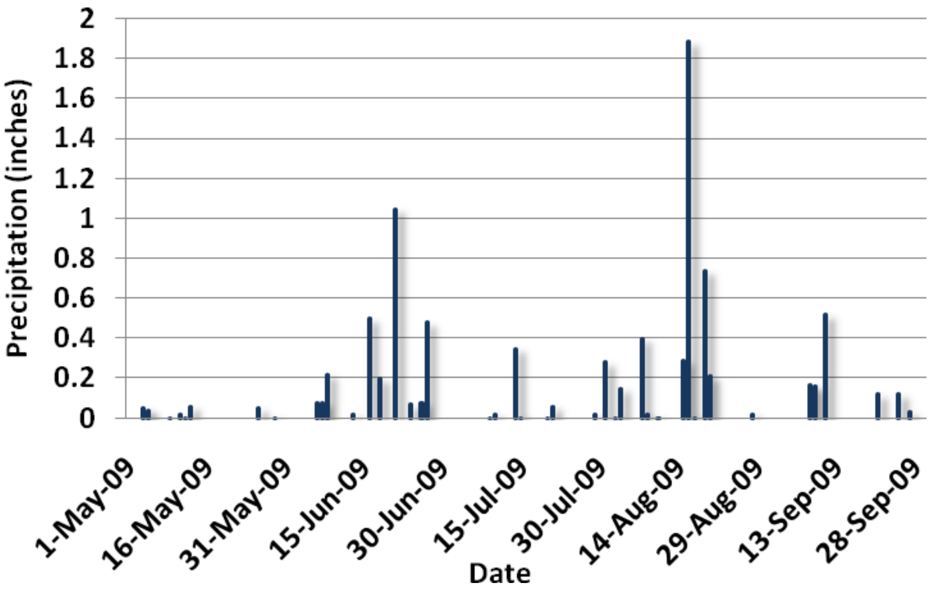
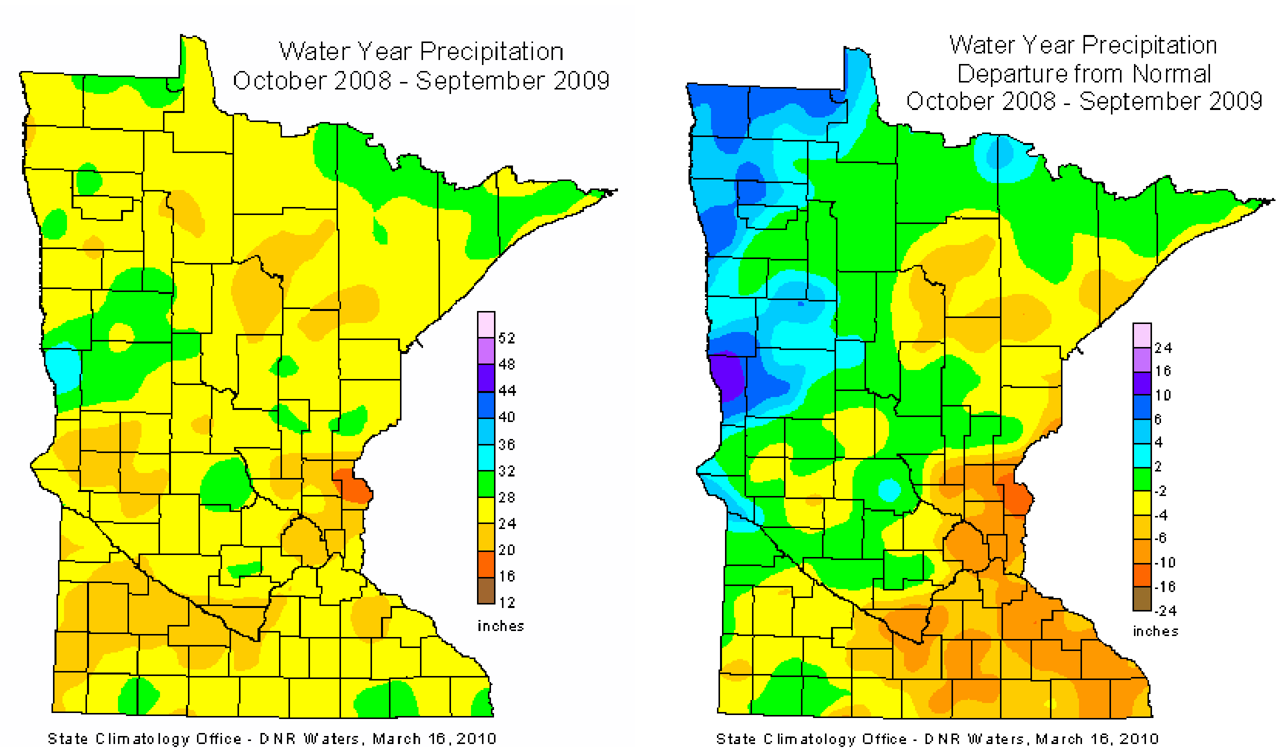


Figure 5. 2009 Minnesota Water Year Precipitation and Departure from Normal
Prepared by State Climatology Office DNR Waters
Values are in inches



Fisheries

DNR fisheries managers utilize netting survey information to assess the well-being of fish communities and measure the efficacy of management programs. Presence, absence, abundance, physical condition of captured fishes, and community relationships among fish species within survey catch information also provide good indicators of current habitat conditions and trophic state of a lake (Schupp and Wilson, 1993). These data are stored in a long-term fisheries survey database, which has proven valuable in qualifying and quantifying changes in environmental and fisheries characteristics over time.

Information on the most recent fish surveys for Lake Cowdry, Stony Lake, North Union Lake, and Taylor Lake can be found at the DNR lake finder website: http://www.dnr.state.mn.us/lakefind/index.html
Additional information on fishery management can be found at:
http://www.dnr.state.mn.us/fisheries/management/index.html

Methods

Water quality data for Lake Cowdry, Stony Lake, North Union Lake, and Taylor Lake were collected in June, July, August, and September 2009. Lake surface samples were collected with an integrated sampler, a polyvinyl chloride tube 2 meters (6.6 feet) in length with an inside diameter of 3.2 centimeters (1.24 inches). A summary of data follows in the Appendix.

Sampling procedures were employed as described in the MPCA Lake Water Quality Sampling Standard Operating Procedures (http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/lakes-and-lake-monitoring-in-minnesota.html). Laboratory analysis was performed by RMB Environmental Laboratories, Inc. in Detroit Lakes, Minnesota using EPA-approved methods. Samples were analyzed for nutrients and chlorophyll-*a* (chl-*a*). Temperature and dissolved oxygen (DO) profiles were not collected on any of the four lakes. Secchi disk transparency measurements were collected for each lake.

Results and Discussion

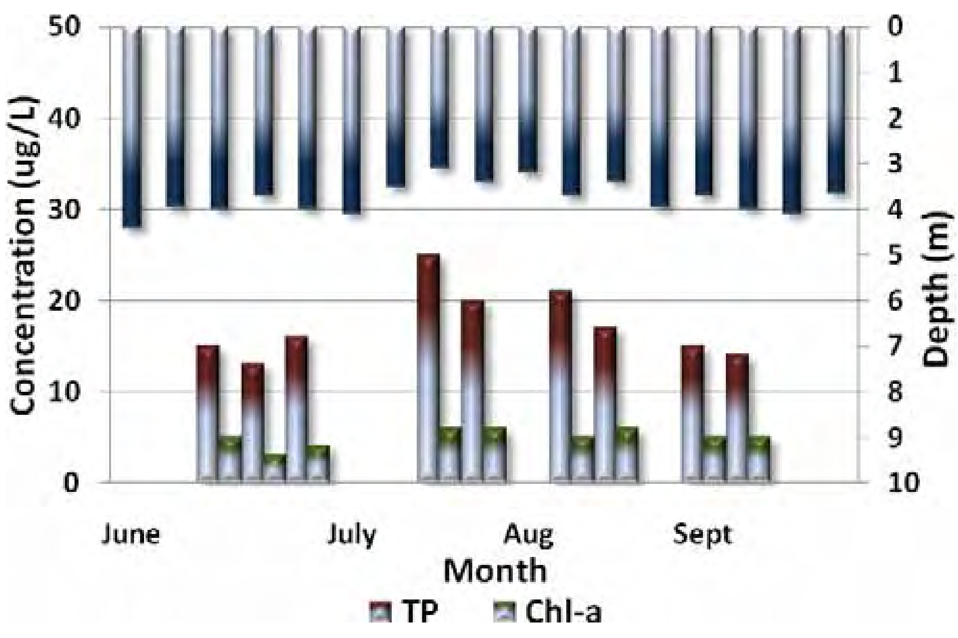
Lake Cowdry

Total Phosphorus (TP) concentrations, collected in 2008 and 2009, for Lake Cowdry averaged 19 micrograms per liter (µg/L) (Table 3). This average was below the assessment criteria for lakes within the NCHF ecoregion. TP concentrations peaked in July and steadily declined through September (Figure 6). Watershed runoff is likely the primary source of P loading to Lake Cowdry, though internal P release may be important during spring and fall mixing. Surface water runoff from the watershed flows to the lake via Taylor Lake and Latoka Lakes.

Chlorophyll-*a* concentrations provide an estimate of the amount of algal production in a lake. During the summer of 2009, chl-*a* concentrations ranged from 3 µg/L to 6 µg/L (Figure 6) with an average of 4.8 µg/L (Table 3). Concentrations greater than 20 µg/L will typically be perceived as a nuisance, while concentrations greater than 30 µg/L are perceived as a severe nuisance algal bloom (Heiskary and Walker, 1988). Based on 2009 data, nuisance algal blooms did not occur in Lake Cowdry. The summer-mean for Lake Cowdry was below the assessment criteria for NCHF lakes.

Secchi disk transparency on Lake Cowdry averaged 3.5 meters (11.5 feet) for the summer of 2009 (Table 3). The average Secchi depth is greater than the assessment criteria for the NCHF ecoregion. Additionally, the changes in the transparency of Lake Cowdry over the course of the summer closely mirrored the changes in nutrient availability (TP) and algal production (chl-*a*). The Secchi disk transparency reached a low of 3.1 meters (10.2 feet) in July and a high of 4.4 meters (14.4 feet) in June (Figure 6).

Figure 6. Lake Cowdry 2009 TP & Chl-*a* concentrations and Secchi depth



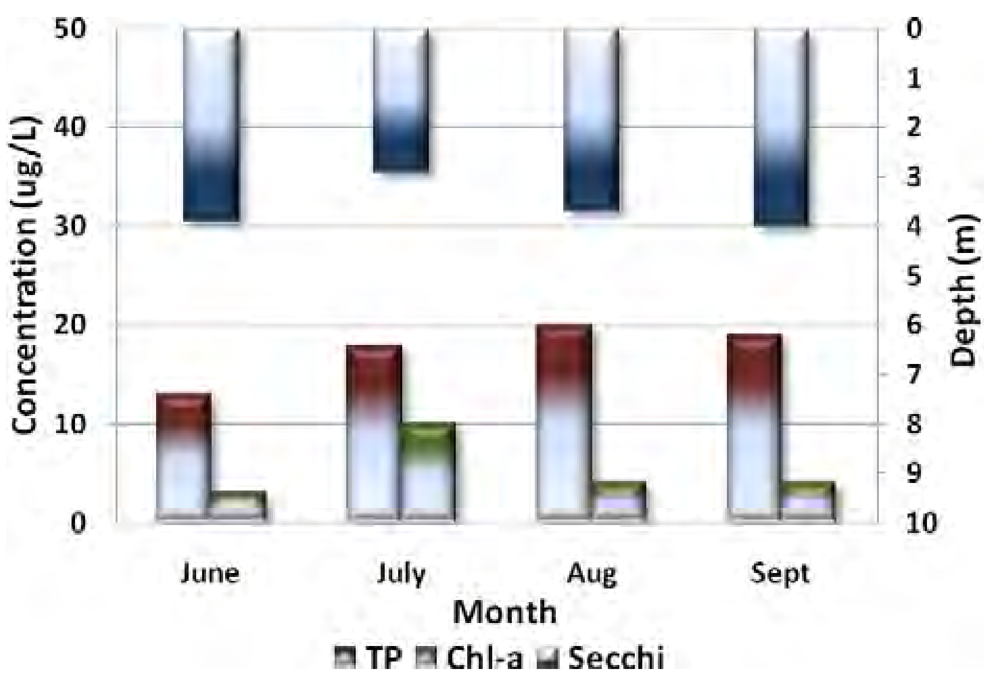
Stony Lake

Total Phosphorus concentrations, collected in 2008 and 2009, for Stony Lake averaged 15 µg/L (Table 3). This average was below the assessment criteria for lakes within the NCHF ecoregion. TP concentrations were fairly consistent for most of the summer peaking in August (Figure 7). TP contributions to Stony Lake are likely occurring both externally from watershed runoff and internally from sediment release during lake mixing. Much of the runoff from the watershed is first processed by North Union Lake, which results in much lower TP concentrations than would be the case if the water flowed directly into Stony.

Chlorophyll-*a* concentrations, during the summer of 2009, ranged from 3 µg/L to 10 µg/L (Figure 7) with an average of 5.2 µg/L (Table 3). Based on the results it is unlikely that a nuisance algal bloom would occur within Stony Lake. The summer-mean for Stony Lake was below the assessment criteria for NCHF lakes.

Secchi disk transparency for Stony Lake averaged 3.8 meters (12.5 feet) for the summer of 2009 (Table 3). The average Secchi depth is greater than the assessment criteria for the NCHF ecoregion. Additionally, the changes in the transparency of Stony Lake over the course of the summer closely mirrored the changes in nutrient availability (TP) and algal production (chl-*a*). The Secchi disk transparency reached a low of 2.9 meters (9.5 feet) in July and a high of 4.7 meters (15.4 feet) in June (Figure 7).

Figure 7. Stony Lake 2009 TP & chl-*a* concentrations and Secchi depth



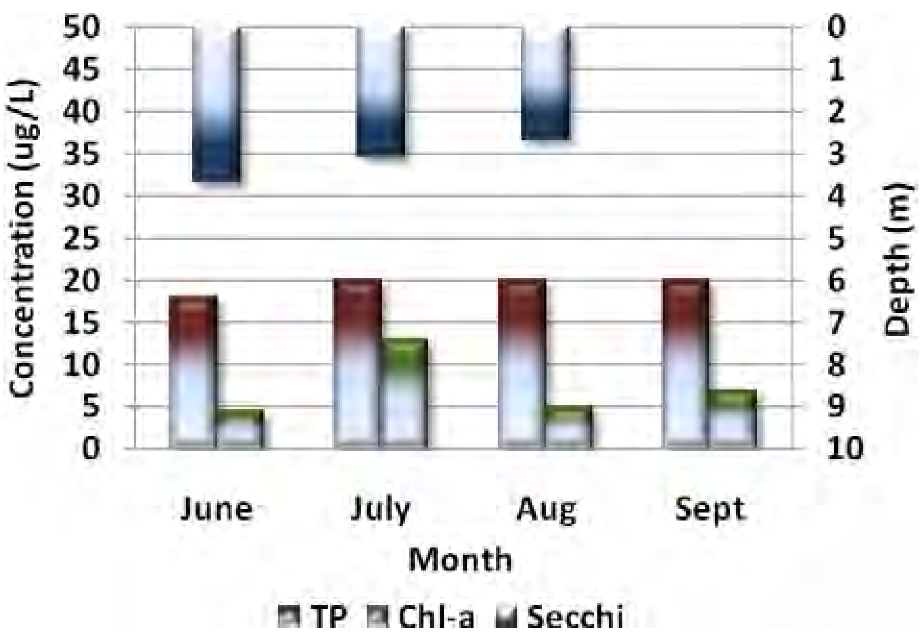
North Union Lake

Total Phosphorus concentrations, collected in 2008 and 2009, for North Union Lake averaged 20 µg/L (Table 3). This average was below the assessment criteria for lakes within the NCHF ecoregion. TP concentrations were steady for most of the summer and were at their lowest in May. TP contributions to North Union Lake are likely occurring both externally from the watershed and internally from sediment release and lake mixing; however, given its relatively low TP, internal recycling does not seem to be excessive (Figure 8).

Chlorophyll-*a* concentrations, during the summer of 2009, ranged from 3 µg/L to 13 µg/L (Figure 8) with an average of 6.2 µg/L (Table 3). Based on 2009 results, chl-*a* remained below nuisance levels. The summer-mean for North Union Lake was below the assessment criteria for NCHF lakes.

Secchi disk transparency for North Union Lake averaged 2.9 meters (9.5 feet) for the summer of 2009 (Table 3). The average Secchi depth is greater than the assessment criteria for the NCHF ecoregion. Additionally, the changes in the transparency of North Union Lake over the course of the summer closely mirrored the changes in nutrient availability (TP) and algal production (chl-*a*) (Figure 8).

Figure 8. North Union Lake 2009 TP & chl-*a* concentrations and Secchi depth



Taylor Lake

Total Phosphorus concentrations, collected in 2008 and 2009, for Taylor Lake averaged 24 µg/L (Table 3). This average was below the assessment criteria for lakes within the NCHF ecoregion. TP concentrations increased steadily throughout the summer and were at their lowest in May. TP contributions to Taylor Lake are likely occurring both externally from the watershed and internally from sediment release and lake mixing; however, given its relatively low TP, internal recycling does not seem to be excessive (Figure 9).

Chlorophyll-*a* concentrations, during the summer of 2009, ranged from 4 µg/L to 7 µg/L (Figure 9) with an average of 5.8 µg/L (Table 3). Based on 2009 results, chl-*a* remained below nuisance levels. The summer-mean for Taylor Lake was below the assessment criteria for NCHF lakes.

Secchi disk transparency for Taylor Lake averaged 2.9 meters (9.5 feet) for the summer of 2009 (Table 3). The average Secchi depth is greater than the assessment criteria for the NCHF ecoregion. Additionally, the changes in the transparency of Taylor Lake over the course of the summer closely mirrored the changes in nutrient availability (TP) and algal production (chl-*a*) (Figure 9).

Figure 9. Taylor Lake 2009 TP & chl-*a* concentrations and Secchi depth

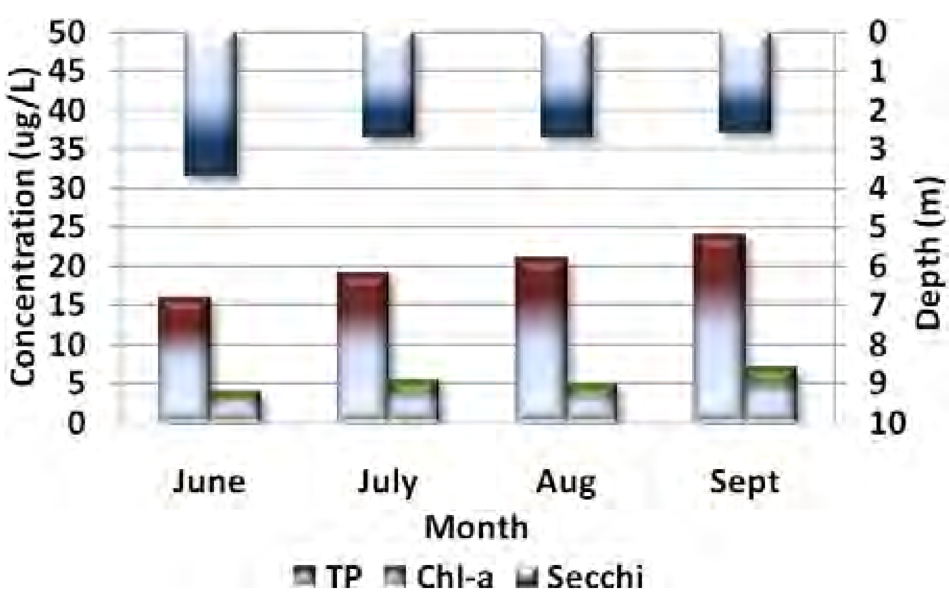


Table 3. Lake Cowdry, Stony Lake, North Union Lake, and Taylor Lake 2008 & 2009 seasonal averages as compared to NCHF assessment standards

Ecoregion	TP	Chl-*a*	Secchi
	ug/L	ug/L	meters
NCHF – Aquatic Rec. Use (Class 2b)	< 40	< 14	> 1.4
NCHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
Lake Cowdry Averages	19	4.8	3.5
Stony Lake Averages	15	5.2	3.8
North Union Lake Averages	20	6.2	2.9
Taylor Lake Averages	24	5.8	3

Trophic State Index (TSI)

One way to evaluate the trophic status of a lake and to interpret the relationship between TP, chl-*a*, and Secchi disk transparency is Carlson's Trophic State Index (Carlson 1977). TSI values are calculated as follows:

TP TSI (TSIP) = 14.42 ln (TP) + 4.15

Chl-*a* TSI (TSIC) = 9.81 ln (Chl-a) + 30.6

Secchi disk TSI (TSIS) = 60 – 14.41 ln (SD)

TP and chl-*a* are in µg/L and Secchi disk is in meters. TSI values range from 0 (ultra-oligotrophic) to 100 (hypereutrophic). In this index, each increase of ten units represents a doubling of algal biomass. Comparisons of the individual TSI measures provides a bases for assessing the relationship among TP, chl-*a*, and Secchi (Figure 9). In general, the TSI values are in fairly close correspondence with each other. The TSI values also correspond with observations for 2009. Based on the values presented in Table 3 and average TSI scores of 45, 44, 47, and 47 for Cowdry Lake, Stony Lake, North Union Lake, and Taylor Lake respectively, all four lakes were classified as mesotrophic.

FIGURE 10. Carlson's Trophic State Index for Lake Cowdry, Stony Lake , North Union Lake, and Taylor Lake
R.E. Carlson

TSI < 30 Classical Oligotrophy: Clear water, oxygen throughout the year in the Hypolimnion, salmonid fisheries in deep lakes.

TSI 30 – 40 Deeper lakes still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion during the summer.

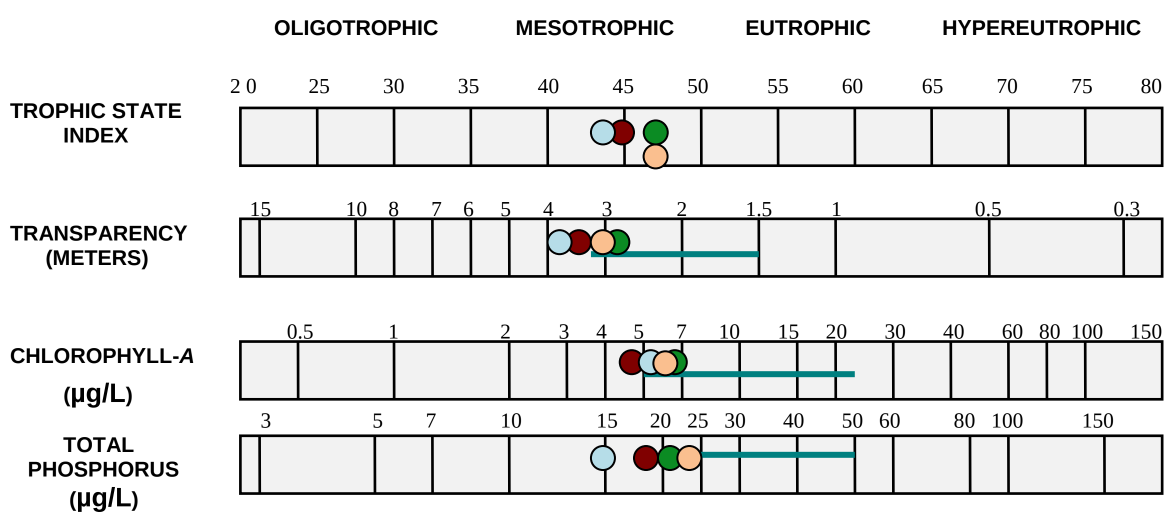
TSI 40 – 50 Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.

TSI 50 – 60 Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnia during the summer, macrophyte problems evident, warm-water fisheries only.

TSI 60 – 70 Dominance of blue-green algae, algal scum probable, extensive Macrophyte problems.

TSI 70 – 80 Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypereutrophic.

TSI > 80 Algal scum, summer fish kills, few macrophytes, dominance of rough fish.



After Moore, I. and K. Thornton, [Ed.]1988. Lake and Reservoir Restoration Guidance Manual. USEPA>EPA 440/5-88-002.

NCHF Ecoregion Range: Cowdry: Stony: North Union: Taylor:

Trophic Status Trends

One aspect of lake monitoring is to assess historical trends where possible based on available STORET data. A review of these data reveals a large amount of historical chemistry and Secchi data for Lake Cowdry (Figure 11) and a fair amount of Secchi data for Stony, North Union, and Taylor Lakes (Figures 12 through 14).

Based on historical chemistry and Secchi data, Lake Cowdry has a long-term mean TP value of 17 µg/L, a long-term mean chl-*a* value of 5 µg/L, and a water clarity value of 3.8 meters (12.4 feet) (Figure 11). All of these values are below the assessment criteria for recreational use on lakes within the NCHF ecoregion indicating that Lake Cowdry has historically maintained excellent water quality.

Based on historical Secchi data, Stony Lake has a long-term mean water clarity value of 3.7 meters (12.1 feet) (Figure 12). North Union Lake has a long-term mean water clarity value of 3.1 meters (10.2 feet) (Figure 13). Finally, Taylor Lake has a long-term mean water clarity value of 3.5 meters (11.5). The long-term Secchi means for all three lakes is better than the assessment criteria for recreational use on lakes within the NCHF ecoregion.

Figure 11. Lake Cowdry historical TP, chl-*a* and Secchi trends. Long-term means indicated by dashed lines.

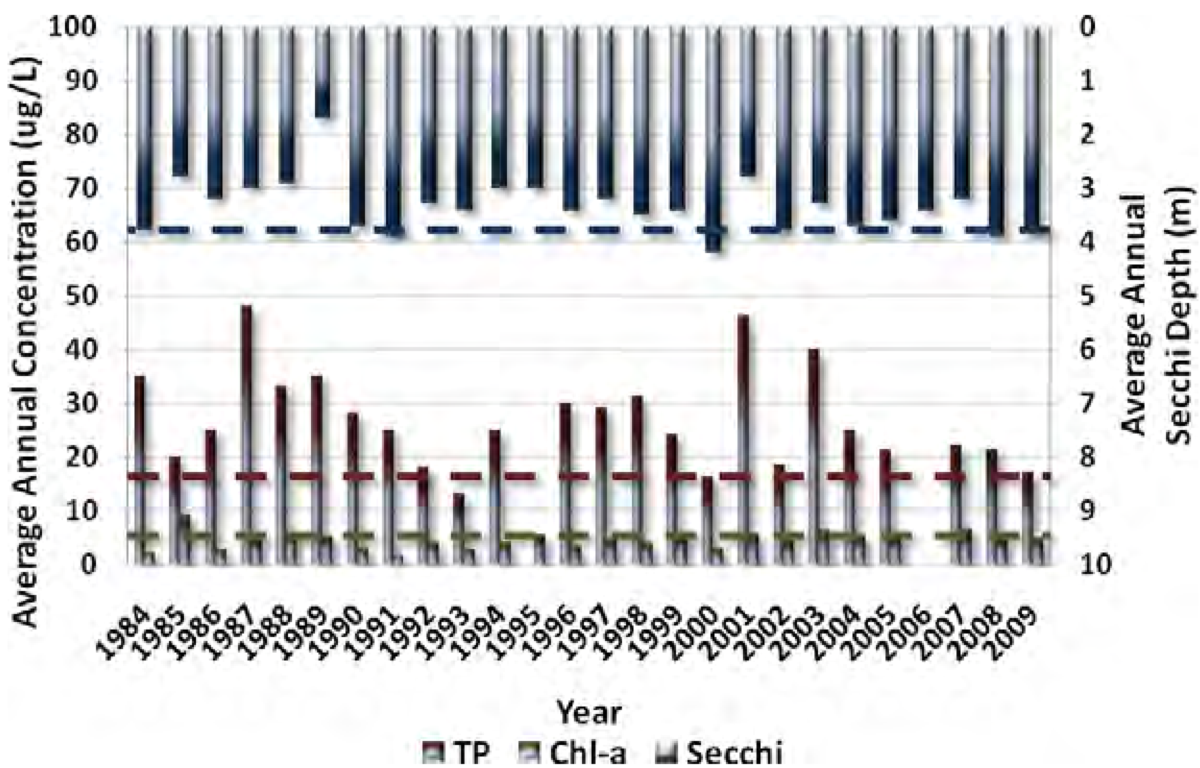


Figure 12. Stony Lake historical Secchi trend.
Long-term mean indicated by dashed line.

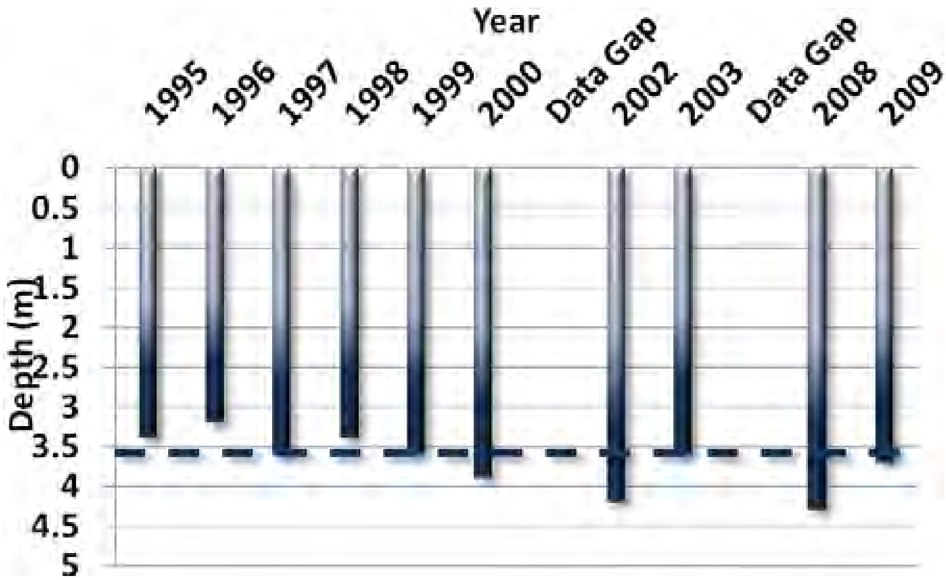


Figure 13. North Union Lake historical Secchi trend.
Long-term mean indicated by dashed line.

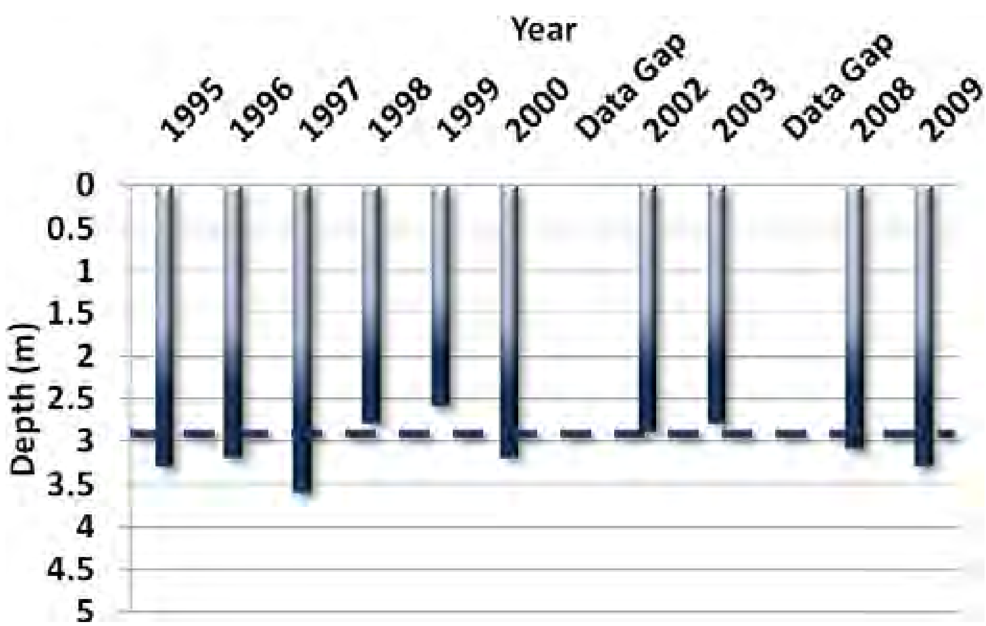
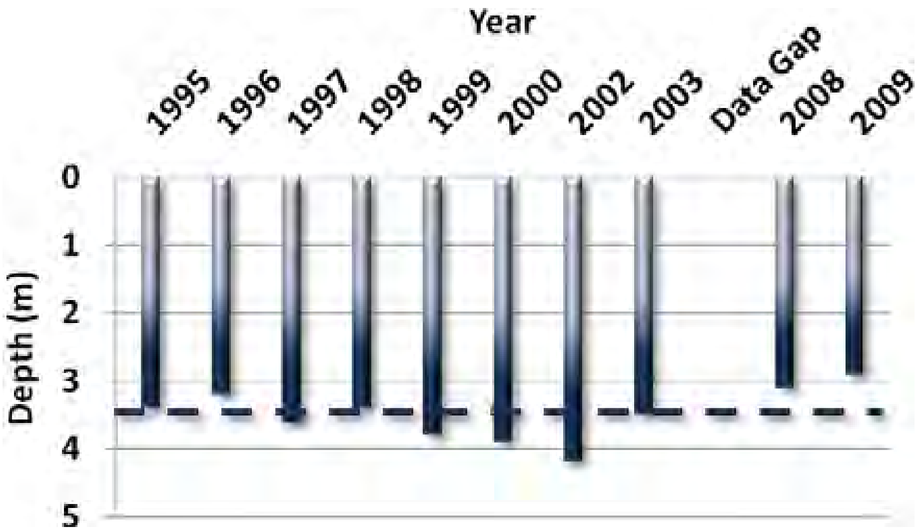


Figure 14. Taylor Lake historical Secchi trend.
Long-term mean indicated by dashed line.



Modeling

Numerous complex mathematical models are available for estimating nutrient and water budgets for lakes. These models can be used to relate the flow of water and nutrients from a lake's watershed to observed conditions in the lake. Alternatively, they may be used for estimating changes in the quality of the lake as a result of altering nutrient inputs to the lake (e.g., changing land uses in the watershed) or altering the flow or amount of water that enters the lake. To analyze the 2008 water quality of Portage Lake, the Minnesota Lake Eutrophication Analysis Procedures (MINLEAP) model (Wilson and Walker, 1989) was used. A comparison of MINLEAP predicted vs. observed values is presented in Table 4.

MINLEAP was developed by MPCA staff based on an analysis of data collected from the ecoregion reference lakes. It is intended to be used as a screening tool for estimating lake conditions with minimal input data and is described in greater detail in Wilson and Walker (1989). The model predicts in-lake TP from these inputs and subsequently predicts chl-*a* based on a regression equation of TP and Secchi based on a regression equation based on chl-*a*. To assist with the analysis of Lake Cowdry, Stony Lake, North Union Lake, and Taylor Lake MINLEAP was applied as a basis for comparing the observed (2009) TP, chl-*a,* and Secchi values with those predicted by the model based on the lake depth and size as well as the size of the catchment watershed.

All four lakes are located in the NCHF ecoregion and the model was run using NCHF ecoregion-based inputs. It should be noted that the model predicts in-lake TP from these inputs and subsequently predicts chl-*a* based on a regression equation of TP and Secchi based on a regression equation based on chl-*a*. A comparison of MINLEAP predicted vs. observed values is presented in Table 4.

The observed and MINLEAP predicted TP, chl-*a*, and Secchi values for all four lakes were different from what is typically predicted for lakes of their size, depth, and catchment watershed area in the NCHF ecoregion. The predicted TP, and chl-*a* values are much higher than the actual values. As a result, model-predicted Secchi is less than what was observed. Though the upstream watershed for these lakes is large much of the watershed flows through other lakes, which allows for sedimentation of P and thus much lower than predicted P loading to these lakes. Additionally, all four lakes are small and deep resulting in limited internal release of nutrients from the sediment and a low nutrient residency time. Temperature and DO profiles will be required to determine the mixing status of all four lakes.

Table 4. MINLEAP model results for Lake Cowdry, Stony Lake, North Union Lake, and Taylor Lake

Parameter	2009 Lake Cowdry Observed	Lake Cowdry MINLEAP Predicted	2009 Stony Lake Observed	Stony Lake MINLEAP Predicted	2009 North Union Lake Observed	North Union MINLEAP Predicted	2009 Taylor Lake Observed	Taylor MINLEAP Predicted
TP (µg/L)	19	100	15	122	20	123	24	133
Chl-*a* (µg /L	4.8	55	5.2	74	6.2	74	5.8	83
Secchi (m)	3.5	0.7	3.8	0.6	2.9	0.6	3	0.6
P loading rate (kg/yr)	-	8,779	-	8,473	-	8,463	-	8,482
P retention (%)	-	33	-	17	-	17	-	10
P inflow Avg. (µg/L)	-	148	-	148	-	148	-	148
Areal Water Load (m/yr)	-	60	-	163	-	124	-	301
Outflow volume (hm^3/yr)	-	59	-	57	-	57	-	57
Residence time (yrs)	-	0.1	-	0	-	0	-	0

303(d) Assessment and Goal Setting

The federal Clean Water Act requires states to adopt water quality standards to protect waters from pollution. These standards define how much of a pollutant can be in the water and still allow it to meet designated uses, such as drinking water, fishing and swimming. The standards are set on a wide range of pollutants, including bacteria, nutrients, turbidity and mercury. A water body is "impaired" if it fails to meet one or more water quality standards.

Under Section 303(d) of the Clean Water Act, the state is required to asses all waters of the state to determine if they meet water quality standards. Waters that do not meet standards (i.e., impaired waters) are added to the 303(d) list and updated every even-numbered year. In order for a lake to be considered impaired for aquatic recreation use, the average TP concentration must exceed the water quality standard for its ecoregion. In addition, either the chl-*a* concentration for the lake must exceed the standard or the Secchi data for the lake must be below the standard. A minimum of eight samples collected over two or more years are needed to conduct the assessment. There are numerous other water quality standards for which we assess Minnesota's water resources. An example is mercury found in fish tissue. If a water body is listed, an investigative TMDL study must be conducted to determine the sources and extent of pollution, and to establish pollutant reduction goals needed to restore the resource to meet the determined water quality standards for its ecoregion. The MPCA is responsible for performing assessment activities, listing impaired waters, and conducting TMDL studies in Minnesota.

According to Table 5, the TP and chl-*a* standards for the support of aquatic recreation in lakes within the NCHF ecoregion are less than 40 µg/L and 14 µg/L respectively. For chl-*a* levels at or below 30 µg/L, "nuisance algal blooms" (chl-*a* > 20 µg/L) should occur less than 10 percent of the summer and transparency should remain at or above 3 meters (9.8 feet) over 85 percent of the summer. Summer averages for TP, chl-*a*, and Secchi transparency for Lake Cowdry, Stony Lake, North Union Lake, and Taylor Lake were all below the assessment criteria.

Maintaining low levels of TP will be required in order to prevent the occurrence of algal blooms for all three lakes. Alternatively, should in-lake TP concentrations increase, the potential for nuisance algal blooms will also increase. It is important to limit as much external (watershed) phosphorus loading to the lakes as possible to maintain the current concentrations. Additionally, the small size and deep basins of each lake will continue to limit the amount of internal loading of TP. Based on the data used in the 2010 assessment cycle, Lake Cowdry, Stony Lake, North Union Lake, and Taylor Lake fully support aquatic recreational uses (do not exceed the eutrophication standards) and will not be placed on the 303(d) impaired waters list.

Table 5. Eutrophication standard by ecoregion and lake type
(Heiskary and Wilson, 2005)

Ecoregion	TP µg/L	Chl-*a* µg/L	Secchi meters
NLF – Lake trout (Class 2A)	< 12	< 3	> 4.8
NLF – Stream trout (Class 2A)	< 20	< 6	> 2.5
NLF – Aquatic Rec. Use (Class 2B)	< 30	< 9	> 2.0
NCHF – Stream trout (Class 2a)	< 20	< 6	> 2.5
NCHF – Aquatic Rec. Use (Class 2b)	< 40	< 14	> 1.4
NCHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
WCBP & NGP – Aquatic Rec. Use (Class 2B)	< 65	< 22	> 0.9
WCBP & NGP – Aquatic Rec. Use (Class 2b) Shallow lakes	< 90	< 30	> 0.7

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Appendix

Lake Cowdry, Stony Lake, North Union Lake, & Taylor Lake Surface Water Results

Lake Name	Lake ID	Sample Date	Site ID	Secchi	TP	Chl-*a*
				Meters	ug/L	ug/L
Cowdry	21-0103	6/1/1984	6201	3.5	30	1
Cowdry	21-0103	7/1/1984	6201	4.2	30	1
Cowdry	21-0103	8/1/1984	6201	3.5	40	1
Cowdry	21-0103	9/1/1984	6201	4.2	40	5
Cowdry	21-0103	6/1/1985	6201	2.7	10	14
Cowdry	21-0103	7/1/1985	6201	3.4	30	5
Cowdry	21-0103	8/1/1985	6201	2.4		10
Cowdry	21-0103	9/1/1985	6201	2.7	20	8
Cowdry	21-0103	6/1/1986	6201	3.7	20	2
Cowdry	21-0103	7/1/1986	6201	2.4	30	3
Cowdry	21-0103	8/1/1986	6201	2.7	20	3
Cowdry	21-0103	9/1/1986	6201	4.0	30	3
Cowdry	21-0103	6/1/1987	6201	4.0	70	3
Cowdry	21-0103	7/1/1987	6201	2.1	60	4
Cowdry	21-0103	8/1/1987	6201	3.1	20	6
Cowdry	21-0103	9/1/1987	6201	3.1	40	6
Cowdry	21-0103	6/1/1988	6201	3.1	30	7
Cowdry	21-0103	7/1/1988	6201	3.1	30	8
Cowdry	21-0103	8/1/1988	6201	2.4	40	3
Cowdry	21-0103	9/1/1988	6201	3.1	30	5
Cowdry	21-0103	6/1/1989	6201	4.0	30	8
Cowdry	21-0103	7/13/1989	6201	1.0	50	
Cowdry	21-0103	8/14/1989	6201	0.9	20	5
Cowdry	21-0103	9/14/1989	6201	1.0	40	3
Cowdry	21-0103	6/18/1990	6201	3.7	40	4
Cowdry	21-0103	7/16/1990	6201	4.0	10	1
Cowdry	21-0103	8/16/1990	6201	3.7	10	3
Cowdry	21-0103	9/18/1990	6201	3.7	50	4
Cowdry	21-0103	6/18/1991	6201	4.0	20	1
Cowdry	21-0103	7/15/1991	6201	3.7	30	2
Cowdry	21-0103	8/15/1991	6201	5.2	20	2
Cowdry	21-0103	9/19/1991	6201	3.1	30	2
Cowdry	21-0103	6/18/1992	6201	3.7	10	7
Cowdry	21-0103	7/16/1992	6201	3.1	20	2

Cowdry	21-0103	7/20/1992	201	3.2		
Cowdry	21-0103	7/26/1992	201	2.7		
Cowdry	21-0103	8/18/1992	6201	4.0	10	2
Cowdry	21-0103	9/10/1992	201	3.2		
Cowdry	21-0103	9/15/1992	6201	3.1	30	4
Cowdry	21-0103	9/24/1992	201	3.2		
Cowdry	21-0103	5/2/1993	201	2.6		
Cowdry	21-0103	5/31/1993	201	4.9		
Cowdry	21-0103	6/5/1993	201	4.1		
Cowdry	21-0103	6/13/1993	201	4.6		
Cowdry	21-0103	6/15/1993	6201	4.6	10	2
Cowdry	21-0103	6/20/1993	201	4.9		
Cowdry	21-0103	6/27/1993	201	3.7		
Cowdry	21-0103	7/8/1993	201	3.4		
Cowdry	21-0103	7/10/1993	201	3.2		
Cowdry	21-0103	7/15/1993	6201	3.1	10	3
Cowdry	21-0103	7/23/1993	201	3.1		
Cowdry	21-0103	8/1/1993	201	2.9		
Cowdry	21-0103	8/9/1993	201	3.2		
Cowdry	21-0103	8/15/1993	201	2.9		
Cowdry	21-0103	8/16/1993	6201	3.4	10	1
Cowdry	21-0103	8/24/1993	201	3.5		
Cowdry	21-0103	9/10/1993	201	2.9		
Cowdry	21-0103	9/14/1993	6201	2.7	20	5
Cowdry	21-0103	9/18/1993	201	2.9		
Cowdry	21-0103	9/24/1993	201	3.1		
Cowdry	21-0103	10/9/1993	201	2.6		
Cowdry	21-0103	10/16/1993	201	2.9		
Cowdry	21-0103	5/14/1994	201	2.6		
Cowdry	21-0103	5/21/1994	201	2.9		
Cowdry	21-0103	6/4/1994	201	4.1		
Cowdry	21-0103	6/15/1994	201	3.2		
Cowdry	21-0103	6/16/1994	6201	2.7	20	4
Cowdry	21-0103	6/19/1994	201	3.1		
Cowdry	21-0103	6/26/1994	201	3.2		
Cowdry	21-0103	7/4/1994	201	3.4		
Cowdry	21-0103	7/14/1994	201	3.1		
Cowdry	21-0103	7/14/1994	6201	2.4	30	3
Cowdry	21-0103	7/22/1994	201	2.9		
Cowdry	21-0103	7/31/1994	201	2.9		
Cowdry	21-0103	8/13/1994	201	3.1		

Cowdry	21-0103	8/15/1994	6201	2.7		4
Cowdry	21-0103	8/21/1994	201	3.1		
Cowdry	21-0103	8/28/1994	201	3.1		
Cowdry	21-0103	9/7/1994	201	3.2		
Cowdry	21-0103	9/15/1994	201	3.2		
Cowdry	21-0103	9/15/1994	6201	2.7		5
Cowdry	21-0103	10/9/1994	201	3.1		
Cowdry	21-0103	5/17/1995	201	2.3		
Cowdry	21-0103	5/29/1995	201	2.7		
Cowdry	21-0103	6/12/1995	201	3.8		
Cowdry	21-0103	6/15/1995	6201	3.4		2
Cowdry	21-0103	6/24/1995	201	4.6		
Cowdry	21-0103	6/29/1995	201	3.1		
Cowdry	21-0103	7/1/1995	201	3.7		
Cowdry	21-0103	7/5/1995	201	3.1		
Cowdry	21-0103	7/8/1995	201	3.1		
Cowdry	21-0103	7/16/1995	201	2.6		
Cowdry	21-0103	7/16/1995	6201	2.4		7
Cowdry	21-0103	8/3/1995	201	2.6		
Cowdry	21-0103	8/14/1995	6201	2.7		6
Cowdry	21-0103	8/19/1995	201	2.7		
Cowdry	21-0103	8/27/1995	201	2.6		
Cowdry	21-0103	9/9/1995	201	2.9		
Cowdry	21-0103	9/19/1995	6201	3.1		6
Cowdry	21-0103	10/15/1995	201	3.4		
Cowdry	21-0103	6/15/1996	201	3.7		
Cowdry	21-0103	6/17/1996	6201	3.7	30	1
Cowdry	21-0103	7/16/1996	6201	3.7	40	1
Cowdry	21-0103	7/17/1996	201	2.9		
Cowdry	21-0103	8/18/1996	201	3.8		
Cowdry	21-0103	8/20/1996	6201	3.1	10	4
Cowdry	21-0103	9/16/1996	6201	3.1	40	7
Cowdry	21-0103	5/18/1997	200	2.6	28	12
Cowdry	21-0103	5/18/1997	201	2.6		
Cowdry	21-0103	6/17/1997	201	4.3		
Cowdry	21-0103	6/17/1997	6201	4.6	30	1
Cowdry	21-0103	6/22/1997	200	4.3	20	4
Cowdry	21-0103	7/16/1997	6201	2.7	40	1
Cowdry	21-0103	7/20/1997	200	2.6	17	6
Cowdry	21-0103	7/20/1997	201	2.6		
Cowdry	21-0103	8/10/1997	201	2.4		

Cowdry	21-0103	8/17/1997	200	2.4	17	7
Cowdry	21-0103	8/19/1997	6201	2.4	50	2
Cowdry	21-0103	9/14/1997	200	3.5	15	5
Cowdry	21-0103	9/14/1997	201	3.5		
Cowdry	21-0103	9/16/1997	6201	3.7	40	4
Cowdry	21-0103	5/13/1998	201	3.1		
Cowdry	21-0103	5/18/1998	200	3.1	30	11
Cowdry	21-0103	5/25/1998	201	2.3		
Cowdry	21-0103	6/1/1998	6201	3.4	90	1
Cowdry	21-0103	6/14/1998	200	3.5	20	5
Cowdry	21-0103	6/14/1998	201	3.5		
Cowdry	21-0103	6/24/1998	201	3.1		
Cowdry	21-0103	7/1/1998	6201	3.1	40	2
Cowdry	21-0103	7/19/1998	201	4.0		
Cowdry	21-0103	7/20/1998	200	4.0	17	4
Cowdry	21-0103	7/25/1998	201	3.4		
Cowdry	21-0103	8/1/1998	6201	3.7	30	1
Cowdry	21-0103	8/16/1998	200	3.8	22	3
Cowdry	21-0103	8/16/1998	201	3.8		
Cowdry	21-0103	8/31/1998	201	3.5		
Cowdry	21-0103	9/1/1998	6201	4.0	10	2
Cowdry	21-0103	9/20/1998	200	4.1	20	5
Cowdry	21-0103	9/20/1998	201	4.1		
Cowdry	21-0103	9/30/1998	201	3.7		
Cowdry	21-0103	5/16/1999	200	4.0	22	12
Cowdry	21-0103	5/16/1999	201	4.0		
Cowdry	21-0103	5/30/1999	201	3.7		
Cowdry	21-0103	6/1/1999	6201	3.1	20	1
Cowdry	21-0103	6/5/1999	201	4.1		
Cowdry	21-0103	6/20/1999	200	3.2	17	8
Cowdry	21-0103	6/20/1999	201	3.2		
Cowdry	21-0103	7/1/1999	6201	3.1	30	4
Cowdry	21-0103	7/18/1999	200	3.2	17	6
Cowdry	21-0103	7/18/1999	201	3.2		
Cowdry	21-0103	7/31/1999	201	3.4		
Cowdry	21-0103	8/1/1999	6201	3.4	30	2
Cowdry	21-0103	8/15/1999	200	3.5		
Cowdry	21-0103	8/15/1999	201	3.5		
Cowdry	21-0103	8/31/1999	201	3.5		
Cowdry	21-0103	9/1/1999	6201	3.1	30	3
Cowdry	21-0103	9/6/1999	201	3.4		

Cowdry	21-0103	9/18/1999	201	3.5		
Cowdry	21-0103	9/19/1999	200	3.5	22	7
Cowdry	21-0103	5/14/2000	200	4.1	20	3
Cowdry	21-0103	5/14/2000	201	4.1		
Cowdry	21-0103	5/30/2000	201	3.8		
Cowdry	21-0103	6/1/2000	6201	5.5	20	1
Cowdry	21-0103	6/18/2000	200	6.1	15	3
Cowdry	21-0103	6/18/2000	201	6.1		
Cowdry	21-0103	6/29/2000	201	5.0		
Cowdry	21-0103	7/1/2000	6201	2.7	10	3
Cowdry	21-0103	7/9/2000	201	3.4		
Cowdry	21-0103	7/17/2000	200	3.2	17	3
Cowdry	21-0103	7/17/2000	201	3.2		
Cowdry	21-0103	8/1/2000	201	3.5		
Cowdry	21-0103	8/1/2000	6201	4.0	10	2
Cowdry	21-0103	8/20/2000	200	3.7	12	3
Cowdry	21-0103	8/20/2000	201	3.7		
Cowdry	21-0103	9/1/2000	6201	4.3	10	2
Cowdry	21-0103	9/3/2000	201	4.3		
Cowdry	21-0103	9/17/2000	200	4.7	20	5
Cowdry	21-0103	9/17/2000	201	4.7		
Cowdry	21-0103	5/20/2001	200	2.9	35	
Cowdry	21-0103	5/20/2001	201	3.2		
Cowdry	21-0103	5/31/2001	201	2.7		
Cowdry	21-0103	6/1/2001	6201	3.1	90	2
Cowdry	21-0103	6/15/2001	201	3.1		
Cowdry	21-0103	6/30/2001	201	2.9		
Cowdry	21-0103	7/1/2001	6201	2.7	80	1
Cowdry	21-0103	7/15/2001	200	3.2	20	5
Cowdry	21-0103	7/15/2001	201	3.2		
Cowdry	21-0103	8/1/2001	6201	2.1	21	8
Cowdry	21-0103	8/8/2001	201	2.6		
Cowdry	21-0103	8/19/2001	200	2.7	22	9
Cowdry	21-0103	8/19/2001	201	2.7		
Cowdry	21-0103	9/1/2001	6201	2.4	70	5
Cowdry	21-0103	9/2/2001	201	2.7		
Cowdry	21-0103	9/17/2001	200	2.7	28	10
Cowdry	21-0103	9/17/2001	201	2.7		
Cowdry	21-0103	5/19/2002	200	3.7	25	9
Cowdry	21-0103	5/19/2002	201	3.7		
Cowdry	21-0103	5/25/2002	201	3.8		

Cowdry	21-0103	6/2/2002	6201	4.0		4
Cowdry	21-0103	6/16/2002	200	4.1	15	1
Cowdry	21-0103	6/16/2002	201	4.1		
Cowdry	21-0103	6/30/2002	201	4.0		
Cowdry	21-0103	7/2/2002	6201	4.3	19	3
Cowdry	21-0103	7/14/2002	200	5.5	12	
Cowdry	21-0103	7/14/2002	201	5.5		
Cowdry	21-0103	7/28/2002	201	3.5		
Cowdry	21-0103	8/2/2002	6201	2.4	15	5
Cowdry	21-0103	8/18/2002	200	2.6	20	6
Cowdry	21-0103	8/18/2002	201	2.6		
Cowdry	21-0103	8/31/2002	201	3.7		
Cowdry	21-0103	9/2/2002	6201	4.3	23	3
Cowdry	21-0103	9/15/2002	200	4.0		
Cowdry	21-0103	9/15/2002	201	4.0		
Cowdry	21-0103	9/29/2002	201	3.8		
Cowdry	21-0103	5/10/2003	201	3.2		
Cowdry	21-0103	5/23/2003	201	3.4		
Cowdry	21-0103	6/2/2003	201	3.8		
Cowdry	21-0103	6/17/2003	6201	4.3	20	6
Cowdry	21-0103	6/29/2003	201	3.8		
Cowdry	21-0103	7/12/2003	201	3.1		
Cowdry	21-0103	7/15/2003	6201	2.7	101	8
Cowdry	21-0103	7/28/2003	201	2.9		
Cowdry	21-0103	8/9/2003	201	4.0		
Cowdry	21-0103	8/14/2003	6201	3.7	11	4
Cowdry	21-0103	8/24/2003	201	3.1		
Cowdry	21-0103	9/6/2003	201	3.1		
Cowdry	21-0103	9/16/2003	6201	3.1	26	7
Cowdry	21-0103	10/4/2003	201	2.7		
Cowdry	21-0103	5/8/2004	201	3.7		
Cowdry	21-0103	5/19/2004	201	3.2		
Cowdry	21-0103	6/10/2004	201	3.7		
Cowdry	21-0103	6/14/2004	6201	4.3	41	5
Cowdry	21-0103	6/28/2004	201	4.3		
Cowdry	21-0103	7/3/2004	201	3.8		
Cowdry	21-0103	7/14/2004	6201	3.7	22	6
Cowdry	21-0103	7/19/2004	201	4.1		
Cowdry	21-0103	8/3/2004	201	3.5		
Cowdry	21-0103	8/17/2004	6201	3.7	19	3
Cowdry	21-0103	8/28/2004	201	3.1		

Cowdry	21-0103	9/11/2004	201	2.9		
Cowdry	21-0103	9/15/2004	6201	4.3	17	7
Cowdry	21-0103	9/25/2004	201	3.4		
Cowdry	21-0103	5/22/2005	201	3.5		
Cowdry	21-0103	5/31/2005	201	3.2		
Cowdry	21-0103	6/12/2005	201	4.3		
Cowdry	21-0103	6/14/2005	6201	7.3	17	3
Cowdry	21-0103	6/28/2005	201	3.8		
Cowdry	21-0103	7/5/2005	201	2.9		
Cowdry	21-0103	7/14/2005	6201	3.1	20	7
Cowdry	21-0103	7/30/2005	201	3.2		
Cowdry	21-0103	8/18/2005	6201	3.1	18	5
Cowdry	21-0103	8/21/2005	201	3.4		
Cowdry	21-0103	8/28/2005	201	2.6		
Cowdry	21-0103	9/18/2005	201	3.4		
Cowdry	21-0103	9/21/2005	6201	4.0	28	6
Cowdry	21-0103	9/28/2005	201	3.1		
Cowdry	21-0103	10/1/2005	201	3.1		
Cowdry	21-0103	10/24/2005	201	3.4		
Cowdry	21-0103	5/14/2006	201	4.7		
Cowdry	21-0103	5/29/2006	201	4.9		
Cowdry	21-0103	6/20/2006	201	3.2		
Cowdry	21-0103	6/30/2006	201	3.1		
Cowdry	21-0103	7/5/2006	201	2.3		
Cowdry	21-0103	8/19/2006	201	2.9		
Cowdry	21-0103	8/25/2006	201	3.1		
Cowdry	21-0103	9/3/2006	201	3.5		
Cowdry	21-0103	9/20/2006	201	2.7		
Cowdry	21-0103	5/26/2007	201	4.3		
Cowdry	21-0103	6/15/2007	201	3.2		
Cowdry	21-0103	6/18/2007	6201	3.5	23	7
Cowdry	21-0103	6/25/2007	201	3.1		
Cowdry	21-0103	7/4/2007	201	3.4		
Cowdry	21-0103	7/14/2007	201	2.6		
Cowdry	21-0103	7/16/2007	6201	3.1	19	5
Cowdry	21-0103	8/1/2007	201	2.7		
Cowdry	21-0103	8/14/2007	6201	3.4	24	7
Cowdry	21-0103	8/31/2007	201	3.8		
Cowdry	21-0103	9/12/2007	201	2.9		
Cowdry	21-0103	9/24/2007	6201	2.7	23	7
Cowdry	21-0103	9/30/2007	201	2.7		

Cowdry	21-0103	5/15/2008	201	3.2		
Cowdry	21-0103	5/31/2008	201	3.8		
Cowdry	21-0103	6/12/2008	6201	4.9	32	4
Cowdry	21-0103	6/13/2008	201	5.8		
Cowdry	21-0103	6/22/2008	201	4.0		
Cowdry	21-0103	7/16/2008	6201	3.4	17	5
Cowdry	21-0103	7/20/2008	201	3.2		
Cowdry	21-0103	7/21/2008	201	3.8	32	7
Cowdry	21-0103	7/28/2008	201	3.2		
Cowdry	21-0103	8/16/2008	201	4.6		
Cowdry	21-0103	8/18/2008	201	4.3	16	3
Cowdry	21-0103	8/18/2008	6201	4.0	15	4
Cowdry	21-0103	8/25/2008	201	3.7		
Cowdry	21-0103	9/15/2008	201	3.7	18	6
Cowdry	21-0103	9/16/2008	6201	3.7	19	5
Cowdry	21-0103	9/20/2008	201	3.8		
Cowdry	21-0103	9/27/2008	201	4.1		
Cowdry	21-0103	6/6/2009	201	4.4		
Cowdry	21-0103	6/14/2009	201	4.0		
Cowdry	21-0103	6/15/2009	201	4.0	15	5
Cowdry	21-0103	6/16/2009	6201	3.7	13	3
Cowdry	21-0103	6/29/2009	201	4.0	16	4
Cowdry	21-0103	7/4/2009	201	4.1		
Cowdry	21-0103	7/15/2009	201	3.5		
Cowdry	21-0103	7/15/2009	6201	3.1	25	6
Cowdry	21-0103	7/20/2009	201	3.4	20	6
Cowdry	21-0103	8/1/2009	201	3.2		
Cowdry	21-0103	8/17/2009	201	3.7	21	5
Cowdry	21-0103	8/18/2009	6201	3.4	17	6
Cowdry	21-0103	8/30/2009	201	4.0		
Cowdry	21-0103	9/16/2009	6201	3.7	15	5
Cowdry	21-0103	9/21/2009	201	4.0	14	5
Cowdry	21-0103	9/22/2009	201	4.1		
Cowdry	21-0103	9/29/2009	201	3.7		

Lake Name	Lake ID	Sample Date	Site ID	Secchi	TP	Chl-*a*
				Meters	ug/L	ug/L
Stony	21-0101	6/2/1995	201	3.4		
Stony	21-0101	6/9/1995	201	4.4		
Stony	21-0101	6/19/1995	201	4.0		
Stony	21-0101	6/23/1995	201	3.7		
Stony	21-0101	7/7/1995	201	3.4		
Stony	21-0101	7/14/1995	201	3.5		
Stony	21-0101	7/21/1995	201	3.5		
Stony	21-0101	7/27/1995	201	3.4		
Stony	21-0101	8/3/1995	201	3.1		
Stony	21-0101	8/14/1995	201	3.2		
Stony	21-0101	8/23/1995	201	3.2		
Stony	21-0101	8/31/1995	201	3.4		
Stony	21-0101	9/2/1995	201	3.4		
Stony	21-0101	9/12/1995	201	3.2		
Stony	21-0101	9/21/1995	201	3.2		
Stony	21-0101	9/28/1995	201	3.2		
Stony	21-0101	5/16/1996	201	2.4		
Stony	21-0101	5/25/1996	201	2.4		
Stony	21-0101	6/4/1996	201	2.7		
Stony	21-0101	6/11/1996	201	3.4		
Stony	21-0101	6/20/1996	201	3.5		
Stony	21-0101	6/28/1996	201	3.7		
Stony	21-0101	7/5/1996	201	3.7		
Stony	21-0101	7/15/1996	201	3.5		
Stony	21-0101	7/22/1996	201	3.4		
Stony	21-0101	7/31/1996	201	3.5		
Stony	21-0101	8/4/1996	201	3.2		
Stony	21-0101	8/16/1996	201	3.1		
Stony	21-0101	8/21/1996	201	3.2		
Stony	21-0101	8/30/1996	201	3.2		
Stony	21-0101	9/4/1996	201	3.1		
Stony	21-0101	9/13/1996	201	3.4		
Stony	21-0101	9/20/1996	201	3.2		
Stony	21-0101	9/30/1996	201	3.2		
Stony	21-0101	6/3/1997	201	2.4		
Stony	21-0101	6/11/1997	201	3.1		
Stony	21-0101	6/19/1997	201	3.8		
Stony	21-0101	6/27/1997	201	4.6		
Stony	21-0101	7/6/1997	201	4.6		

Stony	21-0101	7/13/1997	201	4.6		
Stony	21-0101	7/21/1997	201	3.7		
Stony	21-0101	7/30/1997	201	3.1		
Stony	21-0101	8/5/1997	201	3.7		
Stony	21-0101	8/14/1997	201	3.7		
Stony	21-0101	8/23/1997	201	3.7		
Stony	21-0101	9/7/1997	201	3.7		
Stony	21-0101	9/15/1997	201	3.4		
Stony	21-0101	9/22/1997	201	3.4		
Stony	21-0101	9/29/1997	201	3.4		
Stony	21-0101	5/8/1998	201	2.7		
Stony	21-0101	5/14/1998	201	3.1		
Stony	21-0101	5/21/1998	201	3.1		
Stony	21-0101	5/30/1998	201	3.2		
Stony	21-0101	6/7/1998	201	3.4		
Stony	21-0101	6/17/1998	201	3.5		
Stony	21-0101	6/25/1998	201	3.7		
Stony	21-0101	7/2/1998	201	3.5		
Stony	21-0101	7/18/1998	201	3.5		
Stony	21-0101	7/23/1998	201	3.2		
Stony	21-0101	7/30/1998	201	3.5		
Stony	21-0101	8/2/1998	201	3.7		
Stony	21-0101	8/15/1998	201	3.8		
Stony	21-0101	8/25/1998	201	3.7		
Stony	21-0101	9/3/1998	201	3.5		
Stony	21-0101	6/5/1999	201	3.4		
Stony	21-0101	6/16/1999	201	3.7		
Stony	21-0101	6/25/1999	201	3.7		
Stony	21-0101	7/1/1999	201	3.7		
Stony	21-0101	7/10/1999	201	3.5		
Stony	21-0101	7/23/1999	201	3.4		
Stony	21-0101	7/31/1999	201	3.4		
Stony	21-0101	8/3/1999	201	3.5		
Stony	21-0101	8/9/1999	201	3.5		
Stony	21-0101	8/18/1999	201	3.7		
Stony	21-0101	8/26/1999	201	3.7		
Stony	21-0101	9/6/1999	201	3.8		
Stony	21-0101	9/16/1999	201	3.7		
Stony	21-0101	9/28/1999	201	3.7		
Stony	21-0101	6/3/2000	201	3.8		
Stony	21-0101	6/14/2000	201	3.8		

Stony	21-0101	6/20/2000	201	4.0		
Stony	21-0101	7/3/2000	201	3.8		
Stony	21-0101	7/11/2000	201	4.0		
Stony	21-0101	7/18/2000	201	4.0		
Stony	21-0101	7/28/2000	201	3.8		
Stony	21-0101	8/8/2000	201	3.7		
Stony	21-0101	8/21/2000	201	4.0		
Stony	21-0101	8/30/2000	201	3.8		
Stony	21-0101	9/7/2000	201	4.0		
Stony	21-0101	9/14/2000	201	4.0		
Stony	21-0101	9/20/2000	201	3.7		
Stony	21-0101	9/29/2000	201	3.8		
Stony	21-0101	5/15/2002	201	4.1		
Stony	21-0101	5/29/2002	201	4.3		
Stony	21-0101	6/12/2002	201	4.3		
Stony	21-0101	6/18/2002	201	4.3		
Stony	21-0101	6/27/2002	201	4.3		
Stony	21-0101	7/7/2002	201	4.3		
Stony	21-0101	7/17/2002	201	4.0		
Stony	21-0101	7/24/2002	201	4.1		
Stony	21-0101	8/1/2002	201	4.3		
Stony	21-0101	8/15/2002	201	4.1		
Stony	21-0101	8/29/2002	201	4.0		
Stony	21-0101	5/15/2003	201	3.4		
Stony	21-0101	6/3/2003	201	3.4		
Stony	21-0101	6/17/2003	201	3.5		
Stony	21-0101	7/1/2003	201	3.4		
Stony	21-0101	7/15/2003	201	3.5		
Stony	21-0101	7/30/2003	201	3.7		
Stony	21-0101	8/10/2003	201	3.8		
Stony	21-0101	8/25/2003	201	3.8		
Stony	21-0101	9/5/2003	201	3.8		
Stony	21-0101	9/22/2003	201	3.7		
Stony	21-0101	6/1/2008	201	4.4	14	3
Stony	21-0101	6/15/2008	201	4.3	16	4
Stony	21-0101	7/20/2008	201	4.4	17	5
Stony	21-0101	8/17/2008	201	4.4	12	4
Stony	21-0101	9/15/2008	201	4.0	18	10
Stony	21-0101	6/15/2009	201	4.7	11	3
Stony	21-0101	6/29/2009	201	3.2	15	3
Stony	21-0101	7/19/2009	201	2.9	18	10

Stony	21-0101	8/14/2009	201	3.7	20	4
Stony	21-0101	9/20/2009	201	4.0	19	4

Lake Name	Lake ID	Sample Date	Site ID	Secchi	TP	Chl-*a*
				Meters	ug/L	ug/L
North Union	21-0095	6/2/1995	201	3.4		
North Union	21-0095	6/9/1995	201	4.3		
North Union	21-0095	6/19/1995	201	3.5		
North Union	21-0095	6/23/1995	201	3.5		
North Union	21-0095	7/7/1995	201	3.4		
North Union	21-0095	7/14/1995	201	3.5		
North Union	21-0095	7/21/1995	201	3.5		
North Union	21-0095	7/27/1995	201	3.4		
North Union	21-0095	8/3/1995	201	3.1		
North Union	21-0095	8/14/1995	201	3.2		
North Union	21-0095	8/23/1995	201	3.1		
North Union	21-0095	8/31/1995	201	3.4		
North Union	21-0095	9/2/1995	201	3.4		
North Union	21-0095	9/12/1995	201	3.1		
North Union	21-0095	9/21/1995	201	3.1		
North Union	21-0095	9/28/1995	201	3.1		
North Union	21-0095	5/16/1996	201	2.4		
North Union	21-0095	5/25/1996	201	2.4		
North Union	21-0095	6/4/1996	201	2.7		
North Union	21-0095	6/11/1996	201	3.8		
North Union	21-0095	6/20/1996	201	3.8		
North Union	21-0095	6/28/1996	201	3.8		
North Union	21-0095	7/5/1996	201	3.8		
North Union	21-0095	7/15/1996	201	3.7		
North Union	21-0095	7/22/1996	201	3.7		
North Union	21-0095	7/31/1996	201	3.7		
North Union	21-0095	8/4/1996	201	3.2		
North Union	21-0095	8/16/1996	201	3.1		
North Union	21-0095	8/21/1996	201	3.2		
North Union	21-0095	8/30/1996	201	3.2		
North Union	21-0095	9/4/1996	201	3.1		
North Union	21-0095	9/13/1996	201	3.1		
North Union	21-0095	9/20/1996	201	2.9		
North Union	21-0095	9/30/1996	201	2.7		
North Union	21-0095	6/3/1997	201	2.6		
North Union	21-0095	6/11/1997	201	3.1		
North Union	21-0095	6/19/1997	201	3.8		
North Union	21-0095	6/27/1997	201	4.6		
North Union	21-0095	7/6/1997	201	4.6		

North Union	21-0095	7/13/1997	201	4.6		
North Union	21-0095	7/21/1997	201	3.7		
North Union	21-0095	7/30/1997	201	3.1		
North Union	21-0095	8/5/1997	201	3.5		
North Union	21-0095	8/14/1997	201	3.7		
North Union	21-0095	8/23/1997	201	3.7		
North Union	21-0095	9/7/1997	201	3.7		
North Union	21-0095	9/15/1997	201	3.4		
North Union	21-0095	9/22/1997	201	3.4		
North Union	21-0095	9/29/1997	201	3.4		
North Union	21-0095	5/8/1998	201	2.9		
North Union	21-0095	5/14/1998	201	3.2		
North Union	21-0095	5/21/1998	201	3.1		
North Union	21-0095	5/30/1998	201	3.2		
North Union	21-0095	6/7/1998	201	3.2		
North Union	21-0095	6/17/1998	201	3.1		
North Union	21-0095	6/25/1998	201	3.1		
North Union	21-0095	7/2/1998	201	3.2		
North Union	21-0095	7/10/1998	201	2.7		
North Union	21-0095	7/23/1998	201	2.4		
North Union	21-0095	7/30/1998	201	2.4		
North Union	21-0095	8/2/1998	201	2.3		
North Union	21-0095	8/15/1998	201	2.3		
North Union	21-0095	8/25/1998	201	2.4		
North Union	21-0095	9/3/1998	201	2.6		
North Union	21-0095	6/5/1999	201	2.6		
North Union	21-0095	6/16/1999	201	2.4		
North Union	21-0095	6/25/1999	201	2.6		
North Union	21-0095	7/1/1999	201	3.1		
North Union	21-0095	7/10/1999	201	2.4		
North Union	21-0095	7/23/1999	201	2.1		
North Union	21-0095	7/31/1999	201	2.1		
North Union	21-0095	8/3/1999	201	2.3		
North Union	21-0095	8/9/1999	201	2.3		
North Union	21-0095	8/18/1999	201	2.4		
North Union	21-0095	9/6/1999	201	2.6		
North Union	21-0095	9/16/1999	201	3.1		
North Union	21-0095	9/28/1999	201	3.2		
North Union	21-0095	6/3/2000	201	3.7		
North Union	21-0095	6/14/2000	201	2.7		
North Union	21-0095	6/20/2000	201	3.2		

North Union	21-0095	7/3/2000	201	2.4		
North Union	21-0095	7/11/2000	201	2.9		
North Union	21-0095	7/18/2000	201	3.1		
North Union	21-0095	7/28/2000	201	3.2		
North Union	21-0095	8/8/2000	201	3.2		
North Union	21-0095	8/21/2000	201	3.4		
North Union	21-0095	8/30/2000	201	3.4		
North Union	21-0095	9/7/2000	201	3.5		
North Union	21-0095	9/14/2000	201	3.5		
North Union	21-0095	9/20/2000	201	3.5		
North Union	21-0095	9/29/2000	201	3.5		
North Union	21-0095	5/15/2002	201	3.7		
North Union	21-0095	5/29/2002	201	3.7		
North Union	21-0095	6/12/2002	201	3.4		
North Union	21-0095	6/18/2002	201	3.2		
North Union	21-0095	6/27/2002	201	3.1		
North Union	21-0095	7/7/2002	201	2.4		
North Union	21-0095	7/17/2002	201	3.1		
North Union	21-0095	7/24/2002	201	2.4		
North Union	21-0095	8/1/2002	201	2.7		
North Union	21-0095	8/15/2002	201	2.6		
North Union	21-0095	8/29/2002	201	2.7		
North Union	21-0095	5/15/2003	201	3.4		
North Union	21-0095	6/3/2003	201	3.1		
North Union	21-0095	6/17/2003	201	3.1		
North Union	21-0095	7/1/2003	201	2.7		
North Union	21-0095	7/15/2003	201	2.6		
North Union	21-0095	7/30/2003	201	2.4		
North Union	21-0095	8/10/2003	201	2.6		
North Union	21-0095	8/25/2003	201	2.7		
North Union	21-0095	9/5/2003	201	2.7		
North Union	21-0095	9/22/2003	201	2.9		
North Union	21-0095	6/1/2008	201	3.1	19	5
North Union	21-0095	6/15/2008	201	3.7	18	7
North Union	21-0095	7/20/2008	201	2.6	22	5
North Union	21-0095	8/17/2008	201	3.5	23	5
North Union	21-0095	9/14/2008	201	3.1	17	9
North Union	21-0095	6/15/2009	201	4.0	18	3
North Union	21-0095	6/29/2009	201	3.4	17	6
North Union	21-0095	7/19/2009	201	3.1	20	13
North Union	21-0095	8/14/2009	201	2.7	20	5

North Union	21-0095	9/21/2009	201		20	7

Lake Name	Lake ID	Sample Date	Site ID	Secchi	TP	Chl-*a*
				Meters	ug/L	ug/L
Taylor	21-0105	6/2/1995	201	3.2		
Taylor	21-0105	6/9/1995	201	4.4		
Taylor	21-0105	6/19/1995	201	3.8		
Taylor	21-0105	6/23/1995	201	3.7		
Taylor	21-0105	7/7/1995	201	3.2		
Taylor	21-0105	7/14/1995	201	3.5		
Taylor	21-0105	7/21/1995	201	3.5		
Taylor	21-0105	7/27/1995	201	3.4		
Taylor	21-0105	8/3/1995	201	3.1		
Taylor	21-0105	8/14/1995	201	3.2		
Taylor	21-0105	8/23/1995	201	3.2		
Taylor	21-0105	8/31/1995	201	3.4		
Taylor	21-0105	9/2/1995	201	3.4		
Taylor	21-0105	9/12/1995	201	3.2		
Taylor	21-0105	9/21/1995	201	3.2		
Taylor	21-0105	9/28/1995	201	3.2		
Taylor	21-0105	5/16/1996	201	2.4		
Taylor	21-0105	5/26/1996	201	2.4		
Taylor	21-0105	6/4/1996	201	2.7		
Taylor	21-0105	6/11/1996	201	3.7		
Taylor	21-0105	6/20/1996	201	3.5		
Taylor	21-0105	6/28/1996	201	3.8		
Taylor	21-0105	7/5/1996	201	3.7		
Taylor	21-0105	7/15/1996	201	3.5		
Taylor	21-0105	7/22/1996	201	3.4		
Taylor	21-0105	7/31/1996	201	3.5		
Taylor	21-0105	8/4/1996	201	3.2		
Taylor	21-0105	8/16/1996	201	3.1		
Taylor	21-0105	8/21/1996	201	3.2		
Taylor	21-0105	8/30/1996	201	3.2		
Taylor	21-0105	9/4/1996	201	3.2		
Taylor	21-0105	9/13/1996	201	3.2		
Taylor	21-0105	9/20/1996	201	3.1		
Taylor	21-0105	9/30/1996	201	3.1		
Taylor	21-0105	6/2/1997	201	2.4		
Taylor	21-0105	6/11/1997	201	3.1		
Taylor	21-0105	6/19/1997	201	3.8		
Taylor	21-0105	6/27/1997	201	4.6		
Taylor	21-0105	7/6/1997	201	4.6		

Taylor	21-0105	7/13/1997	201	4.6		
Taylor	21-0105	7/21/1997	201	3.7		
Taylor	21-0105	7/30/1997	201	3.1		
Taylor	21-0105	8/5/1997	201	3.7		
Taylor	21-0105	8/14/1997	201	3.7		
Taylor	21-0105	8/23/1997	201	4.0		
Taylor	21-0105	9/7/1997	201	3.7		
Taylor	21-0105	9/15/1997	201	3.4		
Taylor	21-0105	9/22/1997	201	3.4		
Taylor	21-0105	9/29/1997	201	3.4		
Taylor	21-0105	5/8/1998	201	2.7		
Taylor	21-0105	5/14/1998	201	3.1		
Taylor	21-0105	5/21/1998	201	2.9		
Taylor	21-0105	5/30/1998	201	3.2		
Taylor	21-0105	6/7/1998	201	3.4		
Taylor	21-0105	6/17/1998	201	3.5		
Taylor	21-0105	6/25/1998	201	3.7		
Taylor	21-0105	7/2/1998	201	3.8		
Taylor	21-0105	7/10/1998	201	3.7		
Taylor	21-0105	7/23/1998	201	3.4		
Taylor	21-0105	7/30/1998	201	3.5		
Taylor	21-0105	8/2/1998	201	3.5		
Taylor	21-0105	8/15/1998	201	3.5		
Taylor	21-0105	8/25/1998	201	3.5		
Taylor	21-0105	9/3/1998	201	3.7		
Taylor	21-0105	6/5/1999	201	3.2		
Taylor	21-0105	6/16/1999	201	3.7		
Taylor	21-0105	6/25/1999	201	3.8		
Taylor	21-0105	7/1/1999	201	4.0		
Taylor	21-0105	7/10/1999	201	4.0		
Taylor	21-0105	7/23/1999	201	3.7		
Taylor	21-0105	7/31/1999	201	3.7		
Taylor	21-0105	8/3/1999	201	3.8		
Taylor	21-0105	8/9/1999	201	3.8		
Taylor	21-0105	8/18/1999	201	3.8		
Taylor	21-0105	8/26/1999	201	3.8		
Taylor	21-0105	9/6/1999	201	4.0		
Taylor	21-0105	9/16/1999	201	3.8		
Taylor	21-0105	9/28/1999	201	3.7		
Taylor	21-0105	6/3/2000	201	3.8		
Taylor	21-0105	6/14/2000	201	3.7		

Taylor	21-0105	6/20/2000	201	4.0		
Taylor	21-0105	7/3/2000	201	4.0		
Taylor	21-0105	7/11/2000	201	4.1		
Taylor	21-0105	7/18/2000	201	4.1		
Taylor	21-0105	7/28/2000	201	4.0		
Taylor	21-0105	8/8/2000	201	4.1		
Taylor	21-0105	8/21/2000	201	4.1		
Taylor	21-0105	8/30/2000	201	4.0		
Taylor	21-0105	9/7/2000	201	4.0		
Taylor	21-0105	9/14/2000	201	4.1		
Taylor	21-0105	9/20/2000	201	3.8		
Taylor	21-0105	9/29/2000	201	4.0		
Taylor	21-0105	5/15/2002	201	4.1		
Taylor	21-0105	5/29/2002	201	4.3		
Taylor	21-0105	6/12/2002	201	4.4		
Taylor	21-0105	6/18/2002	201	4.3		
Taylor	21-0105	6/27/2002	201	4.3		
Taylor	21-0105	7/7/2002	201	4.3		
Taylor	21-0105	7/17/2002	201	4.1		
Taylor	21-0105	7/24/2002	201	4.1		
Taylor	21-0105	8/1/2002	201	4.3		
Taylor	21-0105	8/15/2002	201	4.1		
Taylor	21-0105	8/29/2002	201	4.0		
Taylor	21-0105	5/15/2003	201	3.2		
Taylor	21-0105	6/3/2003	201	3.4		
Taylor	21-0105	6/17/2003	201	3.2		
Taylor	21-0105	7/1/2003	201	3.4		
Taylor	21-0105	7/15/2003	201	3.4		
Taylor	21-0105	7/30/2003	201	3.5		
Taylor	21-0105	8/10/2003	201	3.7		
Taylor	21-0105	8/25/2003	201	3.8		
Taylor	21-0105	9/5/2003	201	3.7		
Taylor	21-0105	9/22/2003	201	3.7		
Taylor	21-0105	6/1/2008	201	3.4	30	7
Taylor	21-0105	6/15/2008	201	3.5	53	8
Taylor	21-0105	7/20/2008	201	2.6	20	4
Taylor	21-0105	8/17/2008	201	3.2	14	2
Taylor	21-0105	9/14/2008	201	2.9	21	10
Taylor	21-0105	6/14/2009	201	3.7	16	4
Taylor	21-0105	7/5/2009	201	2.7	17	4
Taylor	21-0105	7/19/2009	201	2.7	21	7

Taylor	21-0105	8/16/2009	201	2.7	21	5
Taylor	21-0105	9/20/2009	201	2.6	24	7