3.5 Other Data Assessment Techniques

Complicated statistical analysis is not always needed for the assessment of data. Water quality results for a monitoring site can be assessed using techniques that involve only simple statistics and/or calculations. Calculations can be performed on data in order to assess the health of a lake (Carlson's Trophic State Index). Data can also be compared to standards in order to determine if a body of water is impaired.

3.51 Carlson's Trophic State Index

The Carlson's Trophic State Index (TSI) is a means of measuring the level of productivity of a lake. Higher TSI scores are caused by higher phosphorous levels, higher chlorophyll-a levels and lower Secchi disk (transparency) levels. Lower TSI scores mean better water quality for recreation, greater transparency, and an absence of nuisance algae blooms. Higher TSI scores indicate poor water quality for recreation (not suitable for swimming), low transparency, and the frequent occurrence of nuisance algae blooms. Although clear water is desirable for recreation, some nutrients are needed to support aquatic life (fish). If too little nutrients are available, the lake is considered oligotrophic (oligo = few, trophic = nutrients).

An example of an oligotrophic lake would be a lake that has recently formed in a gravel pit. When there is a medium amount of nutrients available in a lake, it is considered to be mesotrophic (meso = medium, trophic = nutrients) and has a good balance between nutrients for aquatic life and water quality for recreation. A lake that has a high amount of nutrients is considered to be eutrophic (eu = good, trophic = nutrients). If a lake has an excessive amount of nutrients, it is considered hypereutrophic (hyper = over or excessive). Many lakes become eutrophic or hypereutrophic over time. This progression occurs naturally over time, but has often been hastened by human activities, such as the disposal of raw sewage. Lake restoration projects that reduce the amount of nutrients within a lake's water column can help reduce the TSI level and improve water quality.

A Carlson's TSI value can be calculated for each of three water quality parameters: total phosphorous (limiting nutrient for algae growth), chlorophyll-a (amount of algae present), and Secchi disk readings (transparency). There is a different equation for each parameter. Phosphorous and chlorophyll-a readings should be converted to parts per billion (ppb or μg/L) and Secchi depth readings should be expressed in meters. See the *Standard Operating Procedures for Water Quality Monitoring in the Red River Watershed* for sampling techniques. Remember that ln refers to the natural log of a number.

Total Phosphorous TSI = 14.42 ln(Total Phosphorus concentration in ppb) + 4.15

Chlorophyll-a TSI = 9.81 ln(Chl-a concentration in ppb) + 30.6

Secchi Disk TSI = 60 − 14.41 ln(Secchi Disk depth reading in meters)

The following information is a description of Carlson's Trophic State Index system based upon the EPA's *Lake and Reservoir Restoration Guidance Manual* with a color diagram from the *Volunteer Surface water Monitoring Guide*.

TSI <30   Classical oligotrophy: Clear water, oxygen throughout the year in the hypolimnion (bottom of lake), salmonids fisheries (trout) 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, macrophytes problems evident, warm-water fisheries only.

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

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

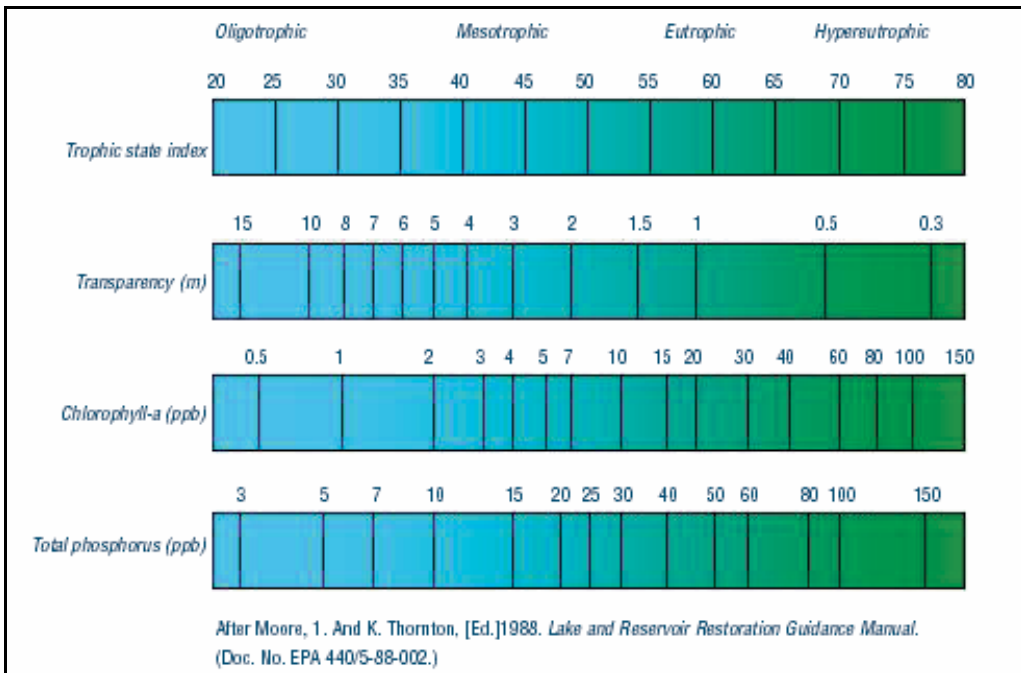TSI > 80   Algal scums, summer fish kills, few macrophytes, dominance of rough fish.

Figure 29. Carlson's Trophic State Index.

3.52 Temperature and Oxygen Profiles

Lakes undergo processes called mixing and stratification. When a lake is stratified it forms three layers. These layers are stratified by both temperature and dissolved oxygen. The top layer, or epilimnion, is well-mixed, relatively warm, and has plenty of dissolved oxygen. The bottom layer, the hypolimnion, is isolated from mixing during periods of stratification and is significantly colder than the epilimnion. The hypolimnion may also experience hypoxia (low levels of dissolved oxygen). In-between these two layers is a transition layer that is referred to as the thermocline or the metalimnion.

Mixing is caused by wind and wave action, as well as turnover in stratified lakes. Mixing can introduce nutrients from the bottom of the lake into the water column. Stratification can prevent mixing below a certain depth in the lake, below which dissolved oxygen will begin to be depleted. Shallow lakes may remain mixed all year due to wave action. Deeper lakes are likely to be stratified during the summer. The extent of mixing that is experienced by a lake may increase during storm events with strong winds, or by increased boating and personal watercraft activity.

Knowing whether or not a lake is stratified can be useful in interpreting water quality data. This is why water temperature and dissolved oxygen profiles should be collected when conducting lake monitoring. A lake that was previously stratified and has become mixed may have higher TSI scores during the mixed period. Anoxia in the hypolimnion of a lake may have a negative effect upon benthic macroinvertebrates, which are a food source for fish. Sometimes, the fact that a lake is stratified or mixed is easy to discern by simply looking at the field data sheet. To confidently assess whether or not a lake is stratified and to determine the depth of layer boundaries, the creation of graphs using a program like Microsoft Excel may be necessary. This can be done by simply creating an XY scatter plot with depth on the Y axis (with 0 at the top and the largest number at the bottom) and dissolved oxygen and/or temperature on the X axis. If the plot is a nearly vertical line or has a consistent slope, then the lake is mixed. If the plot starts out straight for a few meters at the top of the profile (near the water surface), then is angled (usually indicating decreasing temperature and dissolved oxygen), and then becomes nearly vertical again at the bottom of the profile (at a lower temperature or dissolved oxygen concentration than at the top of the profile), the lake is stratified. See the examples below.
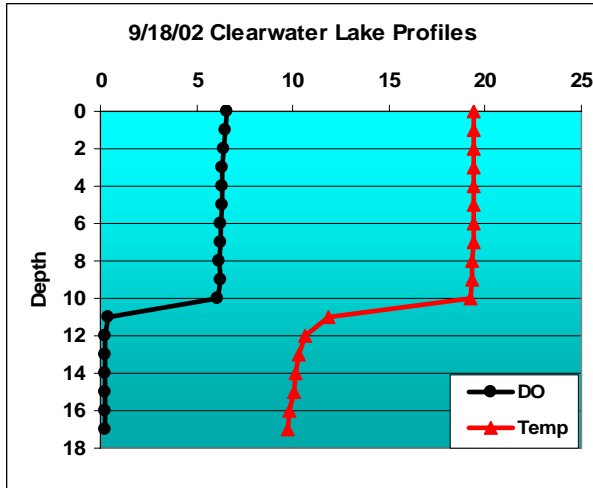
9/18/02 Clearwater Lake Profiles

Figure 30. Stratified Profile.

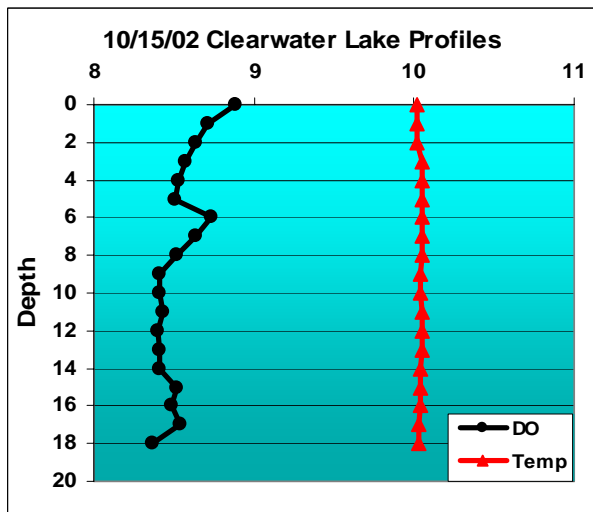**10/15/02 Clearwater Lake Profiles**

Figure 31. Mixed Profile.

3.53 Assessment for Determination of Impairment

One major use of water quality data is for the assessment of streams, rivers, and lakes for impairment. The USEPA requires that states conduct water quality assessments. The MPCA conducts these assessments in Minnesota. When waters are found to be impaired, a TMDL (Total Maximum Daily Load) study is conducted on the water body to determine the cause of the impairment and to determine the extent of nutrient reductions that are needed for the stream to meet its designated uses. The MPCA uses water quality data from the EPA STORET database for these assessments. This is likely due to the accessibility of the data (central location) and the fact that data has to pass a certain amount of QA/QC requirements before it is entered into the database. These assessments currently take place on a biennial basis. The assessments are conducted on odd years. Reports and lists of impaired waters are published on even years. There are two reports that are required by the Federal Clean Water Act. The 305(b) report is a report of all

assessed waters. Waters that have been found to be impaired are listed in the 303(d) list. The assessments rely heavily upon locally collected data from agencies and volunteers. Submitting updated data to the MPCA prior to these assessments is important for ensuring that the waters being monitored are accurately assessed by the MPCA. There are different assessment methods for different types of parameters. There are also minimum data requirements for each parameter. The methods are described in detail in the *MPCA Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment 305(b) Report and 303(d) List.*

RLWD water quality data is used for the assessment of fecal coliform levels, as well as conventional water quality parameters such as dissolved oxygen, pH, turbidity, and temperature. Fecal coliform assessment uses numeric standards for the protection of recreation. Conventional water quality parameters are assessed using numeric standards for the protection of aquatic life. The percentages of samples that exceed the numeric standard are calculated for all parameters and are used in the assessment process. If greater than 10% of the most recent 10 years of conventional pollutants and water quality characteristics (dissolved oxygen, pH, turbidity, and temperature) exceed the standard, then the site is listed on the 303(d) list of impaired waters. The site is also listed in the 305(b) report as either partially supporting or not supporting instead of fully supporting, based upon the percentage of Exceedances (see Tables 5-9 below).

The fecal coliform assessment process adds a second step to the assessment process. The calculation of the percentage of samples that exceed the numeric standard is used as a screening process to weed out sites which are not likely to be impaired. If less than 10% of the samples exceed the standard, then the site is listed in the 305(b) report as fully supporting of recreation. However, if 10% or more of the samples exceed the standard, then another assessment is performed on the data. All fecal coliform data from the most recent 10 years is grouped by calendar month. For example, all results collected during the month of July in the last ten years would be in one group. A geometric mean is then calculated for each month. If any months have a geometric mean greater than the standard (200 col/100ml), there is impairment for fecal coliform at the monitoring site.

Assessment un-ionized ammonia also involves methods that differ from conventional parameters. The un-ionized form of ammonia is toxic to aquatic life, particularly for sensitive species and fish in sensitive early life stages. The level of un-ionized ammonia is dependant upon pH, temperature, and the total ammonia concentration. Temperature and pH are used to determine what fraction of the total ammonia concentration is in the un-ionized form. There are two standards for un-ionized ammonia. For Class 2A waters, the standard is 0.016 mg/L, and the standard for Class 2Bd, B, C, and D waters is 0.04 mg/L. To calculate the fraction of total ammonia that is in the un-ionized form, use the following equation (from an Excel spreadsheet given to the RLWD by the MPCA – AMMACUTE.xls) and then multiply the result by the total ammonia concentration.

Percentage of total ammonia that is in the un-ionized form =

$$\left[1 / \left(\left(10^{\wedge \left((2730 / (temperature + 273.16)) + 0.09) - pH \right)} \right) + 1 \right) \right] \times 100$$

Table 5. Minnesota State Water Quality Standards.

Pollutant Category	Method for Comparison
Conventional Pollutants and Water Quality Characteristics • Low Dissolved Oxygen • pH • Turbidity • Temperature	Percent exceedance of daily minimum, daily average (minimum of 10 values in most recent 10 years) **Dissolve Oxygen Criteria** • Class 2A. Not less than 7 mg/L as a daily minimum • Class 2Bd, 2B, 2C. Not less than 5 mg/L as a daily minimum • Class D. Maintain background • Class 7. Not less than 1 mg/L as a daily average **pH Criteria** • Results should fall within the range: 6.5 – 8.5 **Tubidity** • Class 2A: 10 NTU • Class 2Bd, 2B, 2C, 2D: 25 NTU **Temperature** • No material increase*
Fecal Coliform, Step 1	Percent exceedance of criterion of 200 col/100ml. (minimum of 10 values in 10 years)
Fecal Coliform, Step 2	Number of months with exceedances of the criterion of a geometric mean of 200 col/100 ml. (minimum of 5 values over 10 years for each aggregated calendar month)
Fecal Coliform, Step 2	Percent exceedance of criterion of 2000 col/100ml. (minimum of 10 values in 10 years)
*A demonstration of a "material increase" means that temperature data must show a statistically significant increase when measured, for example, upstream and downstream of a stream modification, upstream an downstream of a point or nonpoint heat source, or before and after a modification that might impact stream temperature. Temperatures must be for similar time frames such a weeks or seasons.	

Table 6. Summary of Data Requirements and Exceedance Thresholds for Assessment of Conventional Pollutants and Water Quality Characteristics *(MPCA Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment).*

Impairment Assessment For	Period of Record	Minimum No. of Data Points	Use Support or Listing Category Based on Chronic Standard Exceedances		
Chronic Standard Exceedance Thresholds →			≤ 10 %	10 – 25 %	> 25 %
305(b) Report	Most recent 10 years	10*	Fully Supporting	Partially Supporting	Not Supporting
303(d) List (TMDL)	Most recent 10 years	10*	Not Listed	Listed	Listed

Table 7. Step One of Assessment of Waterbodies for Impairment of Swimming Use - Data Requirements and Exceedance Thresholds for Fecal Coliform Bacteria.

Impairment Assessment For	Period of Record	Minimum No. of Data Points	Use Support or Listing Category Based on Exceedances of 200 orgs/100mL	
Standard Exceedance Thresholds →			< 10 %	≥ 10 %
305(b) Report	Most recent 10 years	10	Fully Supporting	Potentially Supporting, go to step 2
303(d) List (TMDL)	Most recent 10 years	10	Not Listed	Potentially Supporting, go to step 2

Table 8. Step Two of Assessment of Waterbodies for Impairment of Swimming Use - Data Requirements and Exceedance Thresholds for Fecal Coliform Bacteria.

Impairment Assessment For	Period of Record	Minimum No. of Data Points	Use Support or Listing Category Based on Exceedances of The Fecal Coliform Standard		
Standard Exceedance Thresholds → *Monthly geometric mean > 200 orgs/100 ml*			No months	1 or 2 months	More than 2 months
305(b) Report	Most recent 10 years	see text	Fully Supporting	Partially Supporting	Not Supporting
303(d) List (TMDL)	Most recent 10 years	see text	Not Listed	Listed	Listed
Standard Exceedance Thresholds → *Exceeds 2000 orgs/100 ml**			< 10 %	10 - 25 %	> 25 %
305(b) Report	Most recent 10 years	10	Fully Supporting	Partially Supporting	Not Supporting
303(d) List (TMDL)	Most recent 10 years	10	Not Listed	Listed	Listed

* In full data set over 10 years. Maximum of 400 orgs./100 ml for Class 2A waters

Table 9. Data Requirements for Statewide Water Quality Assessments.

Pollutant category	Parameters (or steps)	Assessed for	Period of record	Minimum number of values
Pollutants with toxicity-based standards	Un-ionized ammonia (total ammonia, pH & temperature) [3], chloride	305(b)	Most recent 10 years	5, within a 3-yr. period[4]
		303(d)	Most recent 10 years	5, within a 3-yr. period
Conventional pollutants and water quality characteristics	Dissolved oxygen, pH, turbidity, temperature	305(b)	Most recent 10 years	10 (minimum of 20 for turbidity based on total suspended solids)
		303(d)	Most recent 10 years	10 (minimum of 20 for turbidity based on total suspended solids)
Fecal coliform bacteria[5]	Step 1 (screening for potential problem)	305(b)	Most recent 10 years	10
		303(d)	Most recent 10 years	10
	Step 2 – impairment determination via monthly geometric mean	305(b)	Most recent 10 years	5 per month (to calculate mean); at least 3 months
		303(d)	Most recent 10 years	5 per month (to calculate mean); at least 3 months
	Step 2 – impairment determination via individual max. values	305(b)	Most recent 10 years	10
		303(d)	Most recent 10 years	10
Eutrophication of lakes (effects of excess nutrients)	Total phosphorus (TP), chlorophyll *a*, Secchi disk transparency	305(b)	Measurements collected from June to Sept. over the most recent 10-year period	At least one TP, Secchi disk or chlorophyll *a* measurement
		303(d)	Measurements collected from June to Sept. over the most recent 10-year period	At least 12 measurements (12 separate sampling dates) for each of TP, Secchi disk & chlorophyll *a*
Impairment of the biological community	Index of Biotic Integrity[6]	305(b)	Most recent 10 years	Can be based on a single biological monitoring event on a given reach
		303(d)	Most recent 10 years	Can be based on a single biological monitoring event on a given reach
Supporting water quality data	TSS, total Kjeldahl nitrogen, nitrite-nitrate nitrogen, conductivity, 5-day biochemical oxygen demand, alkalinity, stream TP	305(b)	Most recent 10 years	As available; supports assessments
		303(d)	Most recent 10 years	As available; supports assessments

3.54 Comparisons to Ecoregion Reference Streams

Official water quality assessments by the MPCA are conducted using standards that apply to the whole state. However, water quality can very naturally among different soil types, land uses, land surface forms, and potential natural vegetation. Therefore, assessing results from a water quality monitoring program by comparing them with standards that reflect local conditions may be desirable. The MPCA and the EPA have each created standards based upon ecoregions. Ecoregions are areas of homogenous ecological characteristics and are defined by climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables. Ecoregion standards are particularly useful in the Red Lake River Watershed, which falls within four different ecoregions.

In order to correctly compare water quality data, some statistical analysis is necessary. Since these standards are listed as quartiles, you will need to find the corresponding quartiles for your monitoring data before you can compare the results with the ecoregion values. See Section 2.21 for instructions for finding quartiles. An example use of this analysis for a water quality report would be a table of the 75th percentile values for each parameter for each monitoring site, with the ecoregion values listed at the top of each parameter's column as a reference.
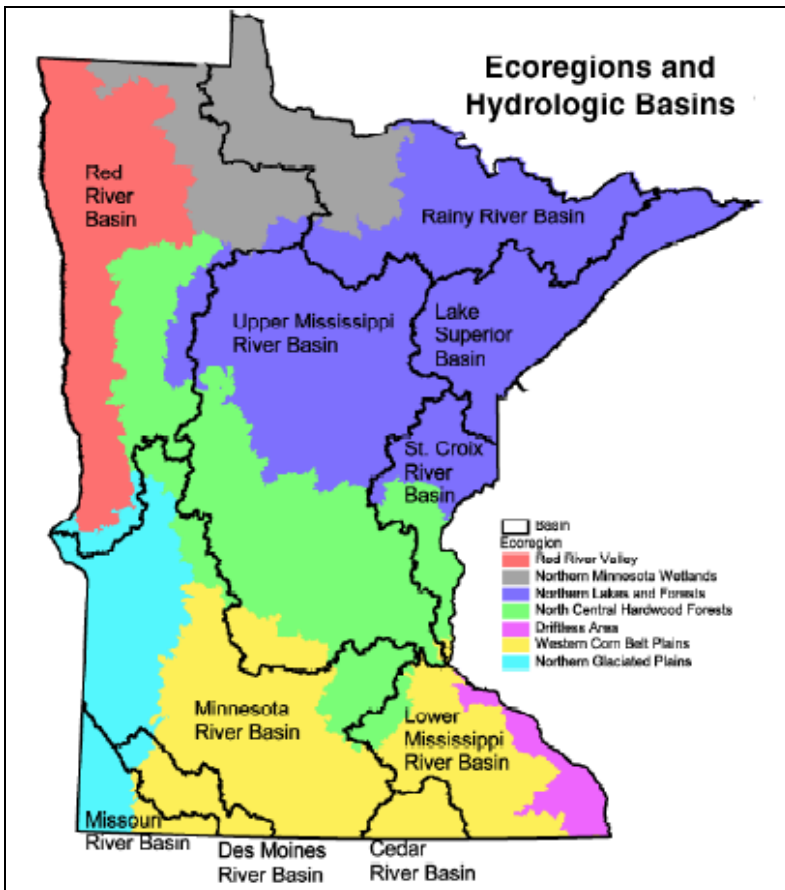

Figure 32. Minnesota Ecoregions and Hydrologic Basins. (From MPCA Website).

Table 10. Water quality of least impacted streams by ecoregion – Red River Basin Ecoregions within Minnesota (at 75th percentile).

Parameter	NLF	NCH	RRV	NMW	NGP	WCB
Conductivity	270	340	658	250	1100	790
pH	7.9	8.1	8.3	7.9	8.2	8.2
Total Suspended Solids	6.4	16.1	56.5	17.2	65.5	57.5
Total Ammonia	0.20	0.22	0.29	0.20	0.31	0.39
Nitrates and Nitrites	0.09	0.29	0.20	0.08	0.52	5.62
Total Phosphorus	0.052	0.170	0.322	0.092	0.271	0.340
Fecal Coliform	20	330	230	50	700	790
Temperature (Celsius)	17.6	20.0	19.9	17.2	20.5	19.2
Turbidity	4.3	8.5	23.0	10.0	23.7	22.0
Biological Oxygen Demand (BOD)5	1.7	3.4	4.2	2.2	4.5	5.6

Table 11. Ecoregion lake water quality summary (summer avg. values by ecoregion)

Parameter	Northern Lakes and Forests	North Central Hardwood Forests	Western Corn Belt Plains	Northern Glaciated Plains
Total Phosphorus (mg/l)	14 - 27	23 - 50	65 - 150	130 - 250
Chlorophyll mean (mg/l)	4 - 10	5 - 22	30 - 80	30 - 55
Chlorophyll maximum (mg/l)	< 15	7 - 37	60 - 140	40 - 90
Secchi Disk (feet)	8 - 15	4.9 - 10.5	1.6 - 3.3	1.0 - 3.3
Total Kjeldahl Nitrogen (mg/l)	0.4 – 0.75	< 0.60 - 1.2	1.3 - 2.7	1.8 - 2.3
Nitrite + Nitrate-N (mg/l)	<0.01	<0.01	0.01 - 0.02	0.01 - 0.1
Alkalinity (mg/l)	40 – 140	75 - 150	125 - 165	160 - 260
Color (Pt-Co Units)	10 – 35	10 - 20	15 - 25	20 - 30
pH (s.u.)	7.2 - 8.3	8.6 - 8.8	8.2 - 9.0	8.3 - 8.6
Chloride (mg/l)	0.6 – 1.2	4 - 10	13 - 22	11 - 18
Total Suspended Solids (mg/l)	<1 – 2	2 - 6	7 - 18	10 - 30
Total Suspended Inorganic Solids (mg/l)	<1 – 2	1 - 2	3 - 9	5 - 15
Turbidity (NTU)	< 2	1 - 2	3 - 8	6 - 17
Conductivity (mmhos/cm)	50 – 250	300 - 400	300 - 650	640 - 900
TN:TP ratio	25:1 - 35:1	25:1 - 35:1	17:1 - 27:1	7:1 - 18:1

Table 12. Water quality summary of reference streams by ecoregion: interquartile range (25th – 75th percentile) and 5th - 95th percentile range.

Parameter	Northern Lakes and Forests	North Central Hardwood Forests	Western Corn Belt Plains	Northern Glaciated Plains
Total Phosphorus (rng/l)	30 - 50	70 - 170	210 - 350	160 - 290
Nitrite +	0.10 – 0.03	0.03 – 0.12	0.89 – 6.50	0.01 – 0.43
Nitrate-N (rng/L)	0.01 – 0.09	0.01 – 0.18	0.01 - 12	0.01 – 2.5
Fecal Coliform	20 - 50	80 - 700	130 - 1200	110 - 790
Bacteria	4 - 130	20 - 10000	40 - 9200	28 - 7900
pH (s.u.)	7.5 – 7.9	8.0 – 8.4	8.0 – 8.3	8.1 – 8.3
	7.0 – 8.1	7.5 – 8.6	7.8 – 8.5	7.8 – 8.5
Temperature (°C)	15 – 22	20 - 24	18 - 24	20 - 25
	11.1 – 25.0	14 - 27	14 - 28	13 - 29
Total Suspended Solids (rng/l)	2 – 6	8 - 18	26 – 76	37 - 89
	0.8 - 13	4 - 45	12 - 200	12 - 180
Turbidity (NTU)	1 - 4	5 - 10	14 – 27.0	20 - 37
	0.9 – 7.5	2.3 - 18	6.3 – 54.0	9.1 - 77
Conductivity (rnmhos/cm)	120 - 260	250 - 310	530 - 810	760 - 990
	41 - 290	170 - 350	320 - 940	510 - 1300
*Derived from McCollor and Heiskary (1993).				

Table 13. Ecoregion Lake Water Quality Summary (Summer Average Water Quality Characteristics for Lakes by Ecoregion).

Parameter	Northern Lakes and Forests	North Central Hardwood Forests	Western Corn Belt Plains	Northern Glaciated Plains
Total Phosphorus (ug/l)	14 - 27	23 - 50	65 - 150	130 - 250
Chlorophyll mean (ug/l)	<10	5 - 22	30 - 80	30 - 55
Chlorophyll maximum (ug/l)	<15	7 - 37	60 - 140	40 - 90
Secchi Disk (feet)	8 -15	4.9 - 10.5	1.6 - 3.3	1.0 - 3.3
(meters)	(2.4 - 4.6)	(1.5 - 3.2)	(0.5 -1.0)	(0.3 - 1.0)
Total Kjeldahl Nitrogen (mg/l)	<0.75	<0.60 - 1.2	1.3 - 2.7	1.8 - 2.3
Nitrite + Nitrate-N (mg/l)	<0.01	<0.01	0.01 - 0.02	0.01 - 0.1
Alkalinity (mg/l)	40 - 140	75 - 150	125 - 165	160 - 260
Color (Pt-Co Units)	10 - 35	10 - 20	15 - 25	20 - 30
pH (SU)	7.2 - 8.3	8.6 - 8.8	8.2 - 9.0	8.3 - 8.6
Chloride (mg/l)	<2	4 - 10	13 - 22	11 - 18
Total Suspended Solids (mg/l)	<1 - 2	2 - 6	7 - 18	10 - 30
Total Suspended Inorganic Solids (mg/l)	<1 - 2	1 - 2	3 - 9	5 - 15
Turbidity (NTU)	<2	1 - 2	3 - 8	6 - 17
Conductivity (umhos/cm)	50 - 250	300 - 400	300 - 650	640 - 900
TN:TP ratio	25:1 - 35:1	25:1 - 35:1	17:1 - 27:1	7:1 - 18:1

* Based on interquartile range (25th - 75th percentile) for ecoregion reference lakes. Derived in part from Heiskary, S.A. and C. B. Wilson (1990).

Table 14. Minnesota Lake Water Quality Summary (1994). Distribution of Carlson TSI Values and Lake Basin Morphometry Measurements by Ecoregion (N = Number of Lakes).

Northern Lakes and Forests

					Percentiles					
MY DATA	Parameter	N	95	90	75	50	25	10	5	Percentile
	Area (acres)	979	20	38	91	227	506	1,453	2,530	
	Depth (feet)	874	10	13	23	37	60	90	115	
	TSI-P	627	34	37	44	50	55	61	63	
	TSI-Chla	267	35	38	43	49	56	63	66	
	TSI-Secchi	785	34	36	39	44	50	56	60	
	TSI-Mean	987	35	37	41	47	52	57	61	

North Central Hardwood Forests

					Percentiles					
MY DATA	Parameter	N	95	90	75	50	25	10	5	Percentile
	Area (acres)	676	25	42	96	223	556	1,317	2,395	
	Depth (feet)	578	8	11	19	32	50	73	84	
	TSI-P	483	46	49	55	64	74	84	89	
	TSI-Chla	431	44	48	53	63	69	75	77	
	TSI-Secchi	666	40	42	47	54	63	70	77	
	TSI-Mean	700	41	44	50	58	67	75	77	

Western Corn Belt Plains

					Percentiles					
MY DATA	Parameter	N	95	90	75	50	25	10	5	Percentile
	Area (acres)	85	83	118	204	362	694	1,844	2,900	
	Depth (feet)	67	3	5	7	9	17	30	48	
	TSI-P	72	63	65	70	76	83	87	93	
	TSI-Chla	65	57	60	65	71	75	82	86	
	TSI-Secchi	85	53	56	62	70	73	83	83	
	TSI-Mean	89	59	63	67	73	77	81	84	

Northern Glaciated Plains

					Percentiles					
MY DATA	Parameter	N	95	90	75	50	25	10	5	Percentile
	Area (acres)	30	91	133	220	496	1,193	4,250	11,528	
	Depth (feet)	19	4	4	5	8	14	18	25	
	TSI-P	24	72	73	76	81	86	92	93	
	TSI-Chla	20	57	63	65	68	73	80	81	
	TSI-Secchi	29	49	51	57	65	70	73	77	
	TSI-Mean	30	49	60	67	71	75	80	82	

3.55 Biological Assessments

Another way to assess the condition of a stream is through biological monitoring. This can involve sampling of macroinvertebrates, fish sampling, habitat assessment, and physical characteristic assessments. The end result of a biological assessment should be an Index of Biotic Integrity (IBI). An IBI score is calculated for each sampling event at a monitoring site. Scores can be calculated for fish, macroinvertebrates, and habitat. This IBI data can then be analyzed like water quality data to compare sites, discover trends, and identify problems.

The methods for biological assessments are not described in detail here because the focus of this document is management of water quality data and the methods are described well enough in other manuals. The RLWD uses the EPA's *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish.* This manual should be used as a source of all biological sampling and data management methods used by the RLWD. The use of similar methods from study to study is recommended. Due to the limited amount of biological assessments being conducted in the RLWD, cooperation among agencies and volunteer groups and the use of similar methods is beneficial for making comparisons among monitoring sites. Although everyone should use the same methods, there are other manuals and documents that may be helpful, especially to volunteer monitors.

EPA: *Volunteer Stream Monitoring: A Methods Manual*. Chapter 4 Macroinvertebrates and Habitat.

Minnesota Pollution Control Agency: *Volunteer Surface Water Monitoring Guide.* Pages 68-73. Using biometrics for assessing wetlands, streams, and rivers; Using habitat indices for streams and rivers. http://www.pca.state.mn.us/publications/manuals/vswmg-section6.pdf

Dates, G. and J. Byrne. *River Watch Network Benthic Macroinvertebrate Monitoring Manual.* 1995. River Watch Network. 153 State St., Montpelier, VT 05602 ($25).

State of Connecticut Department of Environmental Protection: *Rapid Bioassessment in Wadeable Streams & Rivers by Volunteer Monitors.* This simplified set of methods contains color photo demonstrations of sampling methods. Also included on this website is a set of macroinvertebrate field identification cards. http://dep.state.ct.us/wtr/volunmon/volopp.htm.

EPA: *Wadeable Streams Assessment Field Operations Manual.* http://www.epa.gov/owow/monitoring/wsa/index.html

EPA Bioassessment webpage. http://www.epa.gov/owow/monitoring/bioassess.html

3.56 Creating Rating Curves from Flow Measurement Data

When coupled with discharge measurements, stage measurements can be used to create rating curves. Rating curves created using a range of paired stage and discharge measurements. Microsoft Excel can be used to get an equation for the rating curve that can be used in water quality data to convert stage measurements to flow. The relationship between stage and flow at some streams may change significantly at a particular stage (floodplain elevation, for example). These changes may be sufficiently represented by a polynomial equation, or may even require two separate curves. The equation that is the final product of a rating curve plot that involves two curves will require an if-then type of function in Microsoft Excel that will apply one equation if the stage is below a certain value and another if it is at or above that breakpoint.

A rating table may be also be a desired product of flow/stage correlation. These tables list a discharge for each level of stage. In these tables there will likely be a row for each tenth of a foot of stage. There will be one column for each tenth of a foot (.00 through .09). The flow at a stage of 10.18 would be located in the cell that lines up with row 10.1 and the column .08 (10.1 + .08 = 10.18).

Instructions for creating a rating curve:

a) Basically, to create a rating curve, plot the measurements by using graph paper, or by using spreadsheet software such as Microsoft Excel to create an X–Y plot of the stage and discharge data.

b) On graph paper, a draw a curve through the points. In Microsoft Excel, create a trendline through the points by right-clicking on the data points on the chart and then clicking on "add trendline." When adding the trendline, click on the options tab and check the box to display the equation on the chart and check the box to display the R-squared value on the chart.

c) Adjust the type of curve by changing the level of polynomial equation in order to get the R-squared value as close to 1 as possible. The closer the R-squared value is to 1, the more accurately the equation will estimate the amount of flow based upon a stage measurement. A 2nd order polynomial equation should be sufficient. Increasing the order of the equation may create a curve that may peak and start decreasing after a certain stage or a curve that returns negative flows below a certain stage. These types of curves should be avoided.

d) A larger amount of stream gauging records, greater accuracy of stream gauge measurements, and the removal of outliers will all improve the accuracy of a rating curve. The resulting equation can be incorporated into databases to calculate flow based upon stage measurement data.
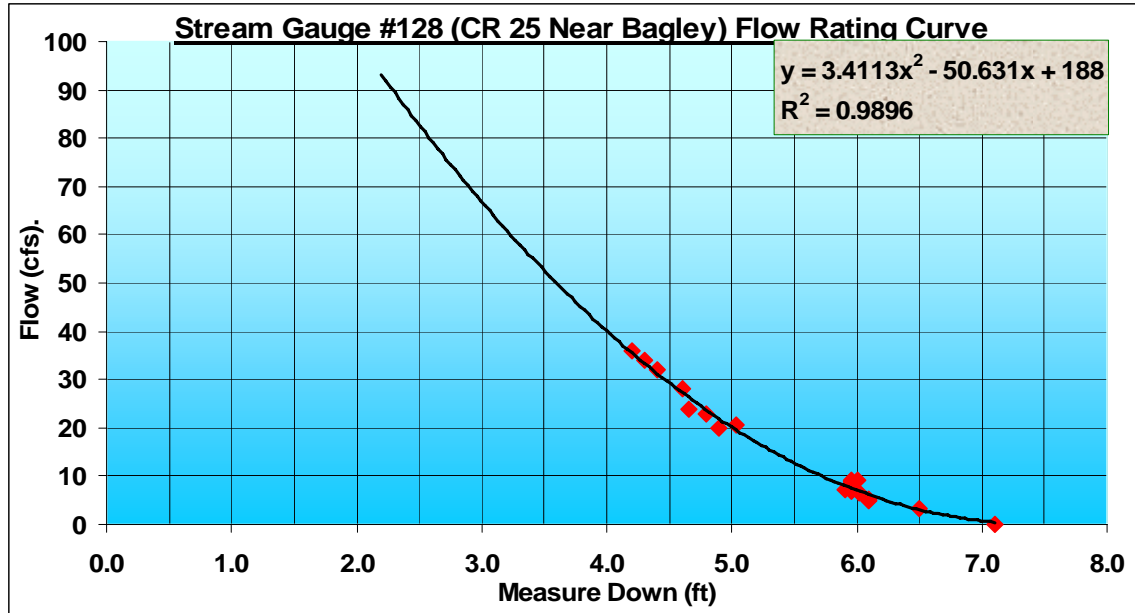
Stream Gauge #128 (CR 25 Near Bagley) Flow Rating Curve

$$y = 3.4113x^2 - 50.631x + 188$$
$$R^2 = 0.9896$$

Figure 33. Rating Curve Example.

3.6 Statistical Software Recommendations

For the purpose of storing data, creating time series plots, and performing other types of statistical analysis, Microsoft Excel is a popular and versatile program. The majority of the statistics needed for analysis of water quality data can be calculated using Microsoft Excel alone, although there are plenty of alternatives available. In Microsoft Excel, the **Insert > Function** feature is very useful and can be used for many different types of statistics, including average, median, count, percentiles, quartiles, standard deviation, correlation coefficients, maximum, minimum, range, t-tests, and variance. The Analysis ToolPak add-in for Microsoft Excel adds a data analysis feature under the tools menu. This add-in analyzes data to find results for the mean, median, mode, standard deviation, skewness, range, minimum, maximum, sum, count, variance, correlation, covariance, histogram, moving average, rank and percentile, regression, t-tests, and z-test. The data analysis feature is beneficial because it does not require the entry of equations. Analyse-It is an add-on for Microsoft Excel that is capable of creating boxplots, descriptive statistics (mean, variance, and standard deviation), correlation plots, and linear regression. It is available at http://www.analyse-it.com/. Webstat, or StatCrunch, is a free tool provided by the University of South Carolina Statistics Dept. for online data analysis. This program is available at http://www.statcrunch.com/. In the "analyze and download data" page for each water quality monitoring site on the RLWD webpage (www.redlakewatershed.org), there is a link that opens up a new window for the StatCrunch program and automatically enters the data from the monitoring site into the program. Almost any type of statistical analysis imaginable can be conducting using StatCrunch.