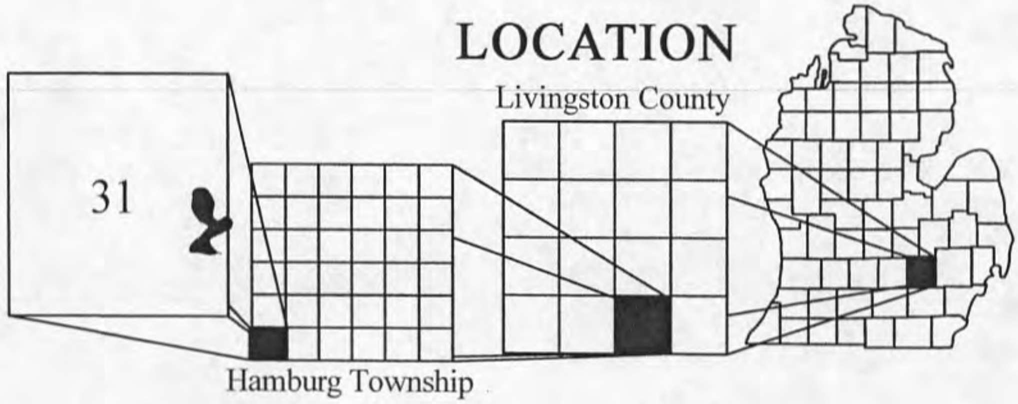
TAMARACK LAKE

Hamburg Township
Livingston County

2004-2010 Water Quality Studies



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TAMARACK LAKE

HAMBURG TOWNSHIP

LIVINGSTON COUNTY

2004-2010 WATER QUALITY STUDIES

TAMARACK LAKE DATA

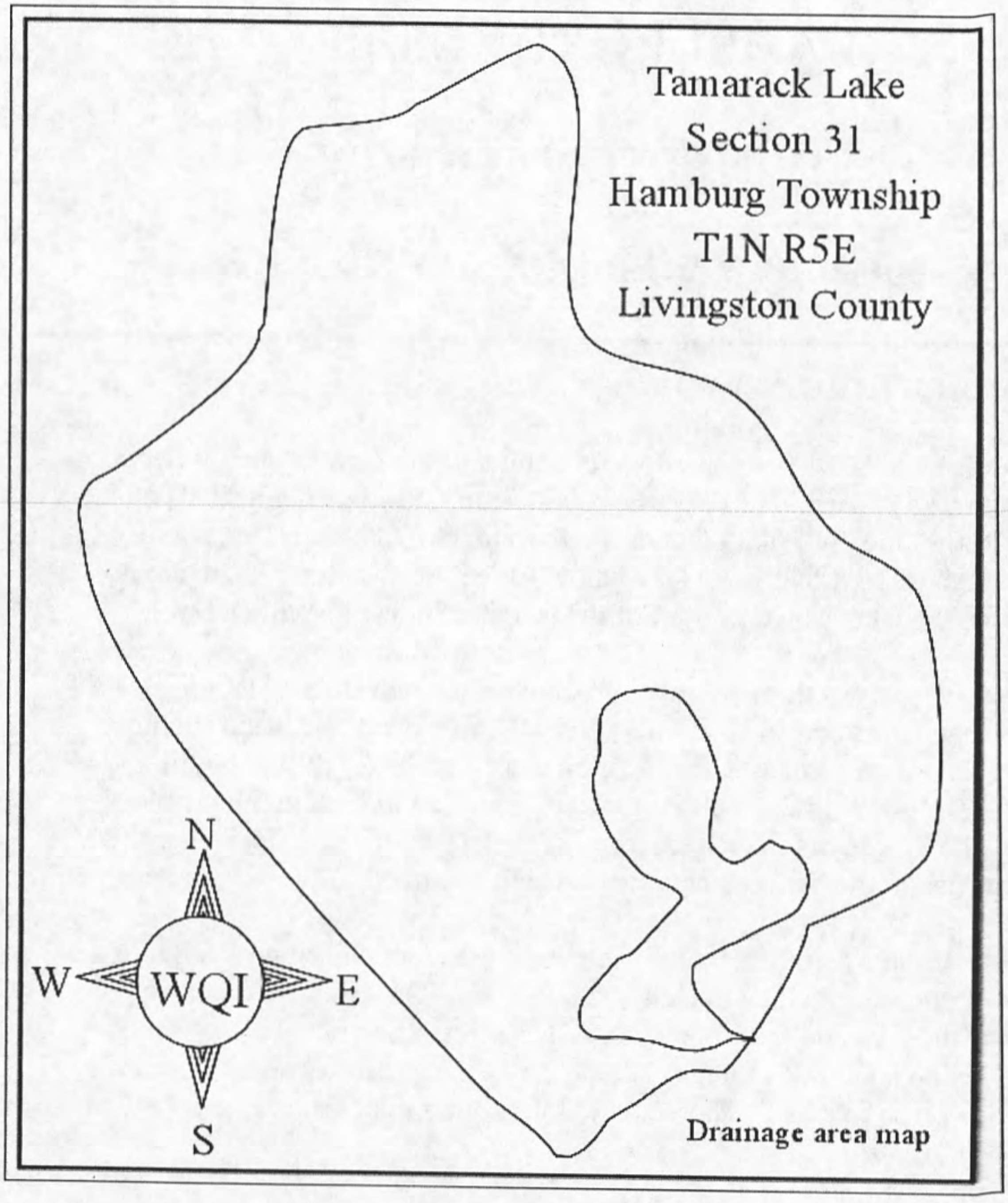
Tamarack Lake is a 17-acre hard water natural kettle lake located in Section 31, Hamburg Township (T1N R5E), Livingston County, Michigan. The lake has a maximum depth of 34 feet, a water volume of 284 acre-feet, and a mean depth of 16.8 feet. The lake has 5210 feet of shoreline. There are no islands in the lake. The elevation of the lake is 850 feet above sea level.

The lake consists of three basins, a 26-foot deep south basin (Station 2), a 34-foot deep north basin (Station 1) and a 24-foot deep east basin (Station 3). The lake was formed when three blocks of ice broke off the melting glacier. Debris from the melting glacier then filled in around the ice blocks. Finally the blocks of ice melted, forming the present basins. However there were no fish in the basins when they were first formed.

The size of the watershed, which is the land area that contributes water to the lake, but does not include the lake, is 206 acres. The drainage area, which includes the lake and the watershed, is 223 acres. (See map below) The watershed to lake ratio is large, 12.1 to 1. The lake flushes about once every 2.6 years on an average. There are no inlets other than groundwater (springs).

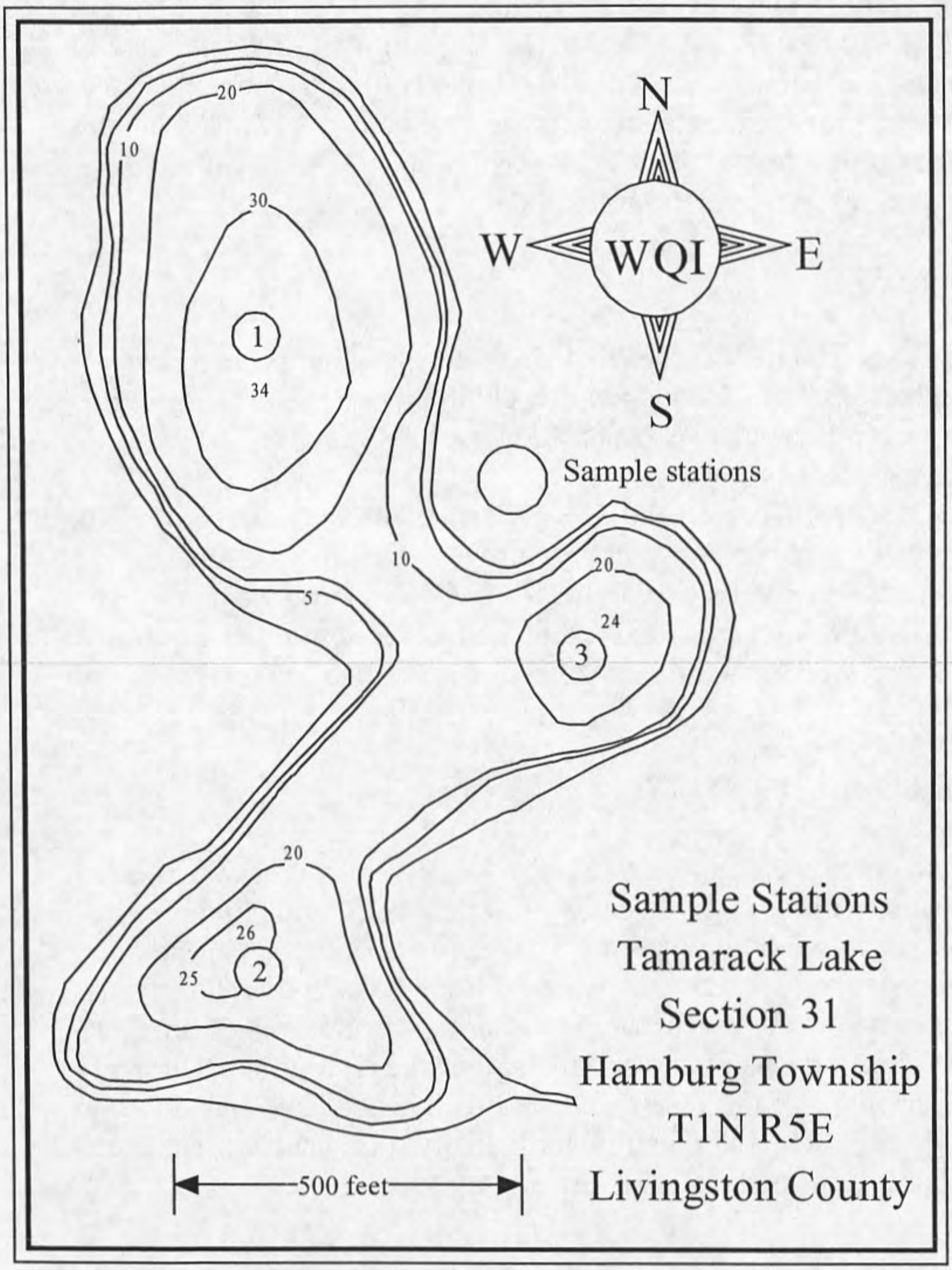
The Tamarack Lake outlet is on the southeast corner. After leaving the lake, the water flows through the Tamarack Lake outlet into the Huron River above Base Lake. The Huron River flows into Lake Erie at Monroe, Michigan.

The longitude and latitude of the 34-foot deep hole is 83° 53.254W and 42° 25.993N.



THE SAMPLE STATIONS

The locations of the three in-lake sample stations are shown on the hydrographic map of the lake.



THE SAMPLE DATES

WQI limnologists took spring samples for water quality testing at the three surface stations shown on the map May 11, 2004, April 18, 2005, April 19, 2006, April 21, 2007, April 18, 2008, April 18, 2009 and April 20, 2010.

They collected three late summer surface samples for water quality testing August 2, 2004, August 3, 2005, August 1, 2006, August 1, 2007, August 1, 2008, August 3, 2009 and August 2, 2010. Top to bottom temperature and dissolved oxygen profiles were collected when the lake was sampled in late summer at the deepest part of the lake. Bottom sediments were collected from the three in-lake stations in spring 2005.

THE ANALYSES

The tests performed on the samples included total phosphorus, total nitrate nitrogen, total alkalinity, pH, conductivity, chlorophyll a, Secchi disk depth, and in summer, temperature and dissolved oxygen.

Temperature, dissolved oxygen and Secchi disk depths were measured in the field. Chlorophyll a, phosphorus, nitrate nitrogen, alkalinity, pH and conductivity tests were performed at the Water Quality Investigators laboratory in Dexter, Michigan. All test procedures followed those outlined in APHA's *Standard Methods for the Examination of Water and Wastewater* (1985).

THE WATER QUALITY STUDY

During certain periods of the year, Michigan lakes have poorer water quality than the remainder of the year. Usually the water quality sampling is designed to look at two of those poor water quality periods, one in early spring when phosphorus which may released from the bottom sediments is distributed throughout the water column by spring mixing, and a second in late summer when the water is warmest, and the lake is stratified. During most of the remainder of the year, the water quality is better. Thus if the lake gets high marks for water quality during early spring and late summer, it probably has pretty good water quality all year long.

THE TEST RESULTS

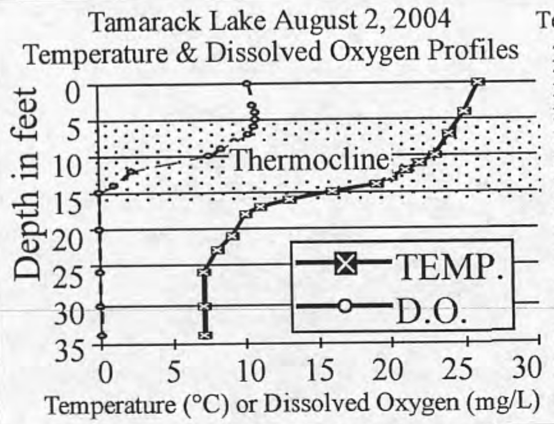
The results of the tests are found in the text, in the table at the end of this report and on the enclosed atlas pages.

TEMPERATURE AND DISSOLVED OXYGEN

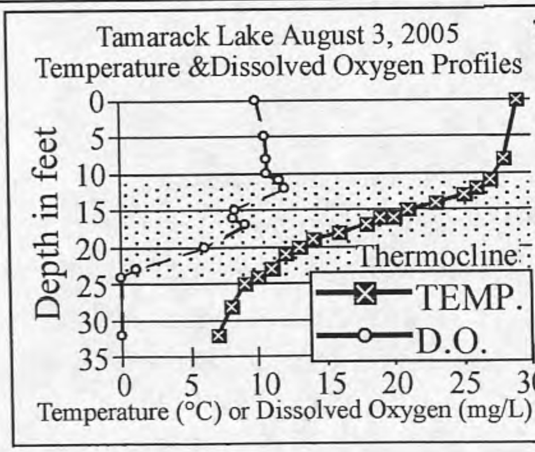
Temperature exerts a wide variety of influences on most lakes, such as the separation of layers of water (stratification), solubility of gases, and biological activity.

Dissolved oxygen is the parameter most often selected by lake water quality scientists as being important. Besides providing oxygen for aquatic organisms, in natural lakes, oxygen is involved in phenomena such as phosphorus precipitation and release from the lake bottom sediments and decomposition of organic material in the lake.

2004



Temp.	Depth	D.O.	Depth
26	0	10.3	0
25	4	10.6	3
24	7	10.8	4
23	10	10.8	5
22	11	10.7	6
21	12	10.3	7
20	13	9.4	8
19	14	8.4	9
16	15	7.6	10
13	16	2.3	12
11	17	1.0	14
10	18	0.0	15
9	21	0.0	20
8	23	0.0	26
7	26	0.0	30
7	34	0.0	34



Temp.	Depth	D.O.	Depth
29	0	10.0	0
28	8	10.6	5
27	11	10.8	8
26	12	10.8	10
25	13	11.6	11
23	14	12.0	12
21	15	8.4	15
20	16	8.2	16
19	16	9.1	17
18	17	6.1	20
16	18	1.1	23
14	19	0.0	24
13	20	0.0	32
12	21		
11	23		
10	24		
9	25		
8	28		
7	32		

In late summer 2004, Tamarack Lake formed a 12-foot-thick thermocline from 5 to 17 feet. (A thermocline is defined as a change in temperature of more than one degree C per meter of depth and is shown shaded on the graphs.)

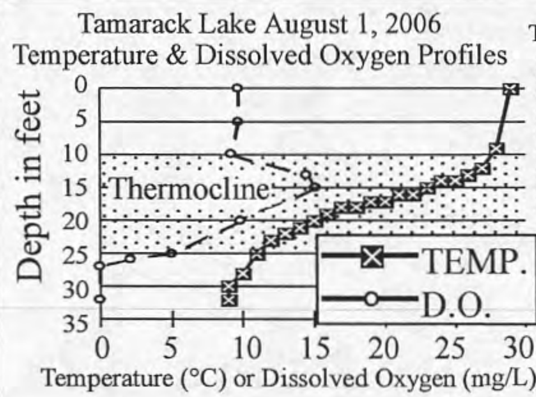
Dissolved oxygen was supersaturated in the top 12 feet. The lake started to lose dissolved oxygen below 5 feet, and at 15 feet it was zero. That condition remained to the bottom. The hypsographic (depth-area) graph shows about 52 percent of the lake is deeper than 15 feet.

2005

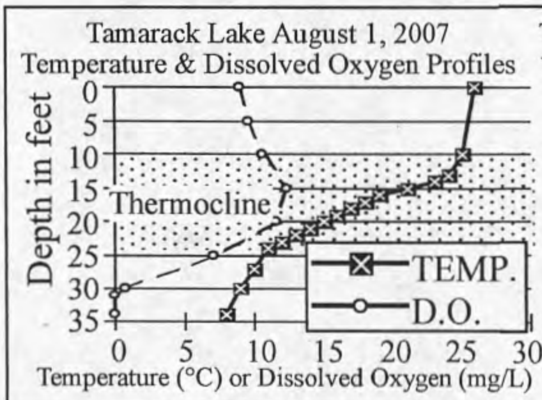
In late summer 2005 Tamarack Lake formed a 15-foot thick thermocline from 10 to 25 feet. Dissolved oxygen was supersaturated above the thermocline. It increased slightly at the top of the thermocline to 12.0 mg/L, then started to decrease. It was zero at 24 feet, and that condition remained to the bottom. About 22 percent of the lake is deeper than 24 feet.

2006

In late summer 2006 the lake formed a 15-foot-thick thermocline from 10 to 25 feet. Dissolved oxygen was supersaturated above the thermocline, and reached a peak of 15.2 mg/L at 15 feet, probably the result of an algal bloom which settled there. From that depth, the dissolved oxygen gradually decreased, and was zero at 27 feet. That condition remained to the bottom About 15 percent of the lake is deeper than 27 feet.



Temp.	Depth	D.O.	Depth
29	0	9.8	0
28	9	9.7	5
27	12	9.3	10
26	13	14.6	13
25	14	15.2	15
23	15	9.9	20
22	16	5.0	25
20	17	2.2	26
18	18	0.0	27
16	19	0.0	32
15	20		
14	21		
13	22		
12	23		
11	25		
10	28		
9	30		
9	32		



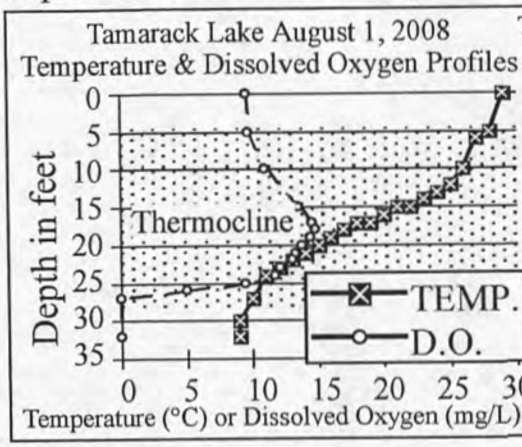
Temp.	Depth	D.O.	Depth
26	0	9.0	0
25	10	9.6	5
24	13	10.6	10
23	14	12.4	15
21	15	11.7	20
19	16	7.1	25
18	17	0.8	30
17	18	0.0	31
16	19	0.0	34
15	20		
14	21		
13	22		
12	23		
11	24		
10	27		
9	30		
8	34		

2007

In late summer 2007 the lake formed a 14-foot-thick thermocline from 10 to 24 feet. The dissolved oxygen profile was most unusual in that it uniformly increased from 9.0 mg/L at the surface to 12.4 mg/L at 15 feet. Below that it gradually decreased and was zero at 31 feet. What makes these data unusual is the dissolved oxygen concentration is not influenced by the thermocline. Usually the thermocline has a dramatic effect on the dissolved oxygen concentration, but in this case it didn't.

2008

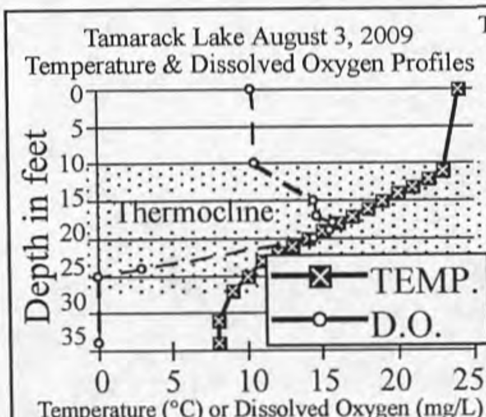
In late summer 2008 Tamarack Lake formed a 22-foot thick thermocline from 5 to 27 feet. Dissolved oxygen was supersaturated at the surface, and increased below five feet to a maximum of 14.8 mg/L at 18 feet. Below that depth dissolved oxygen gradually decreased and was zero at 27 feet. About 15 percent of the lake is deeper than 27 feet. This condition was similar to the dissolved oxygen profile in 2007



Temp.	Depth	D.O.	Depth
29	0	9.6	0
28	5	9.8	5
27	6	11.0	10
26	10	13.5	15
25	12	14.6	17
24	13	14.8	18
23	14	14.4	19
22	15	13.8	20
20	16	13.3	21
18	17	13.0	22
17	18	12.2	23
16	19	11.8	24
15	20	9.5	25
14	21	5.0	26
13	22	0.0	27
12	23	0.0	32
11	24		
10	27		
9	30		
9	32		

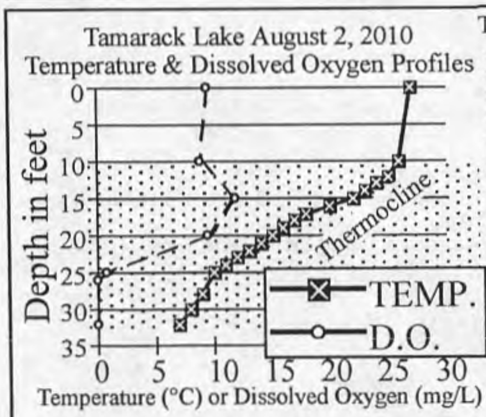
2009

In late summer 2009 Tamarack Lake formed a 21-foot thick thermocline from 10 to 31 feet. Dissolved oxygen was supersaturated at the surface, and increased below 10 feet to a maximum of 15.7 mg/L at 18 feet. Below that depth dissolved oxygen gradually decreased and was zero at 25 feet. About 15 percent of the lake is deeper than 25 feet.



Temp.	Depth	D.O.	Depth
24	0	10.3	0
23	11	10.5	10
22	12	14.5	15
21	13	14.7	17
20	14	15.7	18
19	15	15.5	19
18	16	14.4	20
17	17	3.0	24
16	18	0.0	25
15	19	0.0	34
14	20		
13	21		
12	22		
11	23		
10	25		
9	27		
8	31		
8	34		

2010



Temp.	Depth	D.O.	Depth
27	0	9.5	0
26	10	8.9	10
25	12	11.9	15
24	13	9.5	20
23	14	0.8	25
22	15	0.0	26
20	16	0.0	32
18	17	0.0	32
17	18		
16	19		
15	20		
14	21		
13	22		
12	23		
11	24		
10	25		
9	28		
8	30		
7	32		

In late summer 2010 Tamarack Lake formed a 22-foot thick thermocline from 10 to 32 feet. Dissolved oxygen was plentiful in the surface water and increased to 11.9 mg/L at 15 feet, the result of an algal bloom which settled there. Below that depth the concentration gradually decreased. It was zero at 26 feet and that condition remained to the bottom.

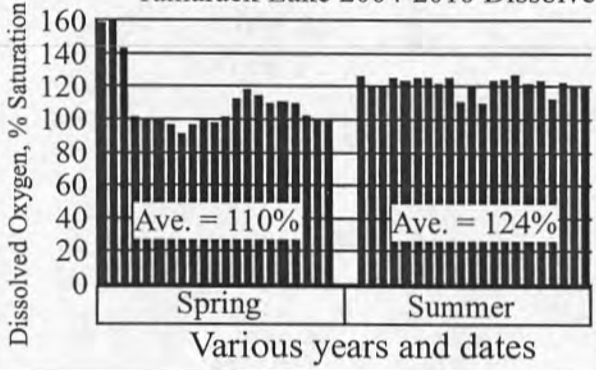
A NOTE ABOUT THE FOLLOWING GRAPHS

The data on the graphs which follow are first sorted by spring and summer, then by year. The purpose of this is to detect differences between spring and summer samples.

DISSOLVED OXYGEN SATURATION

Since the amount of oxygen dissolved in water varies with temperature, with cold water holding more dissolved oxygen than warm water, dissolved oxygen saturation is often a better way to determine if the amount of oxygen dissolved in the water is adequate. Best is near 100 percent.

Tamarack Lake 2004-2010 Dissolved Oxygen Saturation



Spring		4/18/08	114	8/1/06	125
5/11/04	158	4/18/09	109	8/1/06	121
5/11/04	160	4/18/09	110	8/1/06	125
5/11/04	142	4/18/09	109	8/1/07	110
4/18/05	101	4/20/10	102	8/1/07	120
4/18/05	100	4/20/10	98	8/1/07	109
4/18/05	99	4/20/10	98	8/1/08	123
4/19/06	96			8/1/08	124
4/19/06	91	Summer		8/1/08	127
4/19/06	96	8/2/04	126	8/3/09	121
4/21/07	99	8/2/04	118	8/3/09	123
4/21/07	97	8/2/04	119	8/3/09	112
4/21/07	101	8/3/05	125	8/2/10	122
4/18/08	112	8/3/05	123	8/2/10	119
4/18/08	117	8/3/05	125	8/2/10	118

The graph of surface dissolved oxygen saturation values shows when the lake was sampled in spring 2004 it had dissolved oxygen saturation values ranging from 142 to 160 percent, which are high.

Late summer 2004 dissolved oxygen saturation values ranged from 118 to 126 percent.

In 2005 spring values were ideal, ranging from 99 to 101 percent. Late summer 2005 dissolved oxygen saturation values were 123 to 125 percent, which are high, but not nearly as high as the spring 2004 saturation values.

In 2006 spring values ranged from 91 to 96 percent, while summer values were higher, ranging from 121 to 125 percent.

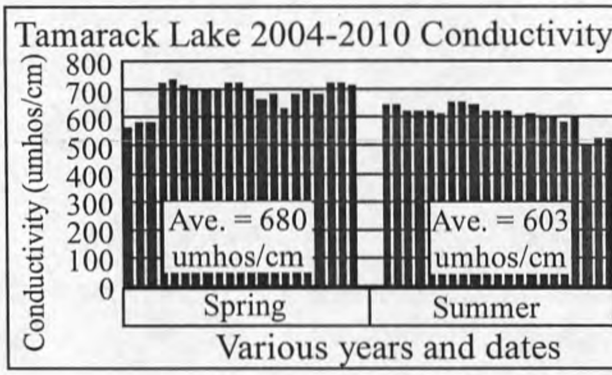
2007 spring saturations were in the normal range, 97 to 101 percent, while summer values were higher, 109 to 120 percent.

In 2008 and 2009 both spring and summer saturation values were high at all stations, ranging from 109 to 117 percent in spring and from 112 to 127 percent in summer.

In 2010 spring saturations were normal, 98 to 102 percent, while in summer they were higher, 118 to 122 percent.

CONDUCTIVITY

Conductivity generally measures salts, and lower is usually better.



Spring		4/18/08	630	8/1/06	650
5/11/04	560	4/18/09	680	8/1/06	650
5/11/04	580	4/18/09	690	8/1/06	640
5/11/04	580	4/18/09	680	8/1/07	620
4/18/05	720	4/20/10	720	8/1/07	620
4/18/05	730	4/20/10	720	8/1/07	620
4/18/05	710	4/20/10	710	8/1/08	590
4/19/06	700			8/1/08	610
4/19/06	700	Summer		8/1/08	600
4/19/06	690	8/2/04	640	8/3/09	600
4/21/07	720	8/2/04	640	8/3/09	580
4/21/07	720	8/2/04	620	8/3/09	590
4/21/07	700	8/3/05	620	8/2/10	500
4/18/08	660	8/3/05	620	8/2/10	520
4/18/08	680	8/3/05	610	8/2/10	520

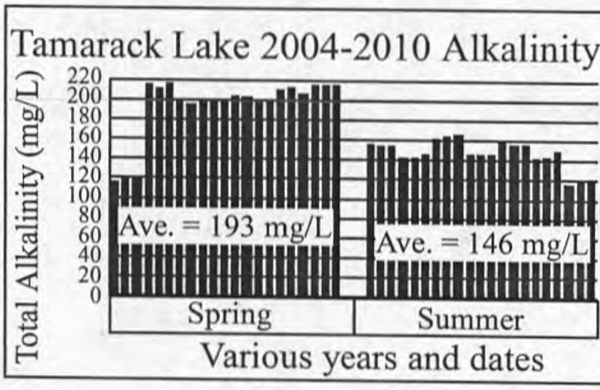
The graph shows the surface water conductivities of Tamarack Lake in spring range from a low of 560 micromhos per centimeter to a high of 730 micromhos per centimeter and average 680 umhos/cm. Summer conductivities range from 500 to 650 and average 603 umhos/cm.

These are higher than normal conductivities for a Michigan hard water inland lake. The data shows salts may be entering the lake from either road salting activities or water softeners, or both. The graph shows spring conductivities are higher than summer conductivities. This seems to implicate road salts because they are washed into lakes in spring with melting snows. The graph also shows spring conductivities are not changing, but summer conductivities are decreasing. Decreasing conductivities is a plus.

TOTAL ALKALINITY

Alkalinity is a measure of the ability of the water to absorb acids (or bases) without changing the hydrogen ion concentration (pH). It is, in effect, a chemical sponge. In most Michigan lakes, alkalinity is due to the presence of carbonates and bicarbonates which were introduced into the lake from ground water or streams which flow into the lake. In lower Michigan, acidification of most lakes should not be a problem because of the high alkalinity concentrations.

Soft water lakes have alkalinities below 75 milligrams per liter. Moderately hard water lakes have alkalinities between 75 and 150 milligrams per liter. Hard water lakes have alkalinities above 150 milligrams per liter.



Spring		4/18/08	199	8/1/06	162
5/11/04	116	4/18/09	210	8/1/06	164
5/11/04	120	4/18/09	212	8/1/06	165
5/11/04	120	4/18/09	206	8/1/07	145
4/18/05	215	4/20/10	215	8/1/07	145
4/18/05	211	4/20/10	215	8/1/07	145
4/18/05	216	4/20/10	215	8/1/08	160
4/19/06	197			8/1/08	155
4/19/06	195	Summer		8/1/08	155
4/19/06	197	8/2/04	155	8/3/09	142
4/21/07	200	8/2/04	154	8/3/09	143
4/21/07	200	8/2/04	154	8/3/09	149
4/21/07	204	8/3/05	142	8/2/10	116
4/18/08	202	8/3/05	142	8/2/10	119
4/18/08	197	8/3/05	145	8/2/10	119

The graph shows the alkalinity of Tamarack Lake surface samples ranges from 116 to 216 milligrams per liter in spring (average 193 mg/L). Summer alkalinities range from 116 to 165 mg/L and average 146 mg/L. This indicates Tamarack Lake is a hard water lake.

Hard water lakes are tougher than soft water lakes because they have the ability to precipitate some phosphorus to the bottom sediments as calcium phosphate. That pretty much ties up the phosphorus.

In 2004 summer alkalinities were higher than spring alkalinities, but that may have been because the large spring algal bloom used the carbonates as a carbon source, reducing the amount of carbonates and bicarbonates in the water.

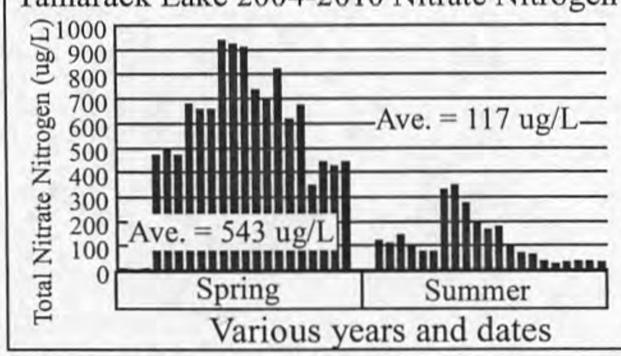
alkalinities, which is normal. This is because carbonates and bicarbonates are less soluble in warm water than in cold water, so in summer they precipitate to the bottom sediments. Hence the lower summer surface alkalinities. However in Tamarack Lake the difference between the spring and summer alkalinities is dramatic, in the range of 40-50 mg/L.

NITRATE NITROGEN

Nitrate, also measured in the parts per billion range, has traditionally been considered by lake scientists to be a limiting nutrient. The experts felt any concentration below 200 parts per billion was excellent in terms of lake water quality. The highest value found by this author was 48,000 parts per billion in a river which flowed into an Ottawa County lake.

On the other hand, we've studied hundreds of Michigan inland lakes, and many times we find them nitrate limited (very low nitrate nitrogen concentrations), especially in summer.

Tamarack Lake 2004-2010 Nitrate Nitrogen



Spring		4/18/08	820	8/1/06	326
5/11/04	3	4/18/09	614	8/1/06	347
5/11/04	2	4/18/09	670	8/1/06	273
5/11/04	6	4/18/09	346	8/1/07	184
4/18/05	467	4/20/10	438	8/1/07	166
4/18/05	493	4/20/10	425	8/1/07	175
4/18/05	467	4/20/10	438	8/1/08	93
4/19/06	680			8/1/08	70
4/19/06	653	Summer		8/1/08	63
4/19/06	657	8/2/04	116	8/3/09	32
4/21/07	936	8/2/04	105	8/3/09	22
4/21/07	922	8/2/04	140	8/3/09	27
4/21/07	909	8/3/05	88	8/2/10	32
4/18/08	737	8/3/05	71	8/2/10	36
4/18/08	697	8/3/05	71	8/2/10	24

The graph shows 2004 spring Tamarack Lake nitrate nitrogen concentrations were low, 2 to 6 micrograms per liter. The reason for the low spring nitrates was the intense algal bloom in the lake used the nitrates for algal growth.

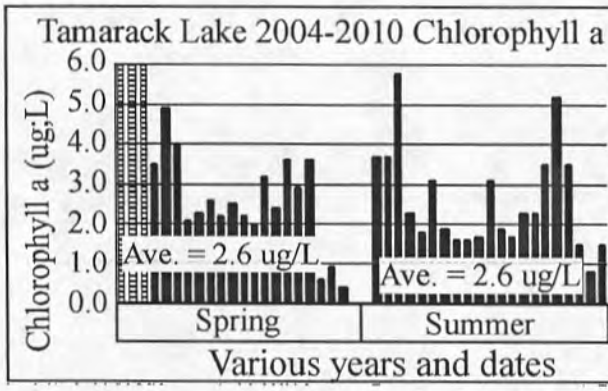
The rest of the spring nitrates were high for a Michigan inland lake (average = 543 ug/L). The chlorophyll a data (below) shows algae were not present in numbers which would seriously decrease the nitrates.

Summer nitrates in the first five years were higher than we normally see (average = 117 ug/L). In 2009 and 2010 they were in the normal range. These data essentially indicate most of the time Tamarack Lake is probably phosphorus limited in both spring and summer. That means don't use lawn fertilizers on near-lake areas.

CHLOROPHYLL A

Chlorophyll a is used by lake scientists as a measure of the biological productivity (amount of algae) of the water. Generally, the lower the chlorophyll a, the better. High concentrations of chlorophyll a are indicative of an algal bloom in the lake, an indication of poor lake water quality.

The highest surface chlorophyll a concentration found by this writer in a Michigan lake was 216 micrograms per liter. Best is below one microgram per liter.



Spring		4/18/08	2.4	8/1/06	1.9
5/11/04	122	4/18/09	3.6	8/1/06	1.6
5/11/04	204	4/18/09	2.9	8/1/06	1.6
5/11/04	58	4/18/09	3.6	8/1/07	1.7
4/18/05	3.5	4/20/10	0.6	8/1/07	3.1
4/18/05	4.9	4/20/10	0.9	8/1/07	1.9
4/18/05	4.0	4/20/10	0.4	8/1/08	1.7
4/19/06	2.1			8/1/08	2.3
4/19/06	2.3	Summer		8/1/08	2.3
4/19/06	2.6	8/2/04	3.7	8/3/09	3.5
4/21/07	2.2	8/2/04	3.7	8/3/09	5.2
4/21/07	2.5	8/2/04	5.8	8/3/09	3.5
4/21/07	2.2	8/3/05	2.3	8/2/10	1.5
4/18/08	2.0	8/3/05	1.8	8/2/10	0.8
4/18/08	3.2	8/3/05	3.1	8/2/10	1.5

The graph shows chlorophyll concentrations were very high in spring 2004, ranging from 58 to 204 micrograms per liter. (The crosshatched bars were truncated because they were high enough to make the remainder of the chlorophyll data appear insignificant, which is not the case.) These data show why dissolved oxygen was supersaturated and Secchi disk readings were only two feet.

Spring chlorophylls (disregarding the high 2004 values) ranged from 2.1 to 4.9 ug/L and averaged 2.6 ug/L

Summer chlorophylls ranged from 0.8 to 5.8 ug/L and averaged 2.6 ug/l as well.

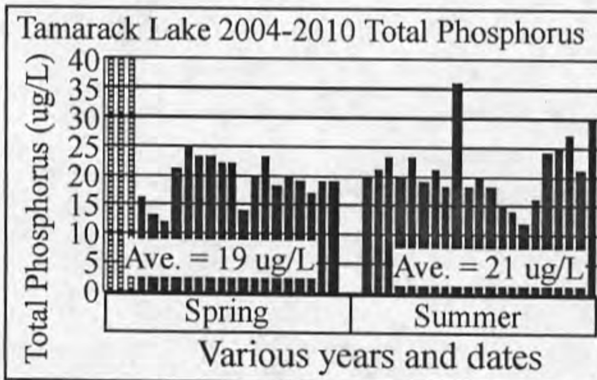
In 2010 chlorophylls were the lowest since we started studying the lake, 0.4 to 0.9 ug/L in spring and 0.8 to 1.5 ug/L in summer. Let's hope this trend continues.

TOTAL PHOSPHORUS

Although there are several forms of phosphorus found in lakes, the experts selected total phosphorus as being most important. This is probably because all forms of phosphorus can be converted to the other forms. Currently, most lake scientists feel phosphorus, which is measured in parts per billion (1 part per billion is one second in 31 years) or micrograms per liter (ug/L), is the one nutrient which might be controlled. If its addition to lake water could be limited, the lake might not become covered with the algal communities so often found in eutrophic lakes.

However, based on our studies of many Michigan inland lakes, we've found many lakes were phosphorus limited in spring (so don't add phosphorus) and nitrate limited in summer (so don't add nitrogen).

10 parts per billion is considered a low concentration of phosphorus in a lake and 50 parts per billion is considered high by many limnologists.



Spring		4/18/08	23	8/1/06	21
5/11/04	**51**	4/18/09	18	8/1/06	18
5/11/04	**175**	4/18/09	20	8/1/06	36
5/11/04	**91**	4/18/09	19	8/1/07	18
4/18/05	16	4/20/10	17	8/1/07	20
4/18/05	13	4/20/10	19	8/1/07	18
4/18/05	12	4/20/10	19	8/1/08	15
4/19/06	21			8/1/08	14
4/19/06	25	Summer		8/1/08	12
4/19/06	23	8/2/04	20	8/3/09	16
4/21/07	23	8/2/04	21	8/3/09	24
4/21/07	22	8/2/04	23	8/3/09	25
4/21/07	22	8/3/05	20	8/2/10	27
4/18/08	14	8/3/05	23	8/2/10	21
4/18/08	20	8/3/05	19	8/2/10	30

The graph shows spring 2004 phosphorus concentrations were high, 51 to 175 micrograms per liter. This was the reason for the intense spring algal bloom. The bars on the graph were truncated so the remainder of the phosphorus data would show, and crosshatched to show they were different than the rest of the data.

In spring, ignoring the 2004 data, phosphorus concentrations ranged from 12 to 25 ug/L and averaged 19 ug/L. Summer phosphorus concentrations ranged from 12 to 36 ug/L and averaged 21 ug/L.

2010 spring phosphorus concentrations were 17 or 19 ug/L while summer values were higher, ranging from 21 to 30 ug/L.

As the concentration of phosphorus nears 20 ug/L, it will cause algal blooms if other nutrients are also present in sufficient quantities.

SECCHI DISK TRANSPARENCY (originally Secchi's disk)

In 1865, Angelo Secchi of Rome, Italy devised a 20 centimeter (8 inch) white disk for studying the transparency of the water in the Mediterranean Sea. Later an American limnologist (lake scientist) named Whipple divided the disk into black and white quadrants which many are familiar with today.

The Secchi disk transparency is a lake test widely used and accepted by limnologists. The experts generally felt the greater the Secchi disk depth, the better quality the water. However, one Canadian scientist pointed out acid lakes have very deep Secchi disk readings. Most lakes in southeast Michigan have Secchi disk transparencies of less than ten feet in summer. On the other hand, Elizabeth Lake in Oakland County had 34 foot Secchi disk readings in summer 1996, evidently caused by a zebra mussel invasion a couple of years earlier.

Most limnology texts recommend the following: to take a Secchi disk transparency reading, lower the disk into the water on the shaded side of an anchored boat to a point where it disappears. Then raise it to a point where it's visible. The average of these two readings is the Secchi disk transparency depth.

We do it slightly differently. We lower the disk on the shaded side of an anchored boat until the disk disappears, and note the depth, then report the depth to the next deepest foot. For example if the disk disappears at six and a half feet, we report the Secchi disk depth as 7 feet. The reason we do this is that some suggest using a water telescope (a device that works like an underwater mask and eliminates water roughness) to view the disk as it disappears. Since we don't use this device, we compensate for it by noting the slightly deeper depth.

We feel it is only necessary to report Secchi disk measurements to the closest foot. Secchi disk measurements should be taken between 10 AM and 4 PM. Rough water will give slightly shallower readings than smooth water. Sunny days will give slightly deeper readings than cloudy days. However, roughness influences the visibility of the disk more than sunny or cloudy days. Furthermore, it's been reported that most adults can see the Secchi disk disappear at about the same depth, but grand-children see it disappear 3-4 feet deeper than grand-parents.

If there are sample sites where the lake is too shallow and the disk is visible when resting on the bottom, the reading should be taken at a nearby deeper site. Since the sampling procedure is designed to obtain "representative samples" moving the boat to an area where a Secchi disk transparency reading can be properly taken is appropriate. In the case of Secchi disk readings, this procedure is more valid than reporting the disk is visible on the lake bottom.

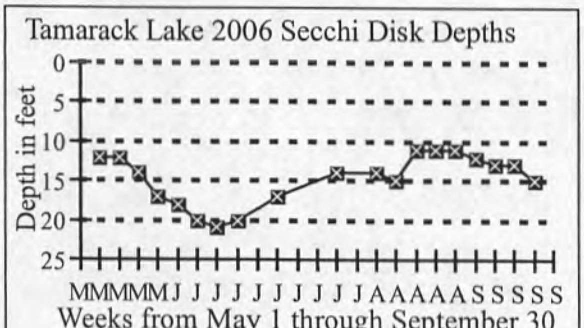
TAMARACK LAKE SECCHI DISK DATA

2006 & 2007

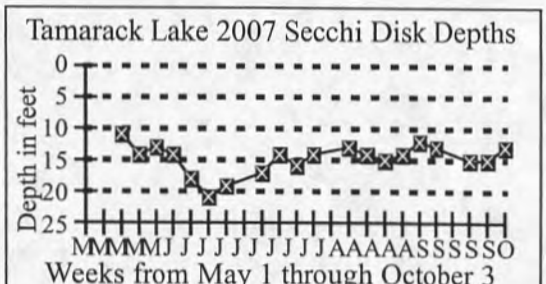
In 2006, 2007, 2008 and 2009 Jim Meyer did a good job of collecting Secchi disk data. The graphs show his data.

2006

The graph shows in 2006 the lake had 12-foot readings in early spring, probably the result of a diatom bloom, an alga that likes cold water. Then as the water started to warm, the clarity increased to a maximum of 21 feet in mid-June. From that depth the clarity gradually decreased to 11 feet in August. The year ended with 15-foot readings at the end of September.



MAY	.	12	12	14	17
JUN	18	20	21	20	.
JUL	17	.	.	14	.
AUG	14	15	11	11	11
SEP	12	13	13	15	.



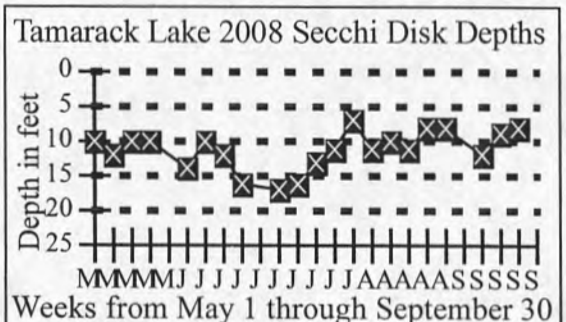
MAY	.	.	11	14	13
JUN	14	18	21	19	.
JUL	17	14	16	14	.
AUG	13	14	15	14	12
SEP	13	.	15	15	.
OCT	13				

2007

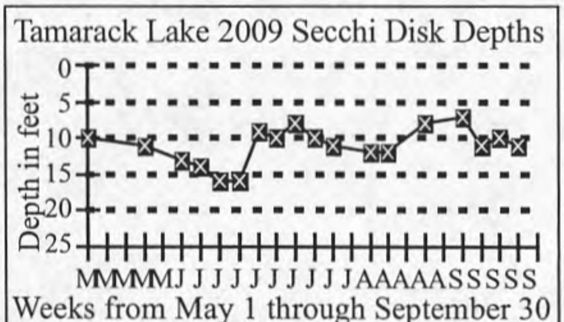
Meyer's 2007 data were similar to 2006, shallow readings in May, then deeper readings in mid-June. After that the clarity decreased to between 11 and 15 feet the rest of the year.

2008

In spring 2008, Meyer's data shows the water clarity was 10 feet, increasing to a maximum of 17 feet the first part of July, then decreasing to between 8 and 12 feet through August and September.



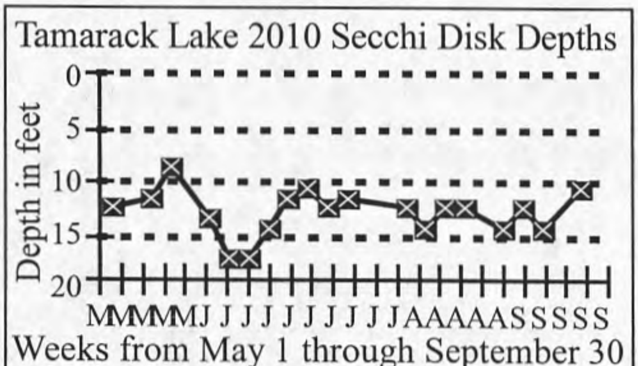
MAY	10	12	10	10	.
JUN	14	10	12	16	.
JUL	17	16	13	11	7
AUG	11	10	11	8	8
SEP	.	12	9	8	.



MAY	10	.	.	11	.
JUN	13	14	16	16	9
JUL	10	8	10	11	.
AUG	12	12	.	8	.
SEP	7	11	10	11	.

2009

In spring 2009, Meyer's data shows the water clarity was 10 feet in early May, increasing to a maximum of 17 feet the first part of July, then decreasing to between 7 and 12 feet through August and September.



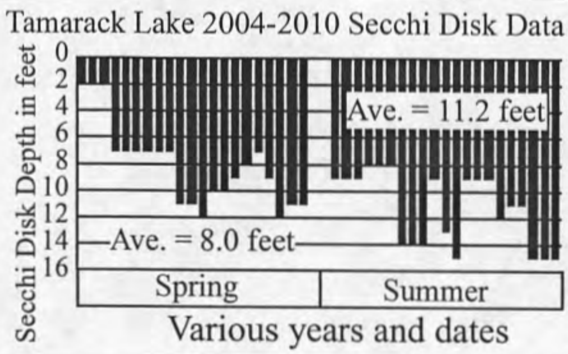
MAY	13	.	12	9	.
JUN	14	18	18	15	12
JUL	11	13	12	.	.
AUG	13	15	13	13	.
SEP	15	13	15	.	11

2010

In 2010 the clarity of Tamarack varied between 9 feet (in May) and 18 feet (in June). The rest of the time they were in the 11 to 15 foot range.

SECCHI DISK READINGS TAKEN WITH THE SAMPLES

Other than Meyer's 2006, 2007, 2008, 2009 and 2010 data, the only Secchi disk data available were those collected with the water samples. The graph shows those data.

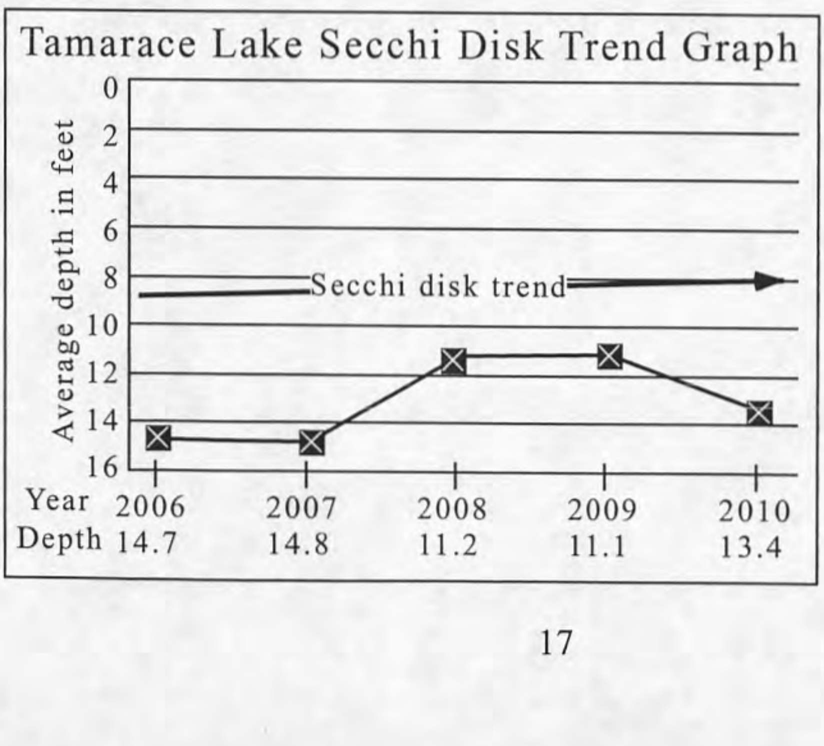


Spring		4/18/08	9	8/1/06	14
5/11/04	2	4/18/09	8	8/1/06	14
5/11/04	2	4/18/09	7	8/1/06	14
5/11/04	2	4/18/09	9	8/1/07	9
4/18/05	7	4/20/10	12	8/1/07	13
4/18/05	7	4/20/10	11	8/1/07	15
4/18/05	7	4/20/10	11	8/1/08	9
4/19/06	7			8/1/08	9
4/19/06	7	Summer		8/1/08	9
4/19/06	7	8/2/04	9	8/3/09	12
4/21/07	11	8/2/04	9	8/3/09	11
4/21/07	11	8/2/04	9	8/3/09	11
4/21/07	12	8/3/05	8	8/2/10	15
4/18/08	10	8/3/05	8	8/2/10	15
4/18/08	10	8/3/05	8	8/2/10	15

The graph shows spring 2004 Secchi disk readings were 2 feet, which is poor. These shallow Secchi disk readings were the result of the algal bloom in the lake.

The graph shows in spring Secchi disk readings range from 2 feet to 12 feet (average = 8.0 feet), and the trend is to deeper readings.

Summer Secchi disk readings range from 8 to 15 feet (average 11.2 feet), and again the trend appears to be deeper readings.



Let's hope this trend continues in both spring and summer.

THE SECCHI DISK TREND GRAPH

Since we had five years worth of Secchi disk data, we were able to construct a Secchi disk trend graph. The graph shows the trend is to less clear water. It is unusual for the data on this graph not correspond to the data on the previous graph. Usually the data on the two graphs follow the same trend.

Secchi disk readings should be taken on a regular basis through the warm months every year to follow changes in the lake.

THE LAKE WATER QUALITY INDEX

The Lake Water Quality Index used in this study to define the water quality of Tamarack Lake was developed for two reasons.

First, there was no agreement among lake scientists regarding which tests should be used to define the water quality of lakes, and second, there was no agreement among lake scientists regarding what the results of various tests meant in terms of lake water quality.

Development of the index invoked the use of two questionnaires sent to a panel of 555 lake scientists who were members of the American Society of Limnology and Oceanography. The panel was specifically selected because they were chemists and biologists with advanced degrees who studied lake water quality.

The first questionnaire asked the scientists to select tests which they felt should be used to define lake water quality. The tests most often selected by the panel became the index parameters (or tests). They were:

Dissolved oxygen (percent saturation)
Total phosphorus
Chlorophyll a
Secchi disk depth
Total nitrate nitrogen
Total alkalinity
Temperature
Conductivity
pH

The second questionnaire, sent out after the first was returned, asked the scientists what the results of the tests they selected as good indicators of lake water quality meant.

After the responses to the second questionnaire were returned and tabulated, the nine parameters and the accompanying rating curves were combined into a Lake Water Quality Index.

The index ranges from 1 to 100 and rates lakes about the same way professors rate students: 90-100=A, 80-90=B, 70-80=C, 60-70=D, and below 60 = E. The lake with the highest LWQI was Long Lake in Grand Traverse County, with a spring LQWI of 100. The lowest LWQI seen by this author was 16 in an Ottawa County lake.

HOW TO READ THE LAKE WATER QUALITY INDEX CALCULATION SHEETS.

Listed across the top of the calculation sheets are the tests selected by the panel of experts as being good indicators of lake water quality. The results of the tests are entered into the square boxes immediately under the names of the tests.

The figures which look like thermometers are actually graphs which convert the test results (the numbers found outside the thermometer) to a uniform 1-100 lake water quality rating (found inside the thermometer).

The calculation sheet permits calculation of the Lake Water Quality Index, using the results of all nine lake water quality tests.

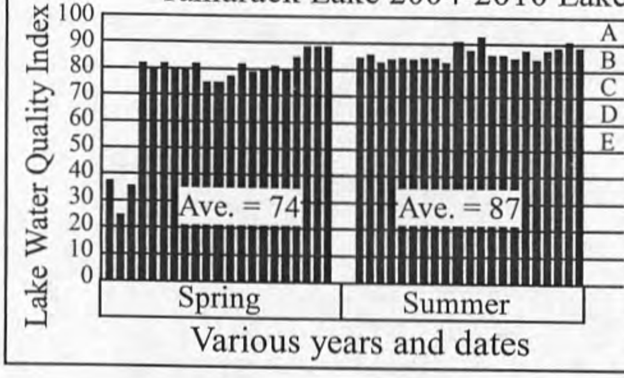
The position of the red lines across the thermometer indicates how the results of each test compare in terms of lake water quality. Test results indicating excellent water quality are indicated by red lines near the top of the thermometer. Test results indicating poor water quality are indicated by red lines lower on the thermometer. And the lower the red line on the thermometer, the greater the water quality problem. A glance at the top of the calculation sheet indicates the test and the actual test results.

The thermometer rating scales also allow you to determine what test results would be considered excellent in terms of lake water quality. They are the numbers found outside the thermometer near the top.

The index is shown three different ways, as a number between 1 and 100 in the circle marked LWQI, and by a color and position on the sheet edge scale. The purpose of the sheet edge scale is to review quickly large numbers of lakes or test sites within a lake, and determine how the water quality of the various lakes, or test sites within a lake compare.

THE 2004-2010 TAMARACK LAKE WATER QUALITY INDICES

Tamarack Lake 2004-2010 Lake Water Quality Indices



Spring		4/18/08	80	8/1/06	85
5/11/04	37	4/18/09	81	8/1/06	85
5/11/04	24	4/18/09	80	8/1/06	83
5/11/04	35	4/18/09	85	8/1/07	91
4/18/05	82	4/20/10	89	8/1/07	88
4/18/05	80	4/20/10	89	8/1/07	93
4/18/05	82	4/20/10	89	8/1/08	86
4/19/06	80			8/1/08	86
4/19/06	80	Summer		8/1/08	85
4/19/06	82	8/2/04	85	8/3/09	88
4/21/07	75	8/2/04	86	8/3/09	84
4/21/07	75	8/2/04	83	8/3/09	88
4/21/07	77	8/3/05	84	8/2/10	89
4/18/08	82	8/3/05	85	8/2/10	91
4/18/08	79	8/3/05	84	8/2/10	89

The graph shows the spring 2004 Lake Water Quality Indices for Tamarack Lake ranged from 24 to 37, or in the E range. These low LWQIs were caused by high dissolved oxygen saturations, shallow Secchi disk readings, high chlorophyll a concentrations and high phosphorus concentrations. 2004 summer LWQIs were more normal, 83 to 86.

The 2005 and 2006 LWQIs in both spring and summer ranged from 80 to 85, or in the B range.

In 2007 spring LWQIs were 75 or 77 (C) while summer values ranged from 88 to 93 (B to A). These summer LWQIs were the best so far.

In 2008 spring LWQIs ranged from 79 to 82, while in summer they were 85 or 86, which means the water quality was in the B to C range that year.

In 2009 spring LWQIs ranged from 80 to 85, while in summer they ranged from 84 to 88. These data indicate the water quality of Tamarack Lake was in the B range in both spring and summer in 2009

In 2010 spring LWQIs were 89 at all three stations or in the B range. Summer 2010 LWQIs were 89 or 91, or in the B to A range.

The average spring LWQI was 74, but this includes the very low 2004 samples, while the summer LWQIs averaged 87.

The graph seems to show the water quality is getting better in both spring and summer. If that is the case, it's a plus.

THE 2010 LAKE WATER QUALITY INDEX CALCULATION SHEETS

Because the spring 2010 water quality indices were the same (89 89 89), one Lake Water Quality Index calculation sheet is included in this report for the three spring 2010 surface samples, using averaged data.

Because the late summer 2010 water quality indices were similar (89 91 89), a second Lake Water Quality Index calculation sheet is included for the three late summer 2010 surface samples, again using averaged data.

In the report marked MASTER, all six of the LWQI calculation sheets are included. That is the only difference between the MASTER and the rest of the reports.

BOTTOM SEDIMENTS

Many times bottom sediments tell us more about what is happening in a lake than the water quality tests do. That's because bottom sediments provide sort of a history of what's been happening in a lake, while water testing just provides a snapshot.

Bottom sediments are collected with a Pederson dredge, transferred to pint freezer containers and allowed to air dry. Once they are dry, the (usually) shrunken block of material is measured to determine volume, then ground, placed in porcelain dishes, dried at 100 degrees C, weighed, burned at 550 degrees C, and weighed again. Color after air-drying and after burning is also noted.

Bottom sediments almost always come up from the lake bottom black, and many people consider these black sediments "muck". However that's not usually the case.

The bottom sediments are black because no oxygen penetrates them, so the decomposition processes which occur use sulfur rather than oxygen, and in this process, they produce iron sulfides, which are black. However once the sediments are exposed to air, they usually turn some other color.

If the sediments remain black after air drying it usually means they are less than about 65 percent mineral (or more than 35% organic material). Sediments also remain black if they are from soft water lakes, but there's a reason for that.

If the sediments turn gray after air drying it usually means they are made up primarily of carbonates. This is what we usually see in moderately hard water and hard water lakes.

If the sediments turn tan, it usually means they are made up primarily of clays. Further evidence of this occurs when we burn the sediments at 550 degrees C.

We determine how much bottom sediments shrink when they air dry because this information is useful when considering dredging a lake. Normal shrinkage after air-drying is in the range of 50 to 80 percent. However sands and gravels don't shrink at all. Excessive shrinkage is more than 95 percent. In other words, there is only five percent or less of the material remaining after air-drying.

If the gray bottom sediments remain gray after burning they are considered carbonates, and the loss of material during this process is considered organic material. The results are expressed in the percentage of minerals in the bottom sediments.

If the tan bottom sediments turn red after burning, it means the lake is filling with clay. Clay enters the lake from near-lake activities such as road building, home building or farming. Usually clay is not a material that makes up the bottom sediments of most inland lakes.

Highly organic sediments that remained black after air drying usually turn tan after burning, but the mineral content is usually quite low.

I consider high quality bottom sediments from natural lakes to be above 85 percent mineral. And I consider bottom sediments less than 50 percent mineral to be muck.

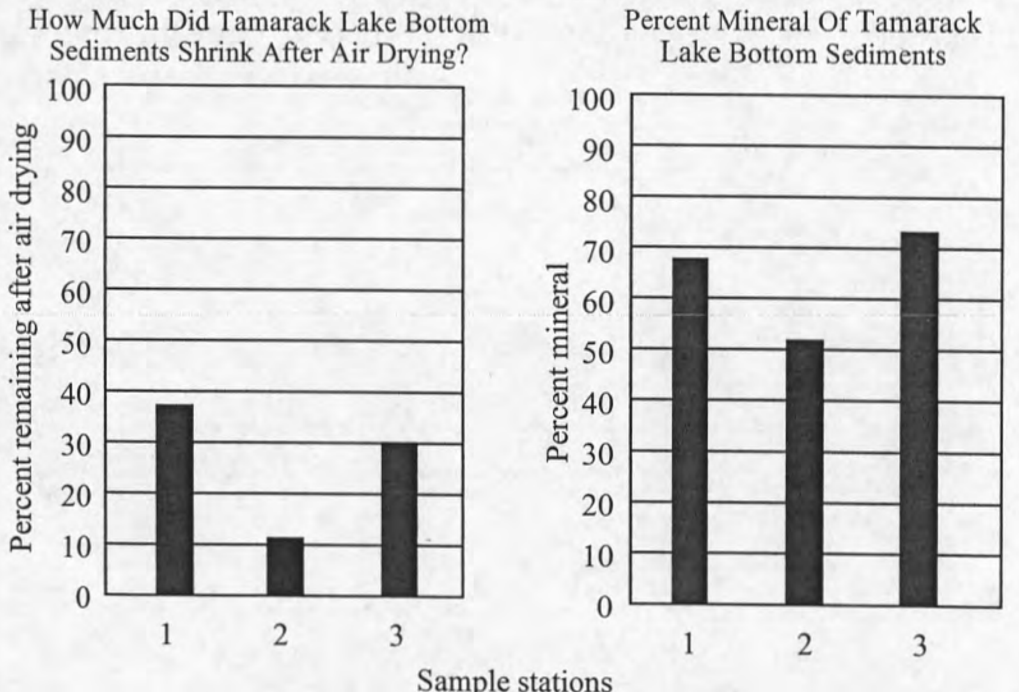
TAMARACK LAKE BOTTOM SEDIMENTS

Bottom sediment samples were collected in Tamarack Lake in spring 2005.

The graph shows the data.

The sample from Station 1, collected in 34 feet of water, was black when recovered, turned gray and shrunk 63 percent after air-drying, and remained gray after burning at 550 degrees C. It was 68 percent mineral.

The sample from Station 2, collected in 20 feet of water, was black when recovered, remained black and shrunk 89 percent after air-drying, and turned gray after burning at 550 degrees C. It was 51 percent mineral.



Characteristics of Tamarack Lake Bottom Sediments (2005)

Sample I.D.	Percent Shrinkage	Percent Mineral	Dried at 100°C Color & Description	Color after burning at 550°C	Depth of water (feet)
1	63	68	Gray	Gray	34
2	89	51	Black	Gray	20
3	70	73	Gray	Gray	18

Average mineral content of bottom sediments = 64%.

The sample from Station 3, collected in 18 feet of water, was black when recovered, turned gray and shrunk 70 percent after air-drying, and remained gray after burning at 550 degrees C. It was 73 percent mineral.

None of the sediments shrunk excessively, although the one from Station 2 came close. Even the deeper sediment from Station 1 did not shrink as much.

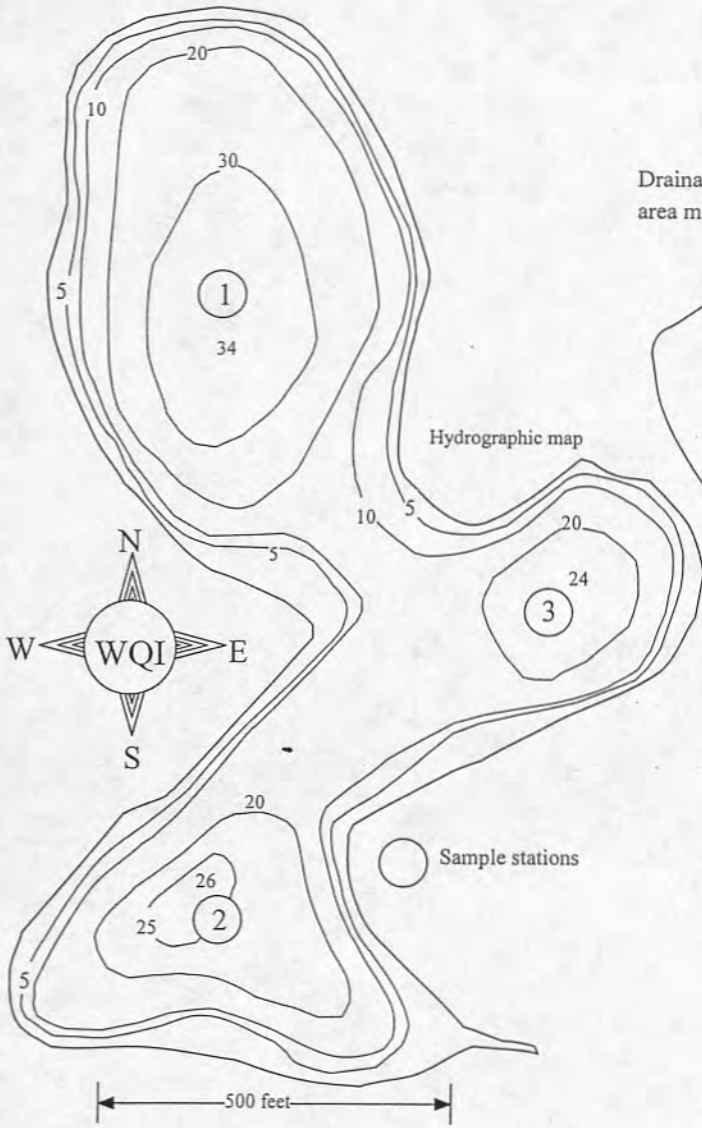
The mineral content of all three sediments was low, ranging from 51 to 73 percent, indicating Tamarack is accumulating organic material in the bottom sediments at a faster than acceptable rate. Residents need to quit fertilizing their lawns.

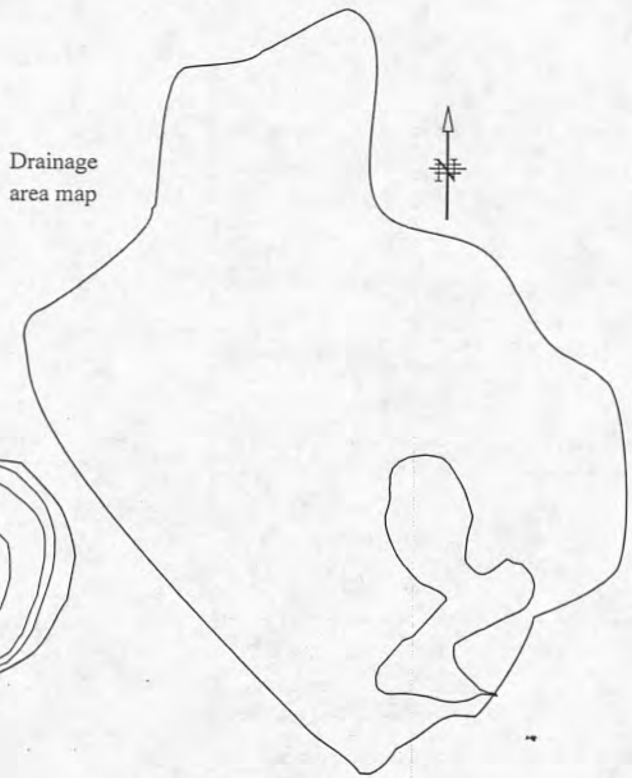
Wallace E. Fusilier

Wallace E. Fusilier
Consulting Limnologist
Water Quality Investigators
Dexter, Michigan
May 2011

Tamarack Lake Water Quality Data

Date	Sample Station Number	Temperature °C	Dissolved Oxygen (mg/L)	Dissolved Oxygen Percent Saturation	Chlorophyll a ug/L	Secchi Disk Depth (feet)	Total Nitrate Nitrogen ug/L	Alkalinity mg/L	pH	Conductivity umhos per cm at 25°C	Total Phosphorus ug/L	Lake Water Quality Index	Grade
5/11/04	1	22	13.8	158	121.5	2	3	116	9.2	560	51	37	E
5/11/04	2	22	14.0	160	203.5	2	2	120	9.2	580	175	24	E
5/11/04	3	22	12.4	142	57.5	2	6	120	9.0	580	91	35	E
8/2/04	1	26	10.3	126	3.7	9	116	155	8.5	640	20	85	B
8/2/04	2	26	9.7	118	3.7	9	105	154	8.5	640	21	86	B
8/2/04	3	26	9.8	119	5.8	9	140	154	8.5	620	23	83	B
4/18/05	1	17	9.8	101	3.5	7	467	215	8.2	720	16	82	B
4/18/05	2	17	9.7	100	4.9	7	493	211	8.2	730	13	80	B
4/18/05	3	17	9.6	99	4.0	7	467	216	8.2	710	12	82	B
8/3/05	1	29	10.0	125	2.3	8	88	142	8.4	620	20	84	B
8/3/05	2	28	9.7	123	1.8	8	71	142	8.4	620	23	85	B
8/3/05	3	28	9.9	125	3.1	8	71	145	8.4	610	19	84	B
4/19/06	1	15	9.8	96	2.1	7	680	197	8.2	700	21	80	B
4/19/06	2	15	9.3	91	2.3	7	653	195	8.2	700	25	80	B
4/19/06	3	15	9.8	96	2.6	7	657	197	8.2	690	23	82	B
8/1/06	1	29	9.8	125	1.9	14	326	162	8.5	650	21	85	B
8/1/06	2	29	9.4	121	1.6	14	347	164	8.6	650	18	85	B
8/1/06	3	29	9.8	125	1.6	14	273	165	8.6	640	36	83	B
4/21/07	1	14	10.3	99	2.2	11	936	200	8.2	720	23	75	C
4/21/07	2	13	10.3	97	2.5	11	922	200	8.1	720	22	75	C
4/21/07	3	14	10.7	101	2.2	12	909	204	8.1	700	22	77	C
8/1/07	1	26	9.0	110	1.7	9	184	145	8.4	620	18	91	A
8/1/07	2	26	9.8	120	3.1	13	166	145	8.4	620	20	88	B
8/1/07	3	26	8.9	109	1.9	15	175	145	8.4	620	18	93	A
4/18/08	1	15	11.4	112	2.0	10	737	202	7.9	660	14	82	B
4/18/08	2	15	11.9	117	3.2	10	697	197	7.9	680	20	79	C
4/18/08	3	15	11.6	114	2.4	9	820	199	7.9	630	23	80	B
8/1/08	1	29	9.6	123	1.7	9	93	160	8.3	590	15	86	B
8/1/08	2	28	9.8	124	2.3	9	70	155	8.3	610	14	86	B
8/1/08	3	28	10.0	127	2.3	9	63	155	8.3	600	12	85	B
4/18/09	1	14	11.3	109	3.6	8	614	210	8.2	680	18	81	B
4/18/09	2	14	11.4	110	2.9	7	670	212	8.2	690	20	80	B
4/18/09	3	14	11.3	109	3.6	9	346	206	8.1	680	19	85	B
8/3/09	1	24	10.3	121	3.5	12	32	142	8.2	600	16	88	B
8/3/09	2	24	10.5	123	5.2	11	22	143	8.2	580	24	84	B
8/3/09	3	24	9.6	112	3.5	11	27	149	8.2	590	25	88	B
4/20/10	1	14	10.4	102	0.6	12	438	215	8.2	720	17	89	B
4/20/10	2	14	10.2	98	0.9	11	425	215	8.2	720	19	89	B
4/20/10	3	14	10.4	98	0.4	11	438	215	8.5	710	19	89	B
8/2/10	1	24	9.8	122	1.5	15	32	116	8.4	500	27	89	B
8/2/10	2	24	9.5	119	0.8	15	36	119	8.3	520	21	91	A
8/2/10	3	24	9.4	118	1.5	15	24	119	8.2	520	30	89	B





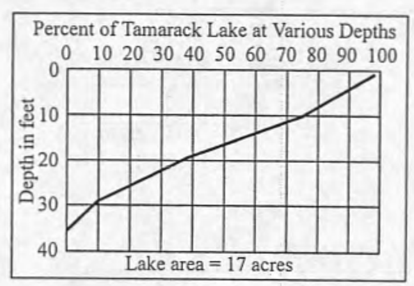


TABLE OF LAKE DATA

Lake name	Tamarack Lake
County	Livingston
U.S.G.S. Map	Pinckney
Type of lake	Natural kettle
River basin	Huron
Lake area (acres)	17
Maximum depth (feet)	34
Mean depth (feet)	16.8
Lake volume (acre feet)	284
Shoreline length (feet)	5210
Watershed area (acres)	206
Drainage area (acres)	223
Watershed to lake ratio	12.1
Flushing rate	2.6 years
Elevation	850
Longest dimension (feet)	1562
Ice out date	3/31/05
	3/11/06
	4/6/08
	3/17/09
Date lake mixed	3/31/05
	3/12/06
	4/6/08
Lake Water Quality Indices	
Spring 2004	37 24 35
Summer 2004	85 86 83
Spring 2005	82 80 82
Summer 2005	84 85 84
Spring 2006	80 80 82
Summer 2006	85 85 83
Spring 2007	76 74 77
Summer 2007	91 93 93
Spring 2008	82 79 80
Summer 2008	86 86 85
Spring 2009	81 80 85
Summer 2009	87 84 87
Spring 2010	89 89 89
Summer 2010	89 91 89
Bottom Sediments, % mineral	68 51 73
Latitude	42° 25.993N
Longitude	83° 53.254W
Official lake monitor	Jim Meyer

FUSILIER'S ATLAS
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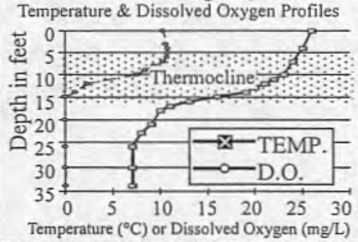
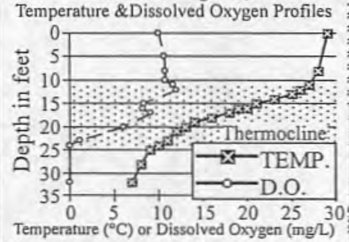
Tamarack Lake
Section 31
Hamburg Township
T1N R5E
Livingston County

Tamarack Lake August 2, 2004
Temperature & Dissolved Oxygen Profiles



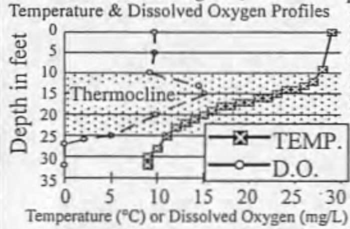
Temp.	Depth	D.O.	Depth
26	0	10.3	0
25	4	10.6	3
24	7	10.8	4
23	10	10.8	5
22	11	10.7	6
21	12	10.3	7
20	13	9.4	8
19	14	8.4	9
16	15	7.6	10
13	16	2.3	12
11	17	1.0	14
10	18	0.0	15
9	21	0.0	20
8	23	0.0	26
7	26	0.0	30
7	34	0.0	34

Tamarack Lake August 3, 2005
Temperature &Dissolved Oxygen Profiles



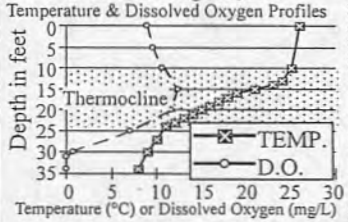
Temp.	Depth	D.O.	Depth
29	0	10.0	0
28	8	10.6	5
27	11	10.8	8
26	12	10.8	10
25	13	11.6	11
23	14	12.0	12
21	15	8.4	15
20	16	8.2	16
19	16	9.1	17
18	17	6.1	20
16	18	1.1	23
14	19	0.0	24
13	20	0.0	32
12	21		
11	23		
10	24		
9	25		
8	28		
7	32		

Tamarack Lake August 1, 2006
Temperature & Dissolved Oxygen Profiles



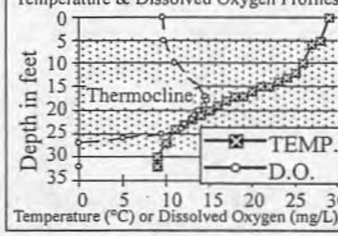
Temp.	Depth	D.O.	Depth
29	0	9.8	0
28	9	9.7	5
27	12	9.3	10
26	13	14.6	13
25	14	15.2	15
23	15	9.9	20
22	16	5.0	25
20	17	2.2	26
18	18	0.0	27
16	19	0.0	32
15	20		
14	21		
13	22		
12	23		
11	25		
10	28		
9	30		
9	32		

Tamarack Lake August 1, 2007
Temperature & Dissolved Oxygen Profiles



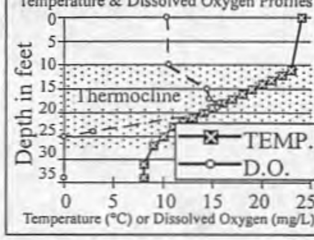
Temp.	Depth	D.O.	Depth
26	0	9.0	0
25	10	9.6	5
24	13	10.6	10
23	14	12.4	15
21	15	11.7	20
19	16	7.1	25
18	17	0.8	30
17	18	0.0	31
16	19	0.0	34
15	20		
14	21		
13	22		
12	23		
11	24		
10	27		
9	30		
8	34		

Tamarack Lake August 1, 2008
Temperature & Dissolved Oxygen Profiles



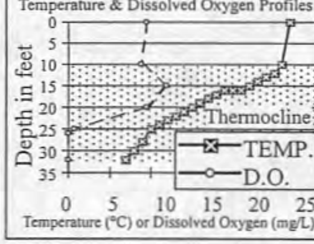
Temp.	Depth	D.O.	Depth
29	0	9.6	0
28	5	9.8	5
27	6	11.0	10
26	10	13.5	15
25	12	14.6	17
24	13	14.8	18
23	14	14.4	19
22	15	13.8	20
20	16	13.3	21
18	17	13.0	22
17	18	12.2	23
16	19	11.8	24
15	20	9.5	25
14	21	5.0	26
13	22	0.0	27
12	23	0.0	32
11	24		
10	27		
9	30		
9	32		

Tamarack Lake August 3, 2009
Temperature & Dissolved Oxygen Profiles



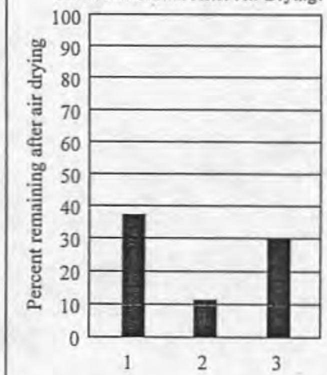
Temp.	Depth	D.O.	Depth
24	0	10.3	0
23	11	10.5	10
22	12	14.5	15
21	13	14.7	17
20	14	15.7	18
19	15	15.5	19
18	16	14.4	20
17	17	3.0	24
16	18	0.0	25
15	19	0.0	34
14	20		
13	21		
12	22		
11	23		
10	25		
9	27		
8	31		
8	34		

Tamarack Lake August 2, 2010
Temperature & Dissolved Oxygen Profiles

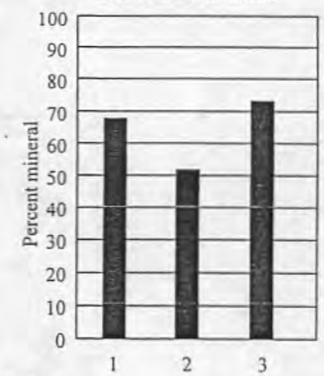


Temp.	Depth	D.O.	Depth
27	0	9.5	0
26	10	8.9	10
25	12	11.9	15
24	13	9.5	20
23	14	0.8	25
22	15	0.0	26
20	16	0.0	32
18	17	0.0	32
17	18	0.0	40
16	19	0.0	50
15	20		
14	21		
13	22		
12	23		
11	24		
10	25		
9	28		
8	30		
7	32		

How Much Did Tamarack Lake Bottom Sediments Shrink After Air Drying?



Percent Mineral Of Tamarack Lake Bottom Sediments



Sample stations

Characteristics of Tamarack Lake Bottom Sediments (2005)

Sample I.D.	Percent Shrinkage	Percent Mineral	Dried at 100°C Color & Description	Color after burning at 550°C	Depth of water (feet)
1	63	68	Gray	Gray	34
2	89	51	Black	Gray	20
3	70	73	Gray	Gray	18

Average mineral content of bottom sediments = 64%.

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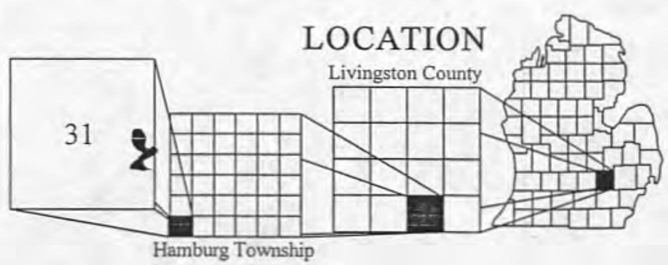
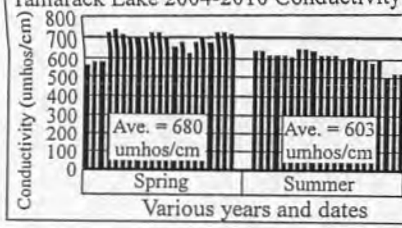
LOCATION



Tamarack Lake Contour Areas & Volumes	
Areas of Various Contours	Volume in Acre feet
Surface area = 16.954 acres	
5 foot = 14.296 acres	78
10 foot = 12.449 acres	67
20 foot = 6.632 acres	95
30-34 foot = 1.620	41
	3
Lake volume = 284 acre feet	

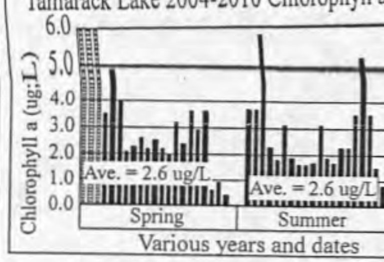
Tamarack Lake
Section 31
Hamburg Township
T1N R5E
Livingston County

Tamarack Lake 2004-2010 Conductivity



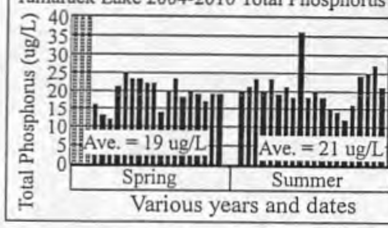
Spring		4/18/08	630	8/1/06	650
5/11/04	560	4/18/09	680	8/1/06	650
5/11/04	580	4/18/09	690	8/1/06	640
5/11/04	580	4/18/09	680	8/1/07	620
4/18/05	720	4/20/10	720	8/1/07	620
4/18/05	730	4/20/10	720	8/1/07	620
4/18/05	710	4/20/10	710	8/1/08	590
4/19/06	700			8/1/08	610
4/19/06	700	Summer		8/1/08	600
4/19/06	690	8/2/04	640	8/3/09	600
4/21/07	720	8/2/04	640	8/3/09	580
4/21/07	720	8/2/04	620	8/3/09	590
4/21/07	700	8/3/05	620	8/2/10	500
4/18/08	660	8/3/05	620	8/2/10	520
4/18/08	680	8/3/05	610	8/2/10	520

Tamarack Lake 2004-2010 Chlorophyll a



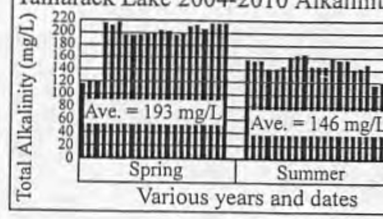
Spring		4/18/08	2.4	8/1/06	1.9
5/11/04	122	4/18/09	3.6	8/1/06	1.6
5/11/04	204	4/18/09	2.9	8/1/06	1.6
5/11/04	58	4/18/09	3.6	8/1/07	1.7
4/18/05	3.5	4/20/10	0.6	8/1/07	3.1
4/18/05	4.9	4/20/10	0.9	8/1/07	1.9
4/18/05	4.0	4/20/10	0.4	8/1/08	1.7
4/19/06	2.1			8/1/08	2.3
4/19/06	2.3	Summer		8/1/08	2.3
4/19/06	2.6	8/2/04	3.7	8/3/09	3.5
4/21/07	2.2	8/2/04	3.7	8/3/09	5.2
4/21/07	2.5	8/2/04	5.8	8/3/09	3.5
4/21/07	2.2	8/3/05	2.3	8/2/10	1.5
4/18/08	2.0	8/3/05	1.8	8/2/10	0.8
4/18/08	3.2	8/3/05	3.1	8/2/10	1.5

Tamarack Lake 2004-2010 Total Phosphorus



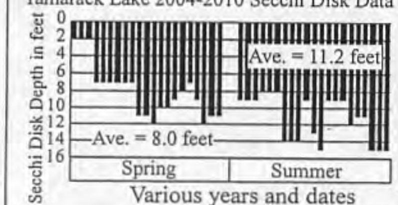
Spring		4/18/08	23	8/1/06	21
5/11/04	51	4/18/09	18	8/1/06	18
5/11/04	175	4/18/09	20	8/1/06	36
5/11/04	91	4/18/09	19	8/1/07	18
4/18/05	16	4/20/10	17	8/1/07	20
4/18/05	13	4/20/10	19	8/1/07	18
4/18/05	12	4/20/10	19	8/1/08	15
4/19/06	21			8/1/08	14
4/19/06	25	Summer		8/1/08	12
4/19/06	23	8/2/04	20	8/3/09	16
4/21/07	23	8/2/04	21	8/3/09	24
4/21/07	22	8/2/04	23	8/3/09	25
4/21/07	22	8/3/05	20	8/2/10	27
4/18/08	14	8/3/05	23	8/2/10	21
4/18/08	20	8/3/05	19	8/2/10	30

Tamarack Lake 2004-2010 Alkalinity



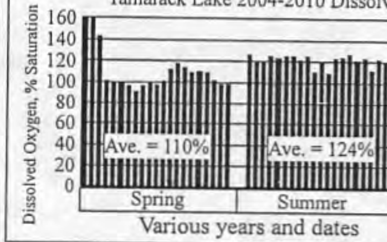
Spring		4/18/08	199	8/1/06	162
5/11/04	116	4/18/09	210	8/1/06	164
5/11/04	120	4/18/09	212	8/1/06	165
5/11/04	120	4/18/09	206	8/1/07	145
4/18/05	215	4/20/10	215	8/1/07	145
4/18/05	211	4/20/10	215	8/1/07	145
4/18/05	216	4/20/10	215	8/1/08	160
4/19/06	197			8/1/08	155
4/19/06	195	Summer		8/1/08	155
4/19/06	197	8/2/04	155	8/3/09	142
4/21/07	200	8/2/04	154	8/3/09	143
4/21/07	200	8/2/04	154	8/3/09	149
4/21/07	204	8/3/05	142	8/2/10	116
4/18/08	202	8/3/05	142	8/2/10	119
4/18/08	197	8/3/05	145	8/2/10	119

Tamarack Lake 2004-2010 Secchi Disk Data



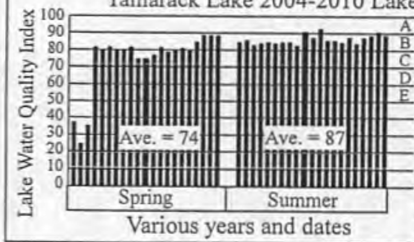
Spring		4/18/08	9	8/1/06	14
5/11/04	2	4/18/09	8	8/1/06	14
5/11/04	2	4/18/09	7	8/1/06	14
5/11/04	2	4/18/09	9	8/1/07	9
4/18/05	7	4/20/10	12	8/1/07	13
4/18/05	7	4/20/10	11	8/1/07	15
4/18/05	7	4/20/10	11	8/1/08	9
4/19/06	7			8/1/08	9
4/19/06	7	Summer		8/1/08	9
4/19/06	7	8/2/04	9	8/3/09	12
4/21/07	11	8/2/04	9	8/3/09	11
4/21/07	11	8/2/04	9	8/3/09	11
4/21/07	12	8/3/05	8	8/2/10	15
4/18/08	10	8/3/05	8	8/2/10	15
4/18/08	10	8/3/05	8	8/2/10	15

Tamarack Lake 2004-2010 Dissolved Oxygen Saturation



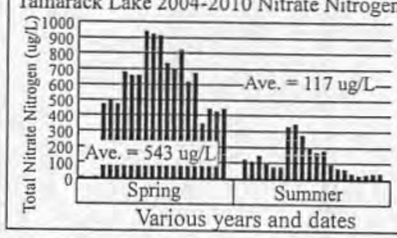
Spring		4/18/08	114	8/1/06	125
5/11/04	158	4/18/09	109	8/1/06	121
5/11/04	160	4/18/09	110	8/1/06	125
5/11/04	142	4/18/09	109	8/1/07	110
4/18/05	101	4/20/10	102	8/1/07	120
4/18/05	100	4/20/10	98	8/1/07	109
4/18/05	99	4/20/10	98	8/1/08	123
4/19/06	96			8/1/08	124
4/19/06	91	Summer		8/1/08	127
4/19/06	96	8/2/04	126	8/3/09	121
4/21/07	99	8/2/04	118	8/3/09	123
4/21/07	97	8/2/04	119	8/3/09	112
4/21/07	101	8/3/05	125	8/2/10	122
4/18/08	112	8/3/05	123	8/2/10	119
4/18/08	117	8/3/05	125	8/2/10	118

Tamarack Lake 2004-2010 Lake Water Quality Indices



Spring		4/18/08	80	8/1/06	85
5/11/04	37	4/18/09	81	8/1/06	85
5/11/04	24	4/18/09	80	8/1/06	83
5/11/04	35	4/18/09	85	8/1/07	91
4/18/05	82	4/20/10	89	8/1/07	88
4/18/05	80	4/20/10	89	8/1/07	93
4/18/05	82	4/20/10	89	8/1/08	86
4/19/06	80			8/1/08	86
4/19/06	80	Summer		8/1/08	85
4/19/06	82	8/2/04	85	8/3/09	88
4/21/07	75	8/2/04	86	8/3/09	84
4/21/07	75	8/2/04	83	8/3/09	88
4/21/07	77	8/3/05	84	8/2/10	89
4/18/08	82	8/3/05	85	8/2/10	91
4/18/08	79	8/3/05	84	8/2/10	89

Tamarack Lake 2004-2010 Nitrate Nitrogen



Spring		4/18/08	820	8/1/06	326
5/11/04	3	4/18/09	614	8/1/06	347
5/11/04	2	4/18/09	670	8/1/06	273
5/11/04	6	4/18/09	346	8/1/07	184
4/18/05	467	4/20/10	438	8/1/07	166
4/18/05	493	4/20/10	425	8/1/07	175
4/18/05	467	4/20/10	438	8/1/08	93
4/19/06	680			8/1/08	70
4/19/06	653	Summer		8/1/08	63
4/19/06	657	8/2/04	116	8/3/09	32
4/21/07	936	8/2/04	105	8/3/09	22
4/21/07	922	8/2/04	140	8/3/09	27
4/21/07	909	8/3/05	88	8/2/10	32
4/18/08	737	8/3/05	71	8/2/10	36
4/18/08	697	8/3/05	71	8/2/10	1.5

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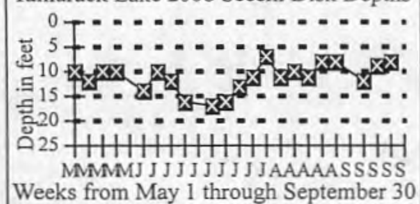
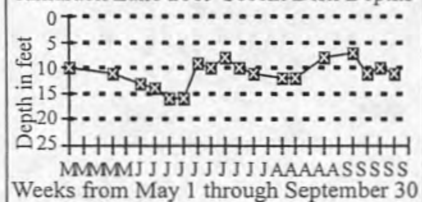
T1N R5E
Livingston County

Tamarack Lake 2008 Secchi Disk Depths



MAY	10	12	10	10	.
JUN	14	10	12	16	.
JUL	17	16	13	11	7
AUG	11	10	11	8	8
SEP	.	12	9	8	.

Tamarack Lake 2009 Secchi Disk Depths



MAY	10	.	.	11	.
JUN	13	14	16	16	9
JUL	10	8	10	11	.
AUG	12	12	.	8	.
SEP	7	11	10	11	.

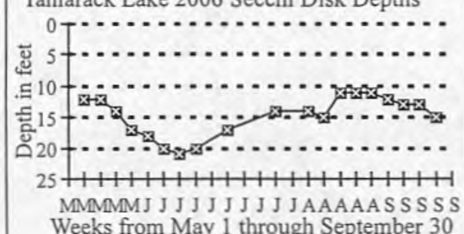
Tamarack Lake Water Quality Data

Date	Sample Station Number	Temperature °C	Dissolved Oxygen (mg/L)	Dissolved Oxygen Percent Saturation	Chlorophyll a ug/L	Secchi Disk Depth (feet)	Total Nitrate Nitrogen ug/L	Alkalinity mg/L	pH	Conductivity umhos per cm at 25°C	Total Phosphorus ug/L	Lake Water Quality Index	Grade
5/11/04	1	22	13.8	158	121.5	2	3	116	9.2	560	51	37	E
5/11/04	2	22	14.0	160	203.5	2	2	120	9.2	580	175	24	E
5/11/04	3	22	12.4	142	57.5	2	6	120	9.0	580	91	35	E
8/2/04	1	26	10.3	126	3.7	9	116	155	8.5	640	20	85	B
8/2/04	2	26	9.7	118	3.7	9	105	154	8.5	640	21	86	B
8/2/04	3	26	9.8	119	5.8	9	140	154	8.5	620	23	83	B
4/18/05	1	17	9.8	101	3.5	7	467	215	8.2	720	16	82	B
4/18/05	2	17	9.7	100	4.9	7	493	211	8.2	730	13	80	B
4/18/05	3	17	9.6	99	4.0	7	467	216	8.2	710	12	82	B
8/3/05	1	29	10.0	125	2.3	8	88	142	8.4	620	20	84	B
8/3/05	2	28	9.7	123	1.8	8	71	142	8.4	620	23	85	B
8/3/05	3	28	9.9	125	3.1	8	71	145	8.4	610	19	84	B
4/19/06	1	15	9.8	96	2.1	7	680	197	8.2	700	21	80	B
4/19/06	2	15	9.3	91	2.3	7	653	195	8.2	700	25	80	B
4/19/06	3	15	9.8	96	2.6	7	657	197	8.2	690	23	82	B
8/1/06	1	29	9.8	125	1.9	14	326	162	8.5	650	21	85	B
8/1/06	2	29	9.4	121	1.6	14	347	164	8.6	650	18	85	B
8/1/06	3	29	9.8	125	1.6	14	273	165	8.6	640	36	83	B
4/21/07	1	14	10.3	99	2.2	11	936	200	8.2	720	23	75	C
4/21/07	2	13	10.3	97	2.5	11	922	200	8.1	720	22	75	C
4/21/07	3	14	10.7	101	2.2	12	909	204	8.1	700	22	77	C
8/1/07	1	26	9.0	110	1.7	9	184	145	8.4	620	18	91	A
8/1/07	2	26	9.8	120	3.1	13	166	145	8.4	620	20	88	B
8/1/07	3	26	8.9	109	1.9	15	175	145	8.4	620	18	93	A
4/18/08	1	15	11.4	112	2.0	10	737	202	7.9	660	14	82	B
4/18/08	2	15	11.9	117	3.2	10	697	197	7.9	680	20	79	C
4/18/08	3	15	11.6	114	2.4	9	820	199	7.9	630	23	80	B
8/1/08	1	29	9.6	123	1.7	9	93	160	8.3	590	15	86	B
8/1/08	2	28	9.8	124	2.3	9	70	155	8.3	610	14	86	B
8/1/08	3	28	10.0	127	2.3	9	63	155	8.3	600	12	85	B
4/18/09	1	14	11.3	109	3.6	8	614	210	8.2	680	18	81	B
4/18/09	2	14	11.4	110	2.9	7	670	212	8.2	690	20	80	B
4/18/09	3	14	11.3	109	3.6	9	346	206	8.1	680	19	85	B
8/3/09	1	24	10.3	121	3.5	12	32	142	8.2	600	16	88	B
8/3/09	2	24	10.5	123	5.2	11	22	143	8.2	580	24	84	B
8/3/09	3	24	9.6	112	3.5	11	27	149	8.2	590	25	88	B
4/20/10	1	14	10.4	102	0.6	12	438	215	8.2	720	17	89	B
4/20/10	2	14	10.2	98	0.9	11	425	215	8.2	720	19	89	B
4/20/10	3	14	10.4	98	0.4	11	438	215	8.5	710	19	89	B
8/2/10	1	24	9.8	122	1.5	15	32	116	8.4	500	27	89	B
8/2/10	2	24	9.5	119	0.8	15	36	119	8.3	520	21	91	A
8/2/10	3	24	9.4	118	1.5	15	24	119	8.2	520	30	89	B

FUSILIER'S ATLAS
AND GAZETTEER OF
MICHIGAN INLAND LAKES
Water Quality Investigators
9200 Dexter Chelsea Road
Dexter, Michigan 48130
(734) 426-8972

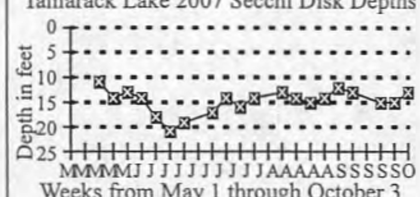
Tamarack Lake
Section 31
Hamburg Township
T1N R5E
Livingston County

Tamarack Lake 2006 Secchi Disk Depths



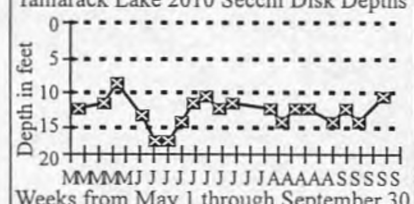
MAY	.	12	12	14	17
JUN	18	20	21	20	.
JUL	17	.	.	14	.
AUG	14	15	11	11	11
SEP	12	13	13	15	.

Tamarack Lake 2007 Secchi Disk Depths



MAY	.	.	11	14	13
JUN	14	18	21	19	.
JUL	17	14	16	14	.
AUG	13	14	15	14	12
SEP	13	.	15	15	.
OCT	13				

Tamarack Lake 2010 Secchi Disk Depths



MAY	13	.	12	9	.
JUN	14	18	18	15	12
JUL	11	13	12	.	.
AUG	13	15	13	13	.
SEP	15	13	15	.	11

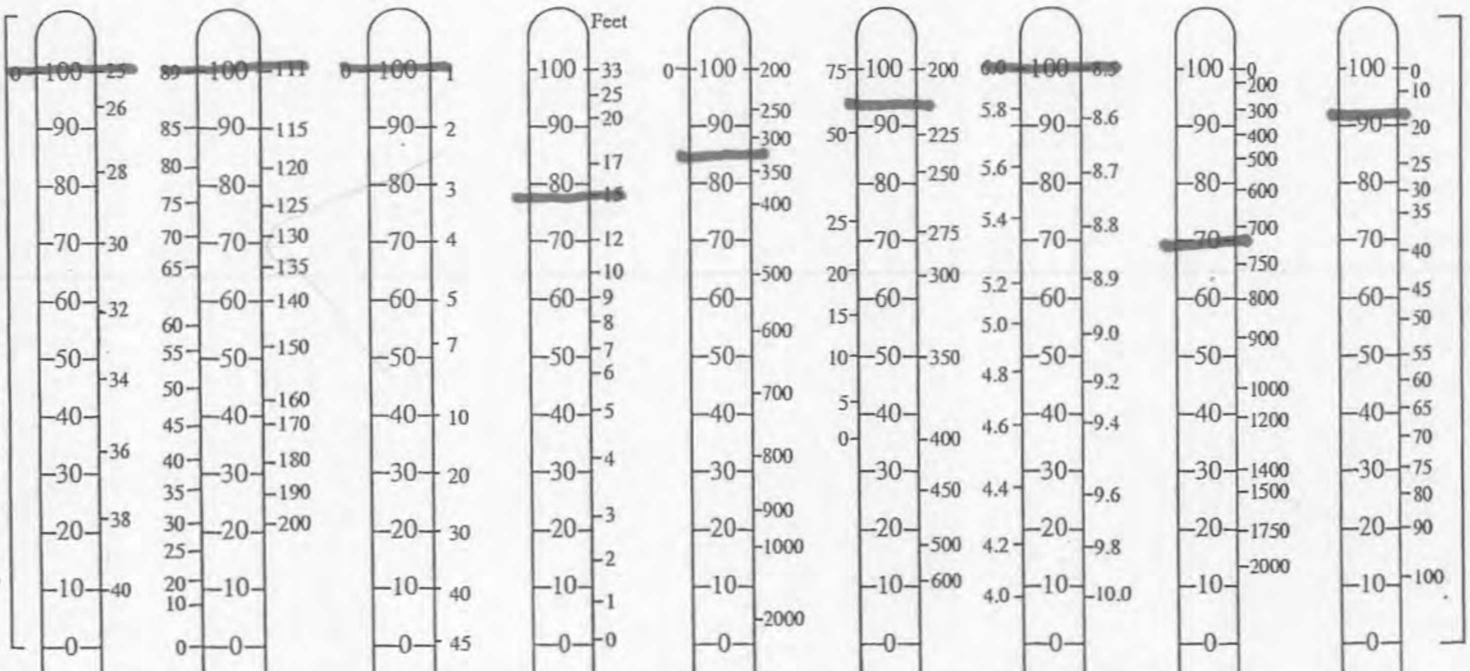
CALCULATION SHEET FOR THE UNWEIGHTED MULTIPLICATIVE LAKE WATER QUALITY INDEX

W. Fusilier, Ph.D.

QUALITY RATING CURVES

(Individual Quality Ratings never exceed 100)

Temperature in degrees C	Dissolved Oxygen, % Saturation	Chlorophyll a ug/L	Secchi Disk Depth in feet	Nitrate-N ug/L	Alkalinity mg/L	pH S. U.	Specific Conductivity umhos/cm@ 25C	Total Phosphorus ug/L
14°	11.3/10.4 99	0.6	15'	434	215	8.2	717	18



9√ 100	X	100	X	100	X	78	X	84	X	93	X	100	X	70	X	92	=	LWQI	89

12.1
Watershed to lake ratio
2.6 years
Flushing rate
Huron
Drainage Basin
223
Drainage Area
284
Lake Volume
Livingston
County
Hamburg
Township
WQI
Analyst
34'
Lake Depth
17
Lake Area

SET THE PARAMETER QUALITY RATING AT 1 IF THE EXTERNAL EXTREME VALUE RANGE IS EXCEEDED

LAKE WATER QUALITY INDEX

0–15	15–25	25–35	35–45	45–55	55–65	65–75	75–85	85–100
Red	Red Orange	Orange	Orange Yellow	Yellow	Yellow green	Green	Blue Green	Blue

DATE 20 April 2018

STATION AVE 1-3

LAKE Tamarack

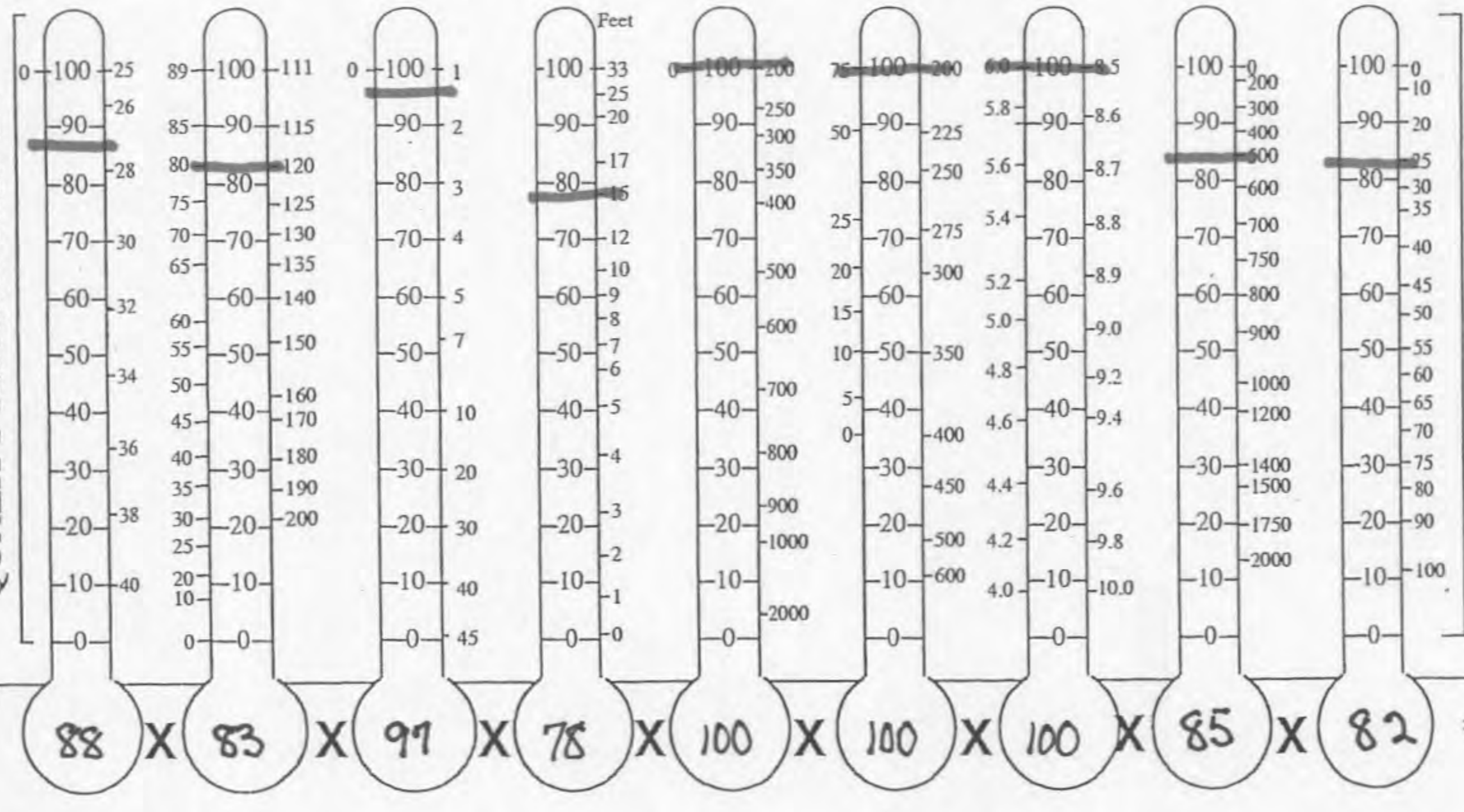
CALCULATION SHEET FOR THE UNWEIGHTED MULTIPLICATIVE LAKE WATER QUALITY INDEX

W. Fusilier, Ph.D.

QUALITY RATING CURVES

(Individual Quality Ratings never exceed 100)

Parameter	Value	Quality Rating
Temperature in degrees C	27°	88
Dissolved Oxygen, % Saturation	9.6/8.0 120	83
Chlorophyll a ug/L	1.3	97
Secchi Disk Depth in feet	15'	78
Nitrate-N ug/L	31	100
Alkalinity mg/L	118	100
pH S. U.	8.3	100
Specific Conductivity umhos/cm@ 25C	513	85
Total Phosphorus ug/L	26	82



$\sqrt[9]{88 \times 83 \times 97 \times 78 \times 100 \times 100 \times 100 \times 85 \times 82} = 90$

LWQI: 90

12.1 Watershed to lake ratio

2.6 years Flushing rate

Huron Drainage Basin

223 Drainage Area

284 Lake Volume

Livingston County

Hamburg Township

WQI Analyst

34' Lake Depth

17 Lake Area

SET THE PARAMETER QUALITY RATING AT 1 IF THE EXTERNAL EXTREME VALUE RANGE IS EXCEEDED

LAKE WATER QUALITY INDEX

0–15	15–25	25–35	35–45	45–55	55–65	65–75	75–85	85–100
Red	Red Orange	Orange	Orange Yellow	Yellow	Yellow green	Green	Blue Green	Blue

DATE 2 August 2010

STATION AVE1-3

LAKE Tamarack