PINE LAKE

WEST BLOOMFIELD TOWNSHIP

OAKLAND COUNTY

1992-2010 WATER QUALITY STUDIES

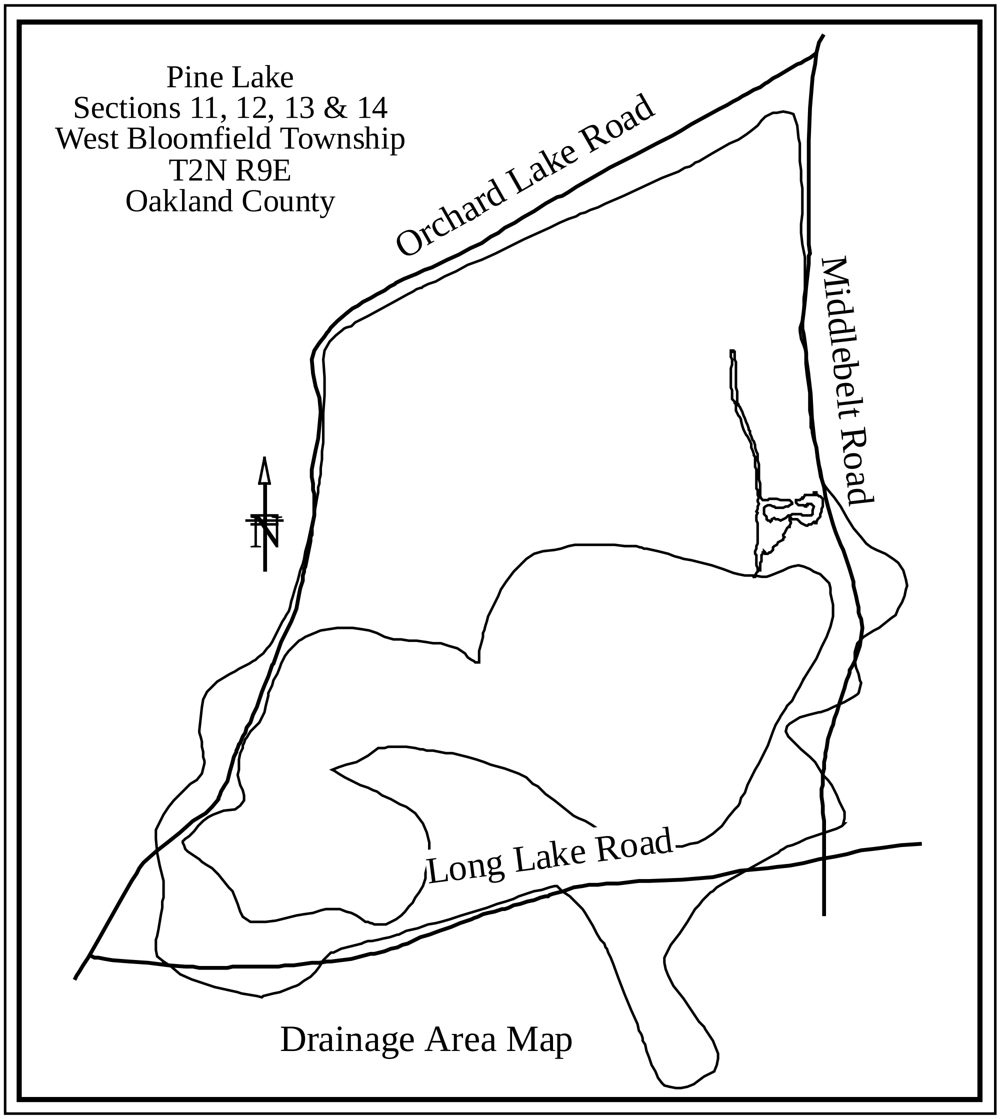
PINE LAKE DATA

Pine Lake is a 370-acre natural moderately hard water kettle lake located in Sections 11, 12, 13 & 14, West Bloomfield Township (T2N R9E), Oakland County, Michigan. The lake has a maximum depth of 95 feet, a water volume of 8163 acre-feet, and a mean depth of 22.1 feet. It has 23018 feet of shoreline. The elevation of the lake is 930 feet above sea level. There are no islands in the lake.

Although the lake bottom is quite irregular with 94 percent of the lake being 50 feet deep or less, there are two basins deeper than 50 feet. The deepest basin (95 feet) is located in the narrowest central part of the lake off the Pine Lake Country Club point. A 70-feet-deep basin is located directly west of the 95-foot basin near the west end of the lake.

The size of the watershed, which is the land area that contributes water to the lake, but does not include the lake, is 806 acres. The drainage area, which includes the lake and the watershed, is 1176 acres (See map below.) The watershed to lake ratio is 2.17 to 1, which is small for a Michigan inland lake. Because of this small ratio, the lake flushes relatively slowly, about once every 8.4 years, on an average. This long flushing rate has a significant impact on activities around the lake because the lake flushes only about 12 percent of the pollutants that get into it each year. It's a great method of concentrating pollutants, which is not what residents want.

There is a single inlet (canal) which enters the lake on the northeast corner. The outlet is on the southwest end. Water from Pine Lake flows into



Orchard Lake then into the Clinton River. The Clinton River flows into Lake St. Clair below Mt. Clemens, Michigan.

The longitude and latitude of the 95-foot deep hole is 83° 20.482W and 42° 34.474N.

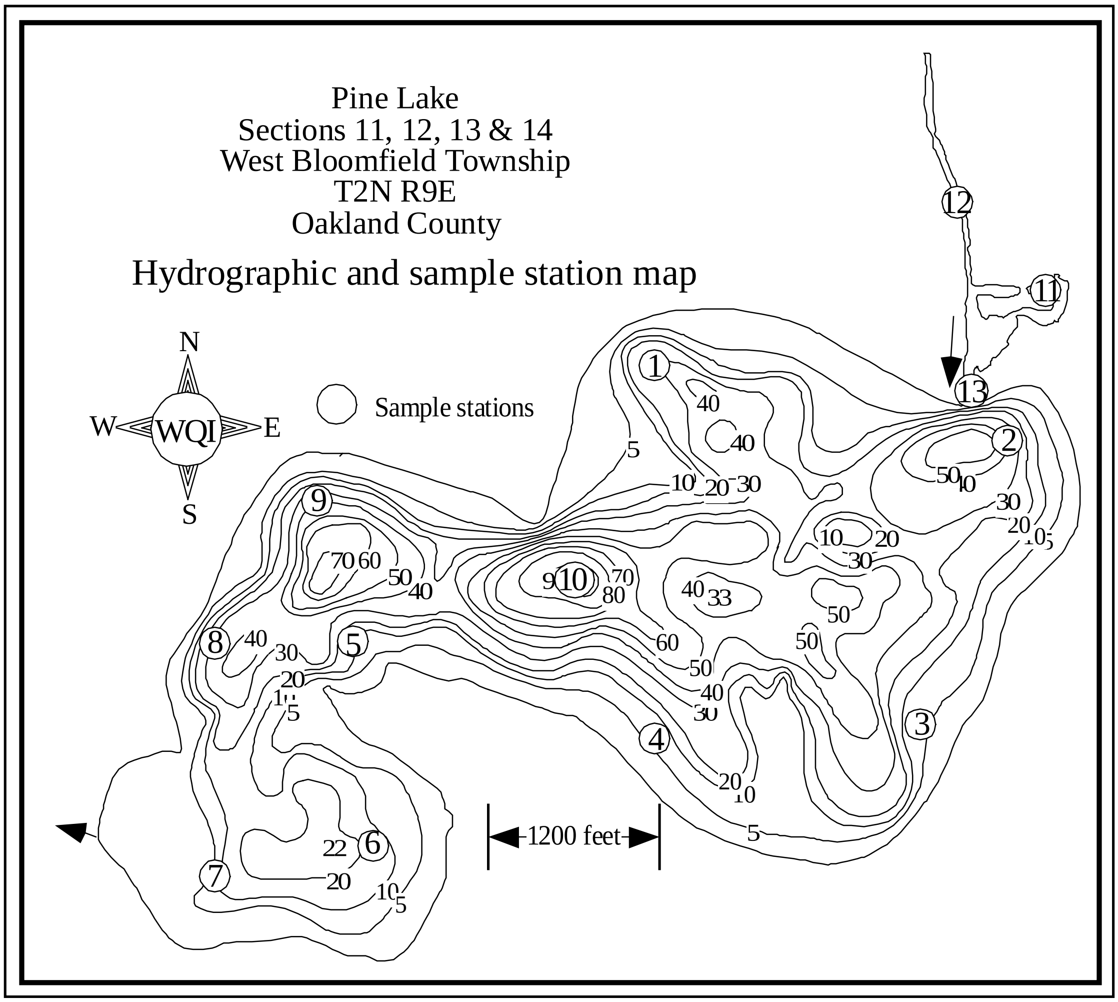
THE SAMPLE DATES

The data in this report covers spring 1992 through late summer 2010 samples.

Bottom sediment samples were collected in August 1990 and again in April 2002.

Top to bottom dissolved oxygen and temperature profiles were collected each time the lake was sampled in both spring and summer. In addition, late summer temperature and dissolved oxygen graphs are included from 1947 (DNR), 1953 (DNR) and 1977 (SEMCOG).

THE SAMPLE STATIONS



The locations of the ten in-lake sample stations are shown as circles on the map of the lake. The lagoon and canal on the northeast end were also sampled at three sites since 1996. Ten surface samples plus top to bottom samples every ten feet for water quality testing were collected from Pine Lake in the 95-foot deep hole every year since 1989 in both spring and summer by WQI limnologists.

THE ANALYSES

The tests performed on the samples included total phosphorus, total nitrate nitrogen, total alkalinity, pH, conductivity, chlorophyll a, Secchi disk depth, 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 TEST RESULTS

The results of the tests are found in the text and on the enclosed atlas pages.

TEMPERATURE AND DISSOLVED OXYGEN

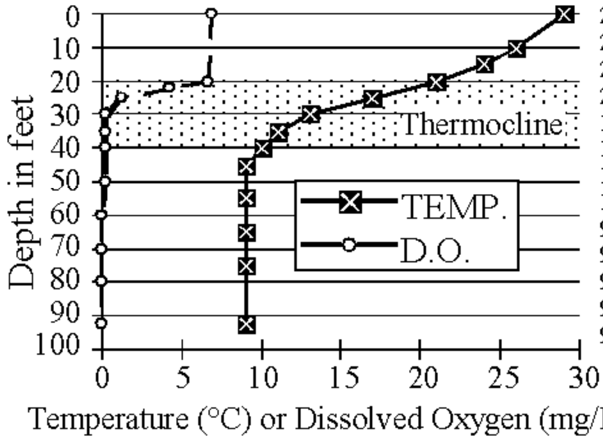
Temperature exerts a wide variety of influences on most lakes, such as the separation of layers of water (stratification), solubility of gasses and biological activity.

Dissolved oxygen is the test most often selected by lake scientists as being important. Besides providing oxygen for aquatic organisms, in natural lakes oxygen is involved the capture and release of various chemicals, such as iron and phosphorus. Dissolved oxygen and temperature profile data were collected every time the lake was sampled in both spring and late summer.

LATE SUMMER 1947

In late summer 1947 the Michigan Department of Natural Resources collected top to bottom temperature and dissolved oxygen data. Their data shows the lake formed a 20-foot-thick thermocline (defined as a layer of water in a lake where the temperature changes more than one degree Centigrade per meter of depth, and shown shaded on the graphs) from the 20 to 40 feet. Dissolved oxygen was plentiful above 20 feet. The lake ran out of dissolved oxygen at 60 feet and that condition remained to the bottom. The hypsographic (depth-area) graph shows about 4 percent of the lake is deeper than 60 feet.

Pine Lake, Oakland County August 19, 1947 DNR
Temperature and Dissolved Oxygen Profiles

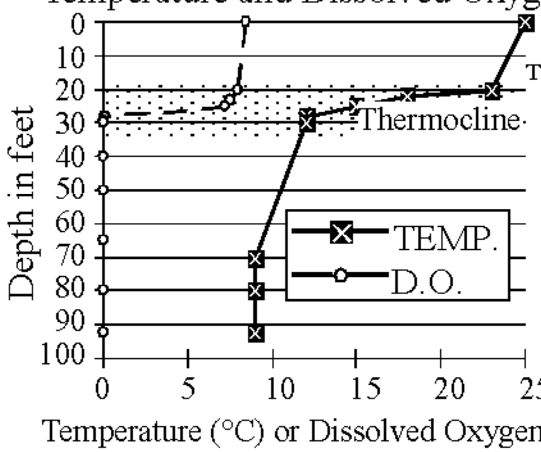


Temp.	Depth	D.O.	Depth
29	0	6.9	0
26	10	6.6	20
24	15	4.3	22
21	20	1.2	25
17	25	0.3	30
13	30	0.3	35
11	35	0.3	40
10	40	0.2	50
9	45	0.0	60
9	55	0.0	70
9	65	0.0	80
9	75	0.0	92
9	92		

1953

In late summer 1953 the MDNR again collected temperature and dissolved oxygen profiles in the deep hole. This year the lake formed a 12-foot thick thermocline from 20 to 32 feet. Dissolved oxygen was again plentiful above the thermocline. Dissolved oxygen was zero at 29 feet, and that condition remained to the bottom. About 32 percent of the lake is deeper than 29 feet.

Pine Lake, Oakland County August 14, 1953
Temperature and Dissolved Oxygen Profiles DNR

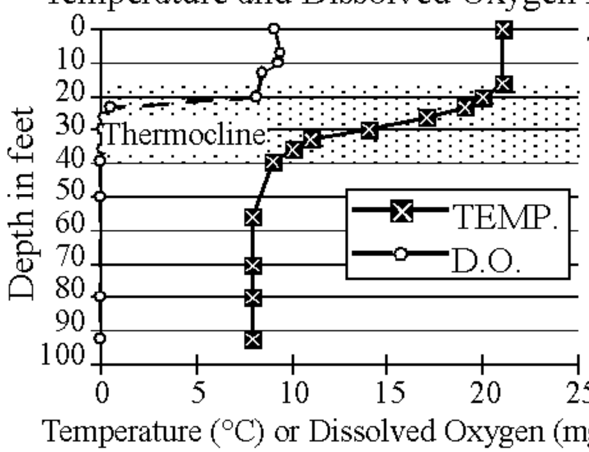


Temp.	Depth	D.O.	Depth
25	0	8.5	0
23	20	8.0	20
18	22	7.5	23
15	25	7.2	25
12	28	0.1	28
12	30	0.0	29
9	70	0.0	30
9	80	0.0	40
9	92	0.0	50
		0.0	65
		0.0	80
		0.0	92

LATE SUMMER 1977

The Southeast Michigan Council of Governments collected late summer temperature and dissolved oxygen profile

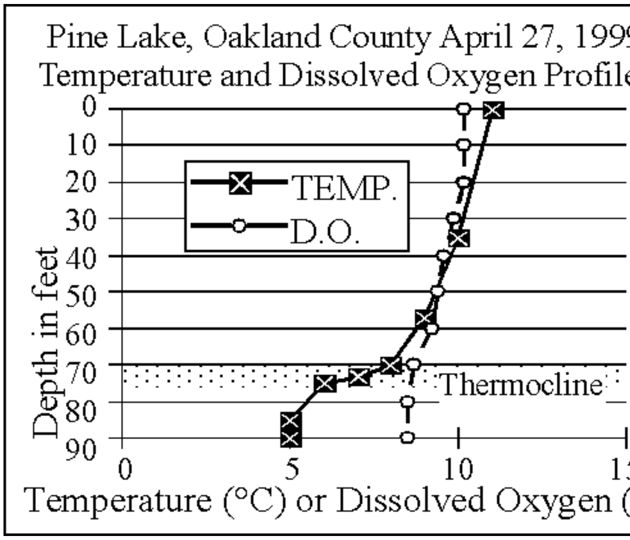
Pine Lake, Oakland County August 26, 1977
Temperature and Dissolved Oxygen Profiles SEMCOG



Temp.	Depth	D.O.	Depth
21	0	9.1	0
21	16	9.4	7
20	20	9.3	10
19	23	8.5	13
17	26	8.2	20
14	30	0.5	23
11	33	0.2	26
10	36	0.1	30
9	39	0.1	36
8	56	0.0	39
8	70	0.0	50
8	80	0.0	80
8	92	0.0	90

data on 78 southeast Michigan inland lakes. Pine Lake was one of those lakes.

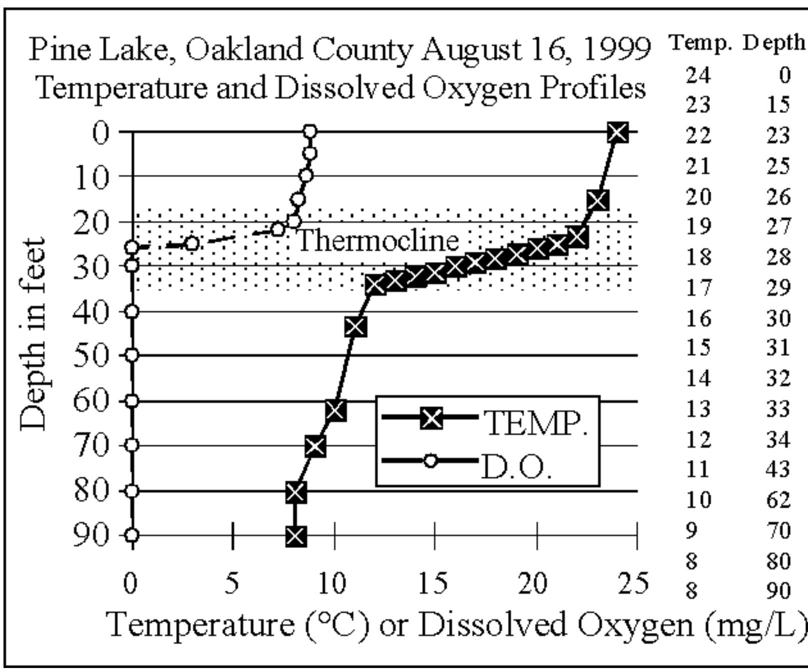
Their data shows in late summer 1977 Pine Lake formed a 19-foot thick thermocline from 20 to 39 feet. Dissolved oxygen was plentiful above the thermocline. The lake ran out of dissolved oxygen at 39 feet, and that condition remained to the bottom. About 20 percent of the lake is deeper than 39 feet.



Temp.	Depth	D.O.	Depth
11	0	10.2	0
10	35	10.2	10
9	57	10.2	20
8	70	9.9	30
7	73	9.6	40
6	75	9.4	50
5	85	9.2	60
5	90	8.7	70
		8.5	80
		8.5	90

1999

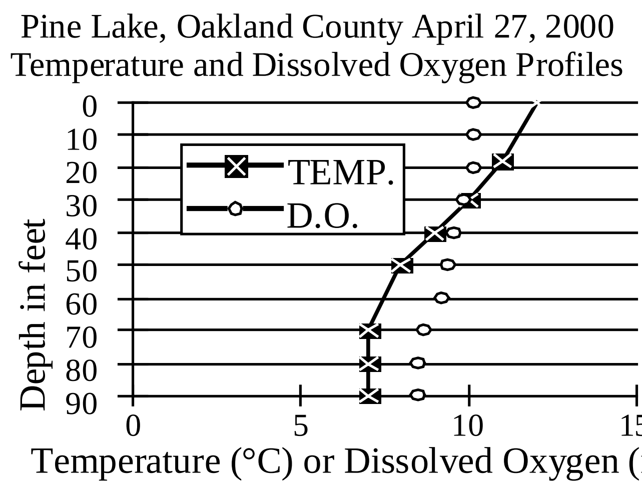
In spring 1999, the lake was mixed top to bottom. A very unusual thermo-cline formed from 70 to 76 feet. Dissolved oxygen was essentially uniform top to bottom at this time.



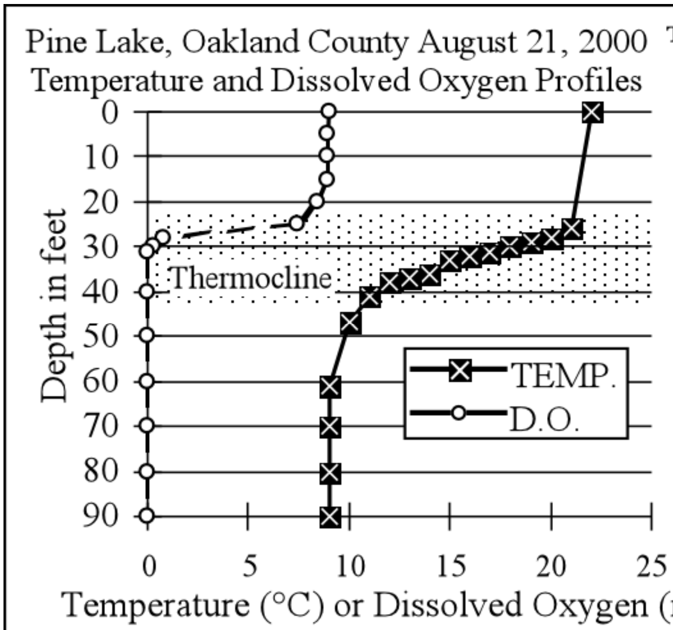
Temp.	Depth	D.O.	Depth
24	0	8.8	0
23	15	8.8	5
22	23	8.6	10
21	25	8.2	15
20	26	8.0	20
19	27	7.2	22
18	28	3.0	25
17	29	0.0	26
16	30	0.0	30
15	31	0.0	40
14	32	0.0	50
13	33	0.0	60
12	34	0.0	70
11	43	0.0	80
10	62	0.0	90
9	70		
8	80		
8	90		

In late summer 1999, the lake formed a 14-foot-thick thermocline from 20 to 34 feet. Dissolved oxygen was plentiful above the thermocline. The lake ran out of dissolved oxygen at 26 feet and that condition remained to the bottom. The hypsographic graph shows about 38 percent of the lake is deeper than 26 feet.

2000



Temp.	Depth	D.O.	Depth
12	0	10.2	0
11	18	10.2	10
10	30	10.2	20
9	40	9.9	30
8	50	9.6	40
7	70	9.4	50
7	80	9.2	60
7	90	8.7	70
		8.5	80
		8.5	90



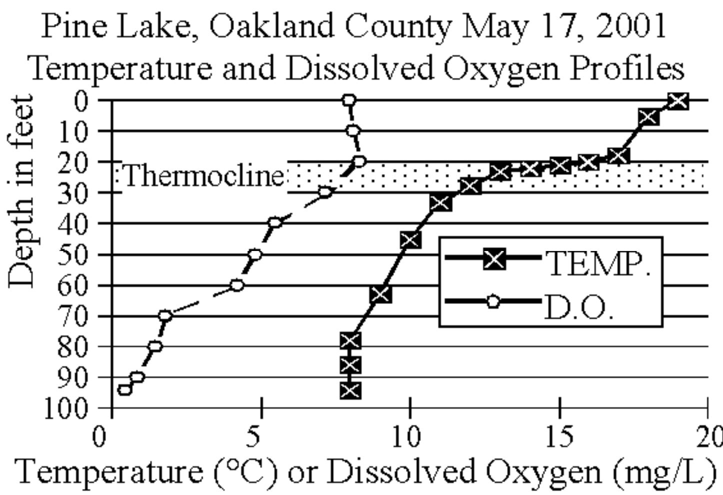
Temp.	Depth	D.O.	Depth
22	0	9.0	0
21	26	8.9	5
20	28	8.9	10
19	29	8.9	15
18	30	8.4	20
17	31	7.4	25
16	32	0.8	28
15	33	0.3	30
14	36	0.0	31
13	37	0.0	40
12	38	0.0	50
11	41	0.0	60
10	47	0.0	70
9	61	0.0	80
9	70	0.0	90
9	80		
9	90		

In spring 2000 the lake was again mixed. Temperature was relatively uniform top to bottom and dissolved oxygen was distributed throughout the water column.

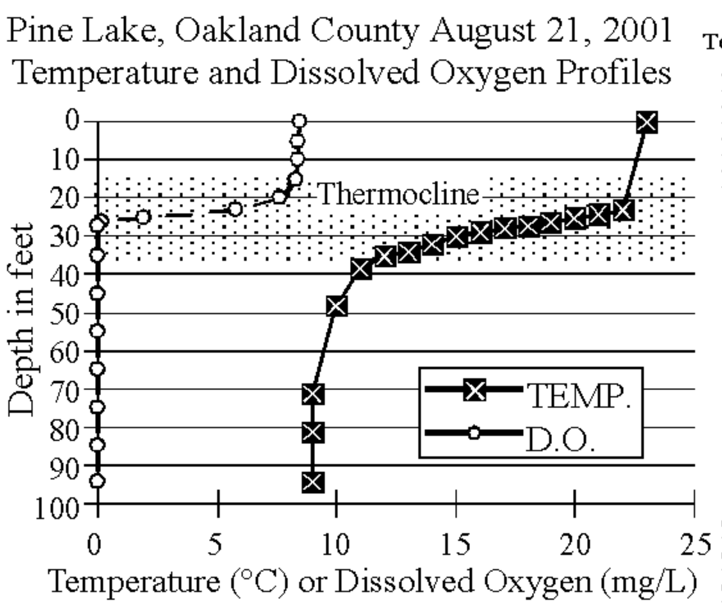
In summer 2000, Pine Lake formed a 21-foot-thick thermocline from 20 to 41 feet. Dissolved oxygen was plentiful above the thermocline. The lake ran out of dissolved oxygen at 31 feet and that condition remained to the bottom. About 30 percent of the lake is deeper than 31 feet.

2001

In spring 2001 (May 17), a ten-foot thick thermocline formed from 20 to 30 feet when the lake was sampled. Above the thermocline, dissolved oxygen concentrations were normal. At the top of the thermocline dissolved oxygen started to drop. At the bottom of the lake at 94 feet the concentration of dissolved oxygen was only 0.5 mg/L. The graph shows the data.



Temp.	Depth	D.O.	Depth
19	0	8.0	0
18	5	8.1	10
17	18	8.3	20
16	20	7.2	30
15	21	5.5	40
14	22	4.8	50
13	23	4.2	60
12	28	1.8	70
11	33	1.5	80
10	45	0.9	90
9	63	0.5	94
8	78		
8	86		
8	94		

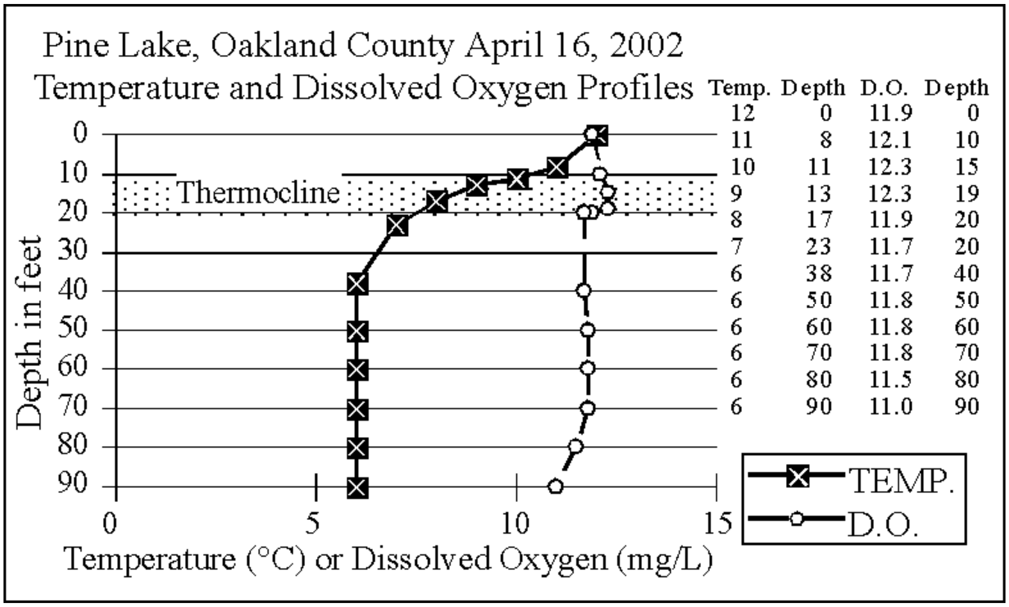


Temp.	Depth	D.O.	Depth
23	0	8.5	0
22	23	8.4	5
21	24	8.4	10
20	25	8.3	15
19	26	7.6	20
18	27	5.8	23
17	28	1.9	25
16	29	0.2	26
15	30	0.0	27
14	32	0.0	35
13	34	0.0	45
12	35	0.0	55
11	38	0.0	65
10	48	0.0	75
9	71	0.0	85
9	81	0.0	94
9	94		

In late summer 2001, Pine Lake formed a 23-foot thick thermocline from 15 to 38 feet. Dissolved oxygen was plentiful above the thermocline. It started to drop at the top of the thermocline, and was zero at 27 feet. That condition remained to the bottom.

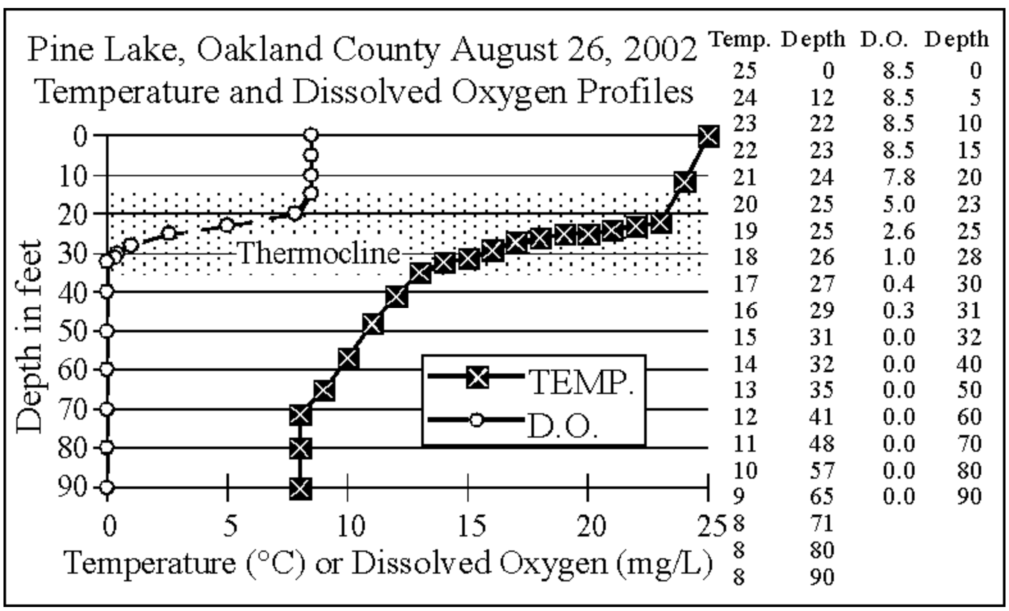
2002

In spring 2002 the lake had already started to stratify. A five-foot thick thermocline was present from 8 to 13 feet. A small algal bloom was present below the thermocline as evidenced by the dissolved oxygen peak at 20 feet.



Temp.	Depth	D.O.	Depth
12	0	11.9	0
11	8	12.1	10
10	11	12.3	15
9	13	12.3	19
8	17	11.9	20
7	23	11.7	20
6	38	11.7	40
6	50	11.8	50
6	60	11.8	60
6	70	11.8	70
6	80	11.5	80
6	90	11.0	90

Other than that, dissolved oxygen was essentially uniform top to bottom, indicating the lake mixed in spring.



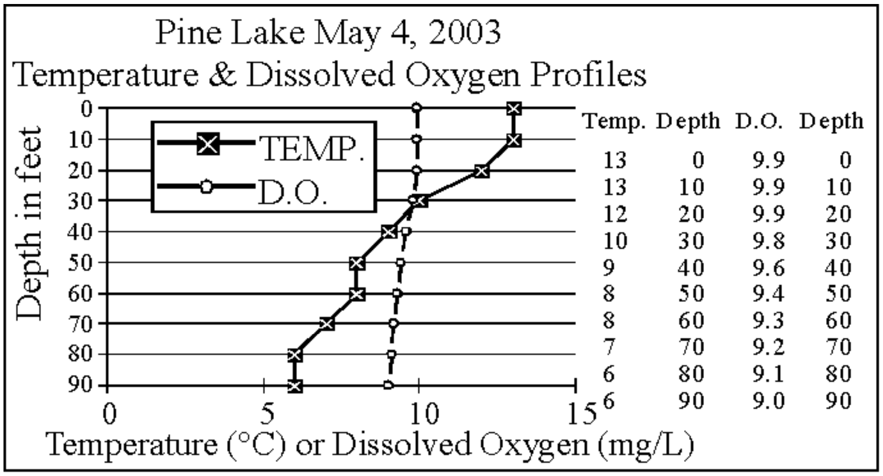
Temp.	Depth	D.O.	Depth
25	0	8.5	0
24	12	8.5	5
23	22	8.5	10
22	23	8.5	15
21	24	7.8	20
20	25	5.0	23
19	25	2.6	25
18	26	1.0	28
17	27	0.4	30
16	29	0.3	31
15	31	0.0	32
14	32	0.0	40
13	35	0.0	50
12	41	0.0	60
11	48	0.0	70
10	57	0.0	80
9	65	0.0	90
8	71		
8	80		
8	90		

In late summer 2002 the lake formed a 20-foot-thick thermocline from 15 to 35 feet. The lake ran out of dissolved oxygen at 32 feet, and that condition remained to the bottom.

2003

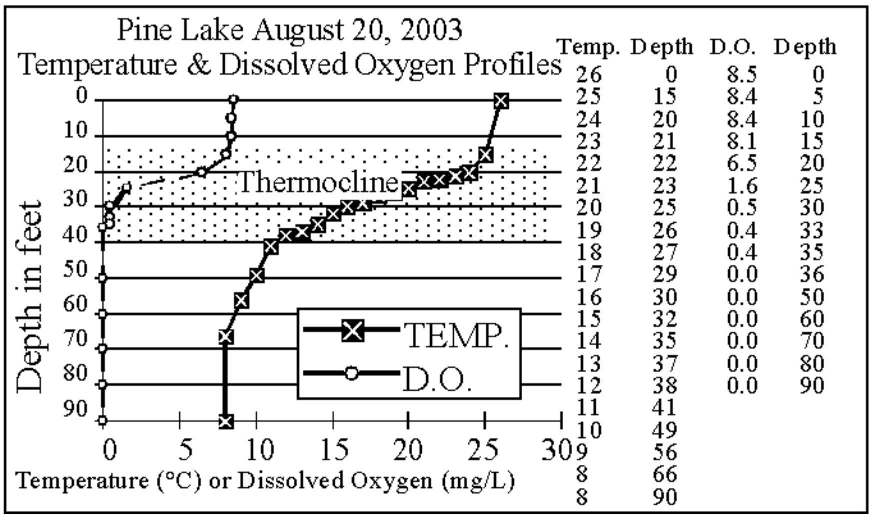
In spring 2003 temperature ranged from 13 degrees C at the surface to 6 degrees C at the bottom, but a thermocline had not started to form. Dissolved oxygen was uniform top to bottom.

In late summer 2003 the lake formed a 26-foot thick thermocline from 15 to 41 feet. Above the thermocline, dissolved oxygen was normal and plentiful.



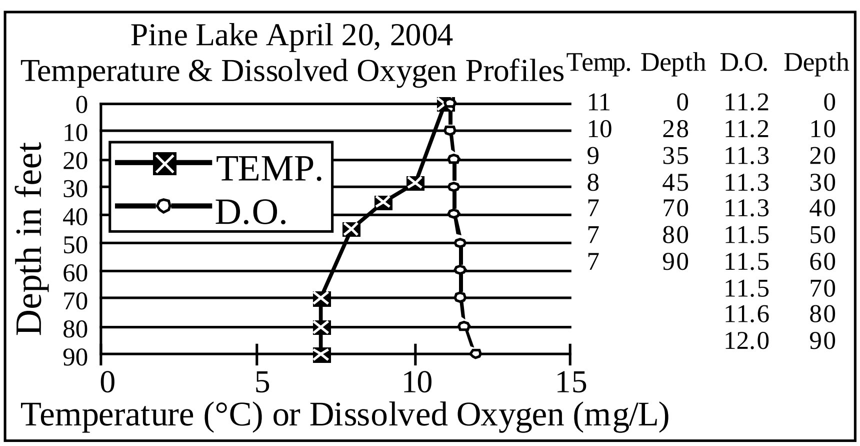
Temp.	Depth	D.O.	Depth
13	0	9.9	0
13	10	9.9	10
12	20	9.9	20
10	30	9.8	30
9	40	9.6	40
8	50	9.4	50
8	60	9.3	60
7	70	9.2	70
6	80	9.1	80
6	90	9.0	90

The lake ran out of dissolved oxygen at 36 feet, and that condition remained to the bottom. About 28 percent of the lake is deeper than 36 feet.



Temp.	Depth	D.O.	Depth
26	0	8.5	0
25	15	8.4	5
24	20	8.4	10
23	21	8.1	15
22	22	6.5	20
21	23	1.6	25
20	25	0.5	30
19	26	0.4	33
18	27	0.4	35
17	29	0.0	36
16	30	0.0	50
15	32	0.0	60
14	35	0.0	70
13	37	0.0	80
12	38	0.0	90
11	41		
10	49		
9	56		
8	66		
8	90		

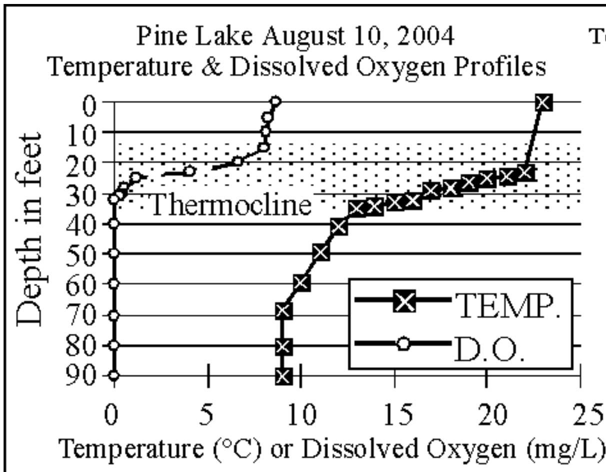
2004



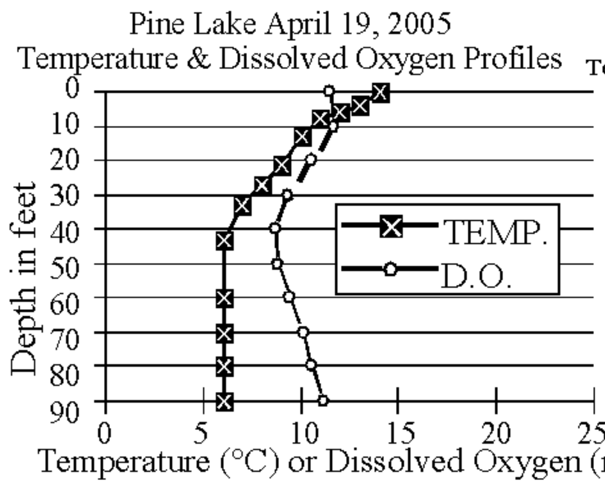
Temp.	Depth	D.O.	Depth
11	0	11.2	0
10	28	11.2	10
9	35	11.3	20
8	45	11.3	30
7	70	11.3	40
7	80	11.5	50
7	90	11.5	60
		11.5	70
		11.6	80
		12.0	90

In spring 2004 temperature ranged from 11 degrees C at the surface to 7 degrees C at the bottom. Dissolved oxygen was fairly uniform top to bottom and was actually higher at the bottom of the lake than at the surface.

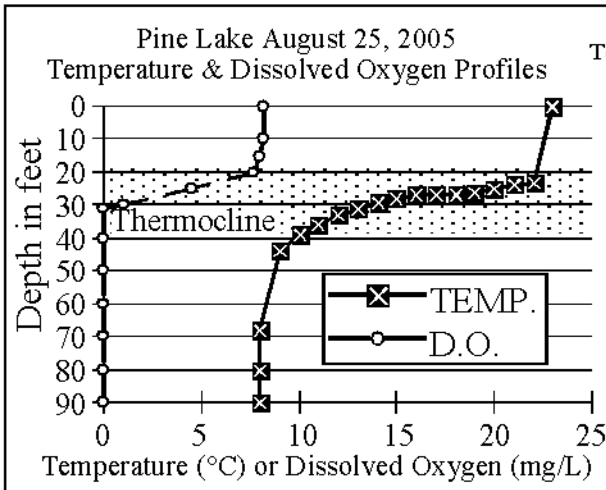
In late summer 2004 the lake formed a 20-foot thick thermocline from 15 to 35 feet. Above the thermocline, dissolved oxygen was normal and plentiful. The lake ran out of dissolved oxygen at 32 feet, and that condition remained to the bottom. About 28 percent of the lake is deeper than 32 feet.



Temp.	Depth	D.O.	Depth
23	0	8.7	0
22	23	8.3	5
21	24	8.2	10
20	25	8.0	15
19	26	6.6	20
18	28	4.1	23
17	29	1.2	25
16	32	0.5	28
15	33	0.4	30
14	34	0.3	31
13	35	0.0	32
12	41	0.0	40
11	49	0.0	50
10	59	0.0	60
9	68	0.0	70
9	80	0.0	80
9	90	0.0	90



Temp.	Depth	D.O.	Depth
14	0	11.5	0
13	4	11.7	10
12	6	10.6	20
11	8	9.3	30
10	13	8.7	40
9	21	8.8	50
8	27	9.4	60
7	33	10.1	70
6	43	10.6	80
6	60	11.2	90
6	70		
6	80		
6	90		



Temp.	Depth	D.O.	Depth
23	0	8.2	0
22	23	8.2	10
21	24	8.0	15
20	25	7.7	20
19	26	4.5	25
17	27	1.0	30
15	28	0.0	31
14	29	0.0	40
13	31	0.0	50
12	33	0.0	60
11	36	0.0	70
10	39	0.0	80
9	44	0.0	90
8	68		
8	80		
8	90		

2005

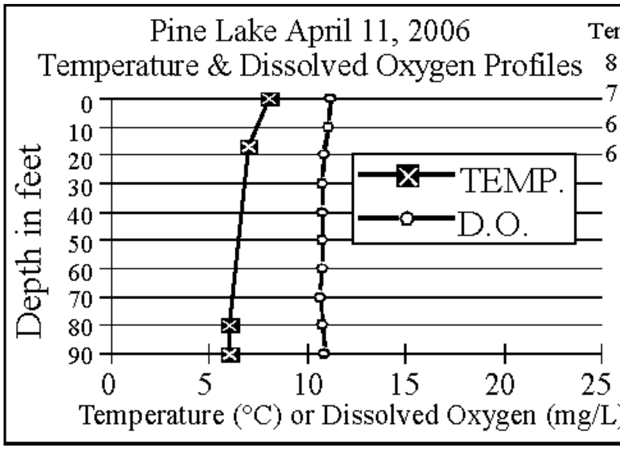
In spring 2005 temperature ranged from 14 degrees C at the surface to 6 degrees C at the bottom, but a thermocline started to form from 4 to 8 feet. Dissolved oxygen was fairly uniform top to bottom and was again higher at the bottom of the lake than in the mid-depth water.

In late summer 2005 the lake formed a 19-foot thick thermocline from 20 to 39 feet. Above the thermocline, dissolved oxygen was normal and plentiful. The lake ran out of dissolved oxygen at 31 feet, and that condition remained to the bottom. About 29 percent of the lake is deeper than 31 feet.

2006

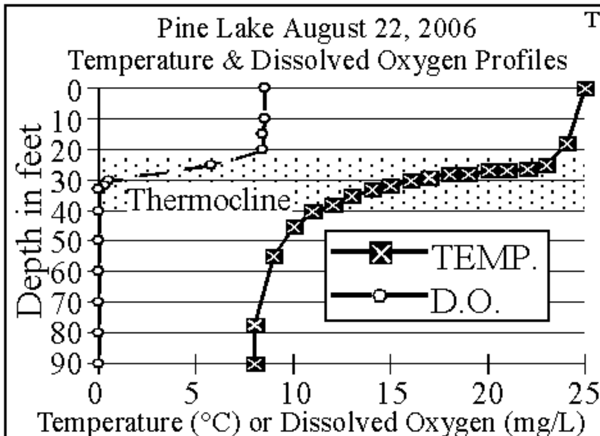
In spring 2006 temperature ranged from 8 degrees C at the surface to 6 degrees C at the bottom. Dissolved oxygen was uniform top to bottom.

These data indicate the lake was mixing when it was sampled.



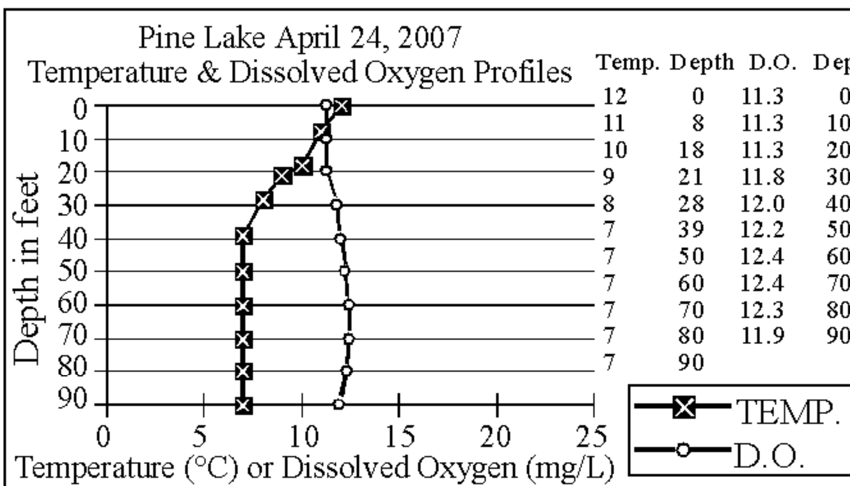
Temp.	Depth	D.O.	Depth
8	0	11.2	0
7	17	11.1	10
6	80	10.9	20
6	90	10.8	30
		10.8	40
		10.8	50
		10.8	60
		10.7	70
		10.8	80
		10.9	90

In late summer 2006, the lake formed a 20-foot thick thermocline from 20 to 40 feet. The lake had plenty of dissolved oxygen above the thermocline. The dissolved oxygen concentration started to decrease at the top of the thermocline and was zero at 33 feet. That condition remained to the bottom.



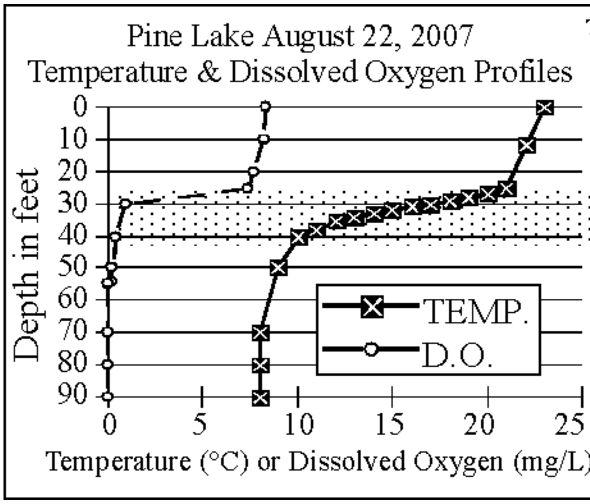
Temp.	Depth	D.O.	Depth
25	0	8.5	0
24	18	8.5	10
23	25	8.4	15
22	26	8.4	20
21	27	5.8	25
19	28	0.5	30
17	29	0.3	32
16	30	0.0	33
15	32	0.0	40
14	33	0.0	50
13	35	0.0	60
12	38	0.0	70
11	40	0.0	80
10	45	0.0	90
9	55		
8	77		
8	90		

2007



Temp.	Depth	D.O.	Depth
12	0	11.3	0
11	8	11.3	10
10	18	11.3	20
9	21	11.8	30
8	28	12.0	40
7	39	12.2	50
7	50	12.4	60
7	60	12.4	70
7	70	12.3	80
7	80	11.9	90
7	90		

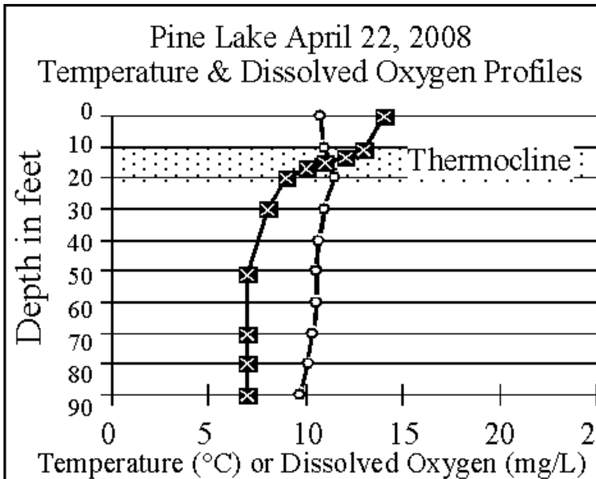
In spring 2007 temperature and dissolved oxygen were about uniform top to bottom,



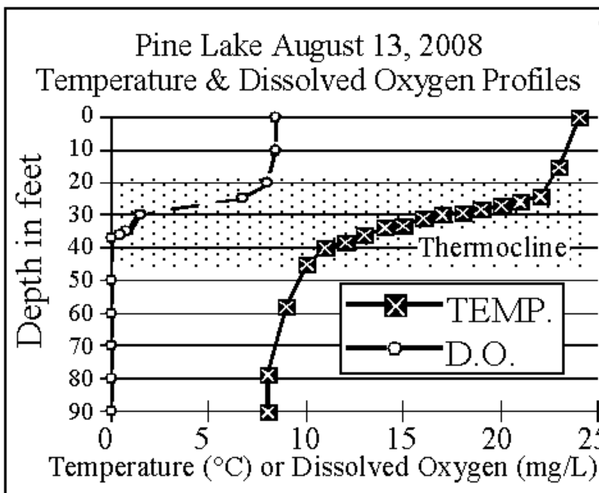
Temp.	Depth	D.O.	Depth
23	0	8.3	0
22	12	8.2	10
21	25	7.7	20
20	27	7.4	25
19	28	0.9	30
18	29	0.4	40
17	30	0.2	50
16	31	0.2	54
15	32	0.0	55
14	33	0.0	70
13	34	0.0	80
12	35	0.0	90
11	38		
10	40		
9	50		
8	70		
8	90		

indicating the lake mixed in spring.

In summer 2007 the graph shows the lake formed a 15-foot thick thermocline from 25 to 40 feet. Dissolved oxygen was adequate in the layer above the thermocline and started to decrease at 25 feet, the top of the thermocline. It was 0.9 mg/L at 30 feet and was zero at 55 feet. That condition remained to the bottom.



Temp.	Depth	D.O.	Depth
14	0	10.8	0
13	11	11.0	10
12	13	11.5	20
11	15	11.0	30
10	17	10.7	40
9	20	10.5	50
8	30	10.5	60
7	51	10.3	70
7	70	10.1	80
7	80	9.7	90
7	90		



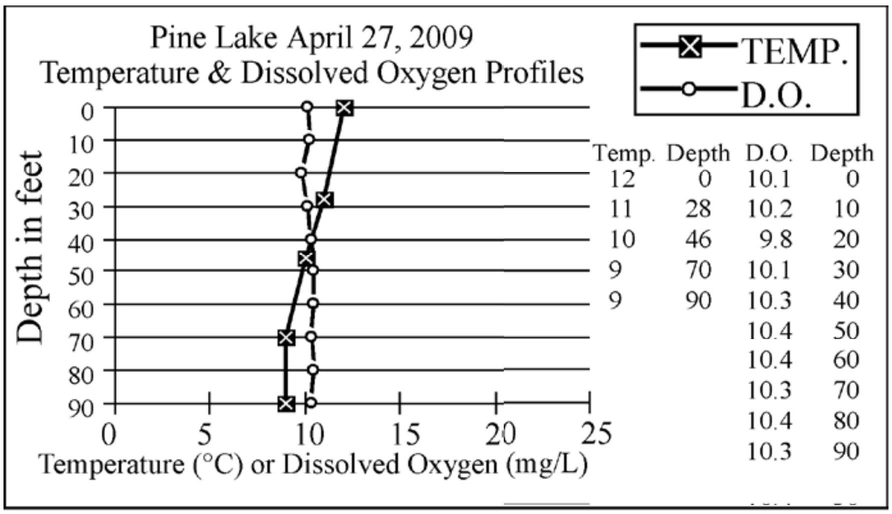
Temp.	Depth	D.O.	Depth
24	0	8.4	0
23	15	8.4	10
22	24	8.0	20
21	26	6.8	25
20	27	1.5	30
19	28	0.7	35
18	29	0.4	36
17	30	0.0	37
16	31	0.0	50
15	33	0.0	60
14	34	0.0	70
13	36	0.0	80
12	38	0.0	90
11	40		
10	45		
9	58		
8	79		
8	90		

2008

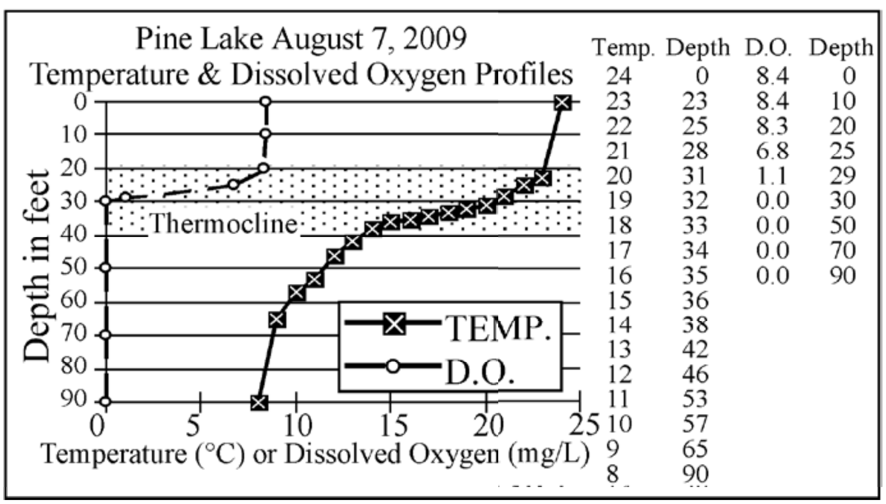
In spring 2008 the lake had a 10-foot-thick thermocline from 10 to 20 feet, indicating the lake had already started to stratify. However dissolved oxygen was essentially uniform top to bottom, indicating the stratification process had just occurred, because there was no loss of dissolved oxygen in the deeper water at that time.

In late summer 2008 the lake formed a 20-foot-thick thermocline from 20 to 40 feet. Dissolved oxygen supplies were plentiful above the thermocline, and started to decrease at 20 feet, the top of the thermocline. The concentration of dissolved oxygen was zero a 37 feet, and that condition remained to the bottom.

2009



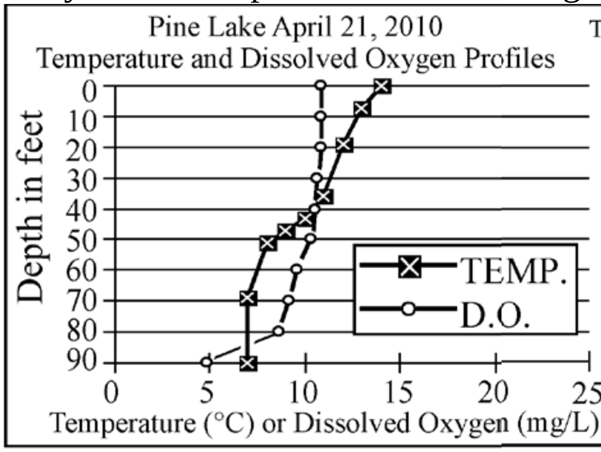
In spring 2009 both temperature and dissolved oxygen were essentially uniform top to bottom, indicating the lake was mixing when it was sampled.



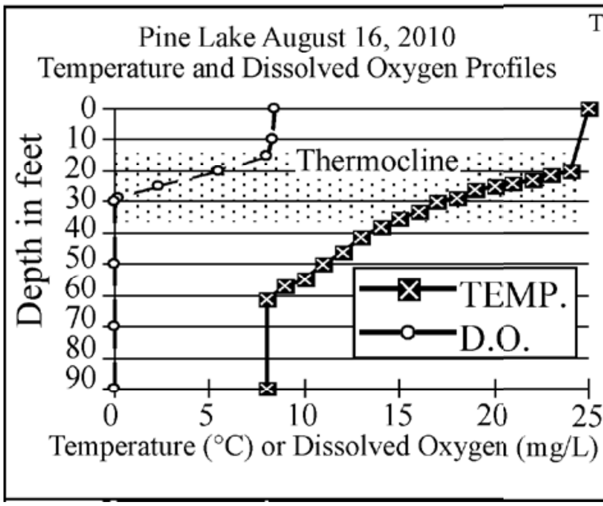
In late summer the lake formed a 20-foot-thick thermocline from 20 to 40 feet. Dissolved oxygen supplies were plentiful above 20 feet and started to decrease below that depth. The dissolved oxygen concentration was zero at 30 feet, and that condition remained to the bottom.

2010

The graph shows in spring 2010 temperature and dissolved oxygen were fairly uniform top to bottom indicating the lake mixed in spring.



Temp.	Depth	D.O.	Depth
14	0	10.9	0
13	7	10.9	10
12	19	10.9	20
11	36	10.7	30
10	43	10.5	40
9	47	10.3	50
8	51	9.6	60
7	69	9.2	70
7	90	8.7	80
		4.8	90



Temp.	Depth	D.O.	Depth
25	0	8.4	0
24	20	8.3	10
23	21	8.0	15
22	23	5.5	20
21	24	2.3	25
20	25	0.2	29
19	26	0.0	30
18	29	0.0	50
17	30	0.0	70
16	33	0.0	90
15	35		
14	38		
13	41		
12	46		
11	50		
10	55		
9	57		
8	61		
8	90		

In summer 2010 the lake formed a 26-foot thermocline from 15 to 41 feet.

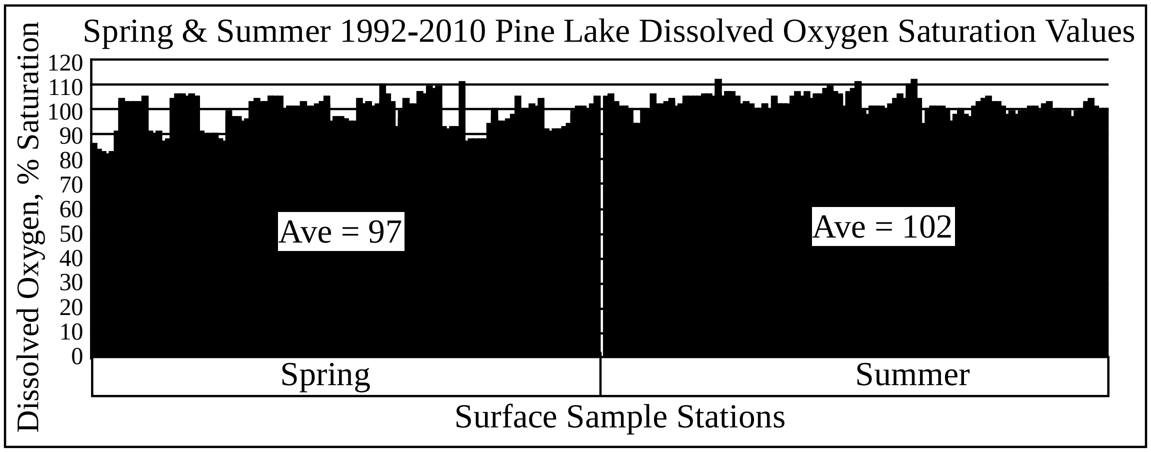
The concentration of dissolved oxygen was plentiful above the thermocline and started to decrease below 15 feet, the top of the thermocline. It was zero at 30 feet, and that condition remained to the bottom.

A NOTE ABOU THE FOLLOWING GRAPHS

The surface water quality data on the graphs below were first sorted by spring and summer, then by date, then by sample station. The purpose of this was to detect differences between the spring and summer data and to detect trends which might be occurring in Pine Lake.

DISSOLVED OXYGEN, PERCENT SATURATION

Since the amount of dissolved oxygen water can hold varies with temperature, with cold water holding more, dissolved oxygen saturation is often a better way to determine if dissolved oxygen levels are adequate, or vary from the norm (supersaturation or under-saturation).



The graph shows spring dissolved oxygen saturation values varied more than summer saturations. But in most cases, they were between 90 and 110 percent in both spring and summer, which is good.

In 2010 spring values ranged from 97 to 105 percent while summer values ranged from 93 to 104 percent.

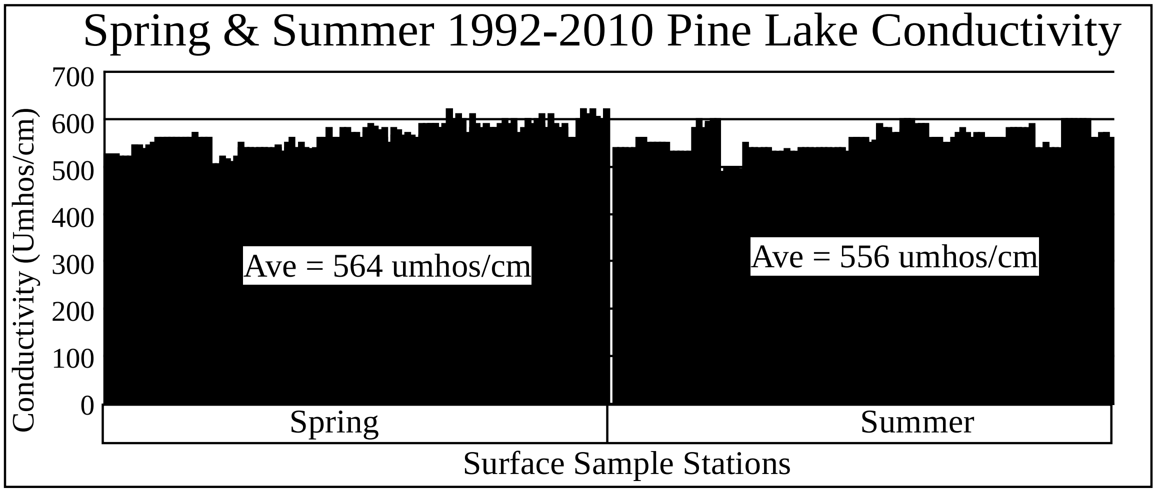
The graph of dissolved oxygen saturation does not show any trend in either spring or summer over the years.

CONDUCTIVITY

Conductivity, measured with a meter, detects the capacity of a water to conduct an electric current. More importantly however, it measures the amount of materials dissolved in the water (salts), since only dissolved materials will permit an electric current to flow. Theoretically, pure water will not conduct an electric current.

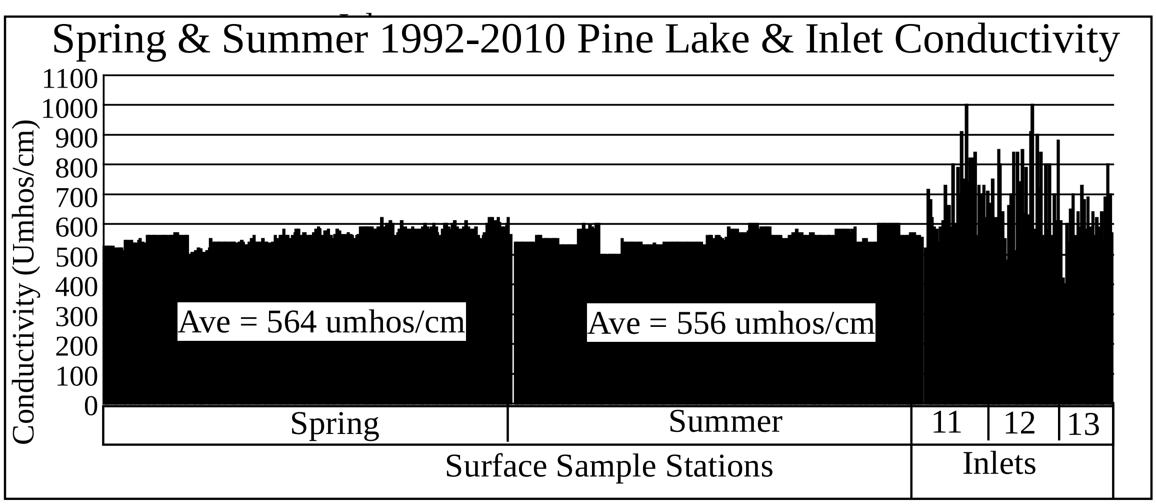
It is the perception of the experts that poor quality water has more dissolved materials than good quality water. I agree. Lower is usually better.

The graph shows the conductivity of Pine Lake is in the 500 to 600+ micromhos/centimeter range. These are higher conductivities than we normally see in a Michigan moderately hard water inland lake. The graph also seems to show the concentration of salts, although gradual, appears to be increasing in Pine Lake, especially in spring. This may be due to salts from winter road salting operations entering the lake.



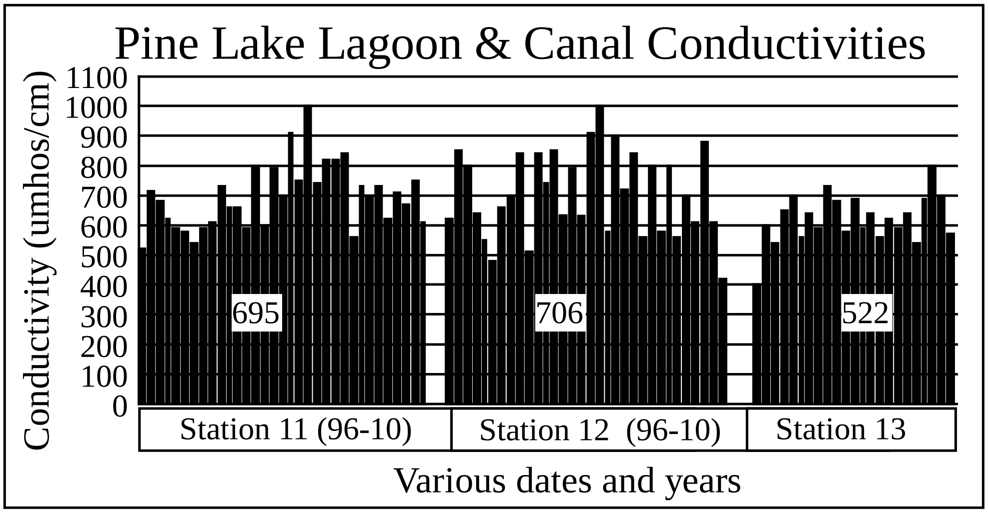
The sources of the salt in Pine Lake are probably water softeners and/or winter road salting operations. The long flushing rate is also coming into play because only 12 percent of the salts that enter the lake each year are flushed from it. That can cause the salt concentration to increase.

The graph shows the 1992-2010 conductivities of Pine Lake and the canal and lagoon samples.

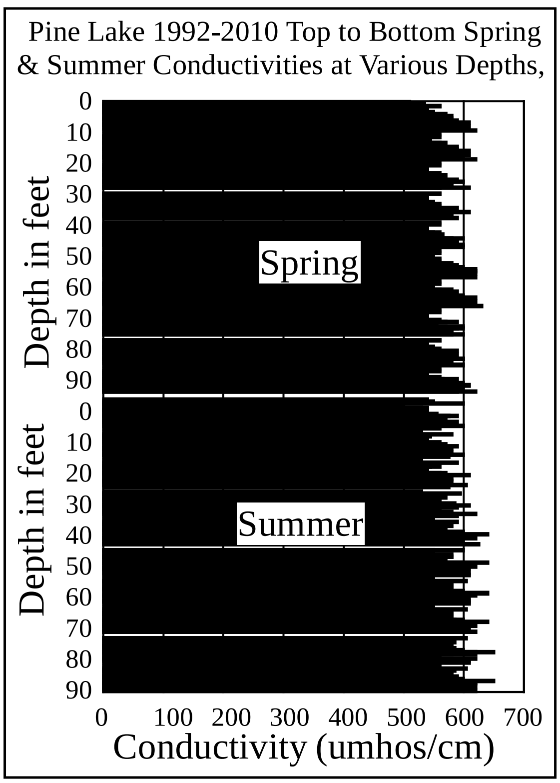


It shows the conductivities of Stations 11 and 12 are higher than the lake. Station 13 data are also higher, but since this station is often influenced by lake water, the conductivities do not vary as much as those from Stations 11 and 12.

The graph of inlet conductivities shows little difference between the data



from Stations 11 and 12. Station 13 data are lower, but that's probably because it is often lake water.

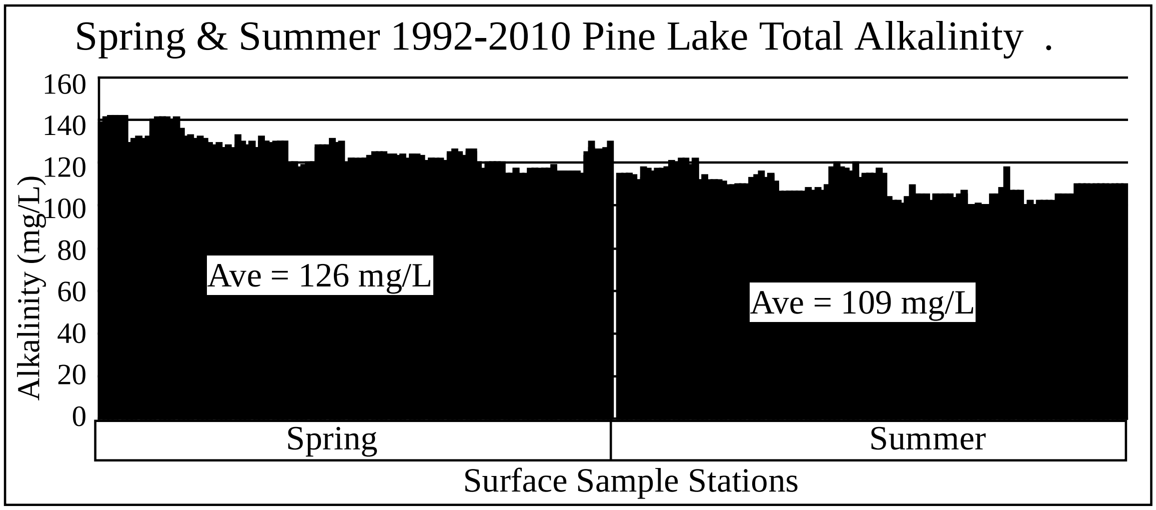


The data on the top to bottom conductivities graph is divided into two parts, with spring data in the top half, and summer data on the lower half. It is further sorted so all the conductivites for each depth are grouped together, i.e. all the conductivites at 10 feet in spring for all years are grouped, all the conductivites for all years at 20 feet in spring are grouped, and so on. The purpose of showing the data in this fashion is to see if conductivites change from top to bottom in spring and/or in summer.

The graph shows in spring, conductivites are more uniform top to bottom. This is not surprising, given the lake mixes in spring. On the other hand, the graph shows in summer when the lake is warm and stratified, conductivities increase near the bottom. This is what we normally see. It's due to increased solubility of salts with increased pressure (depth).

TOTAL ALKALINITY

Alkalinity measures carbonates and bicarbonates in water. 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.



Inlets

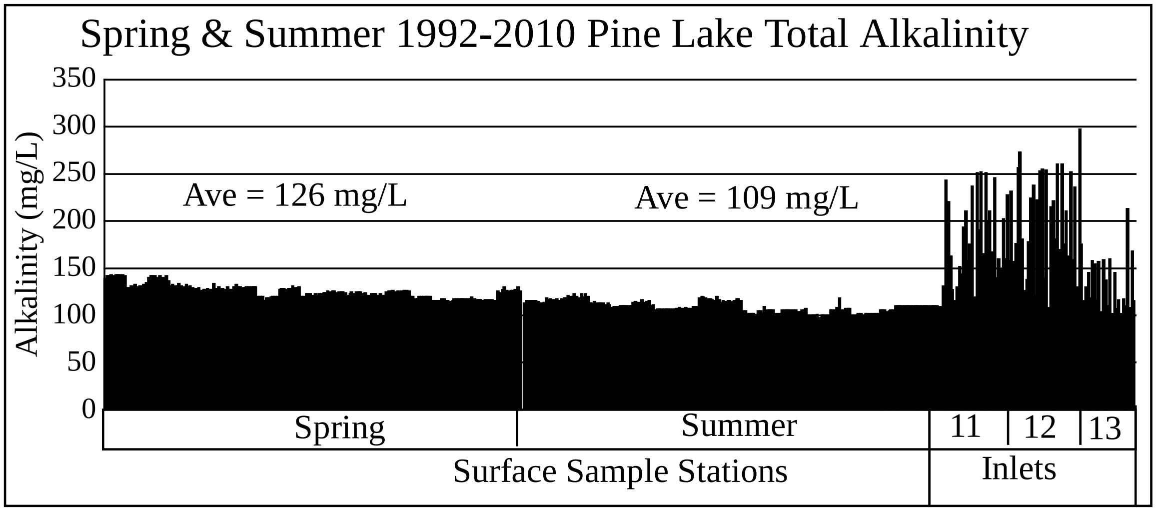
The graph of 1992-2010 Pine Lake surface alkalinity concentrations shows three things.

First, spring alkalinities are higher than summer alkalinities. That is expected given carbonates and bicarbonates (which are what the alkalinity test measures) are less soluble in warm water than in cold water, so in summer the alkalinity materials in the surface water precipitate to the bottom sediments.

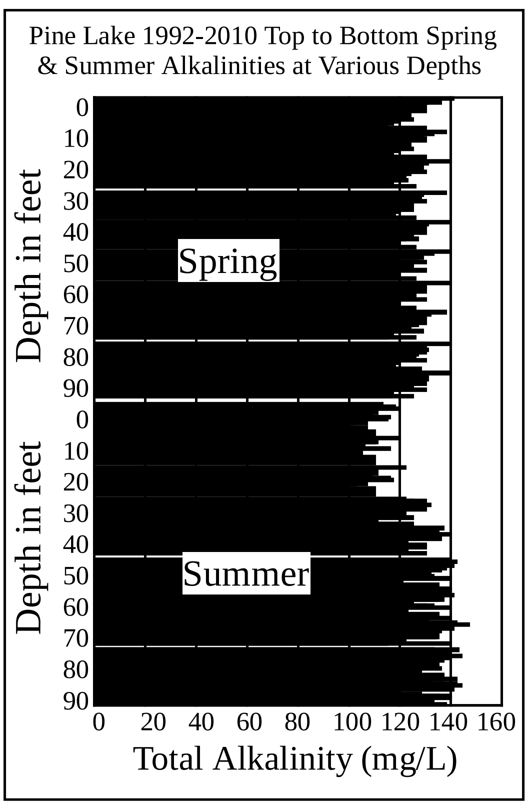
Second, the surface alkalinity in Pine Lake ranges from about 115 to 142 milligrams per liter in spring, and from 97 to 122 milligrams per liter in summer.

These data indicate Pine Lake is a moderately 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.

Third, the graph shows alkalinity concentration seems to be decreasing in both spring and summer. The cause of this is unknown. This is not the only lake we study where this is occurring, but it is one of the most dramatic.



The graph of spring, summer and inlet alkalinities shows Stations 11 and 12 alkalinities are considerably higher than the lake. This is expected, because the canal and lagoon are fed directly by groundwater, and groundwater has more carbonates and bicarbonates than lake water because those materials precipitate to the bottom sediments during the warm months in the lake. They precipitate to the bottom sediments during the warm months because they are less soluble in warm water than in cold water, which is also why the precipitate in water heaters and tea kettles.

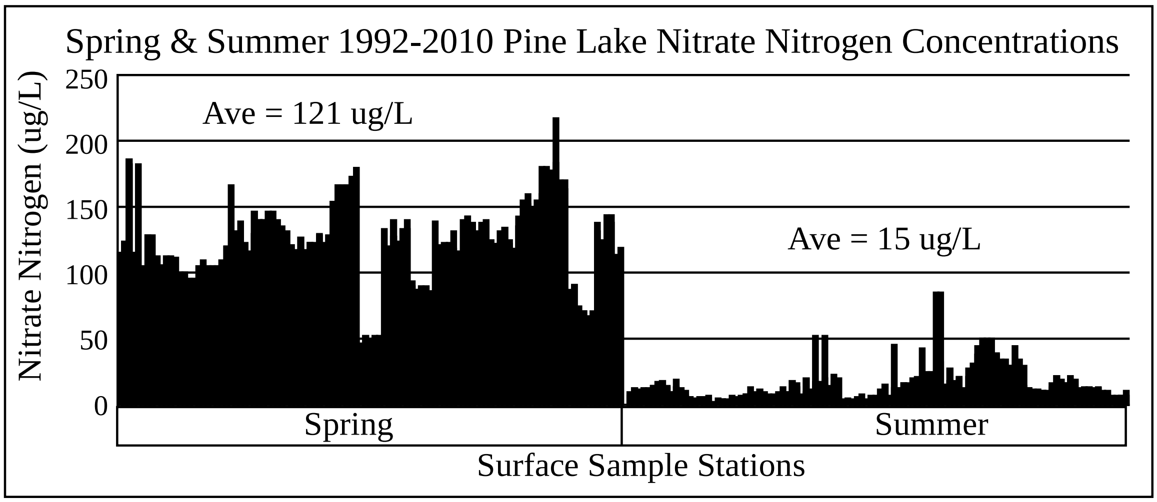


The graph of top to bottom alkalinites is constructed with the data grouped by spring and summer, then by depth, then date.

The graph shows in spring alkalinities are uniform top to bottom, again indicating the lake mixes in spring. In summer, the graph shows clearly that the alkalinities are lower in the top 20 feet and increase below the thermocline. This is because, as noted above, carbonates and bicarbonates in the warmer surface layers (above 30 feet) are settling to the bottom of the lake (which is why we find lots of these materials in the sediments). The graph pretty clearly shows the alkalinity concentrations of the deep, cold water in summer are about the same as the alkalinity of the entire water column in spring when the water is cold.

NITRATE NITROGEN

Most Michigan inland lakes have spring nitrate nitrogen concentrations around 200 micrograms per liter (or parts per billion). Summer nitrate nitrogen concentrations are generally much lower, in the 10 to 40 micrograms per liter range.

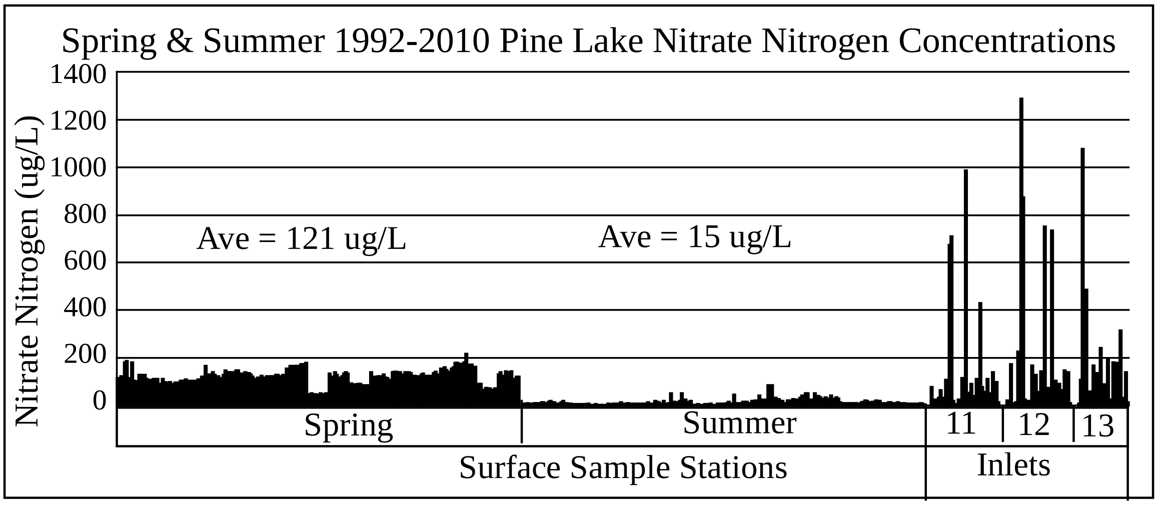


Spring nitrate nitrogen concentrations, based on the 1992-2010 data, are generally in the 100-200 microgram per liter range. The lower 2001 spring nitrate nitrogen concentrations may be related to when samples were collected, mid-May.

Summer nitrate nitrogen concentrations are much lower, generally less than 20 micrograms per liter. The nitrate nitrogen variation between spring and summer is normal for a Michigan inland lake.

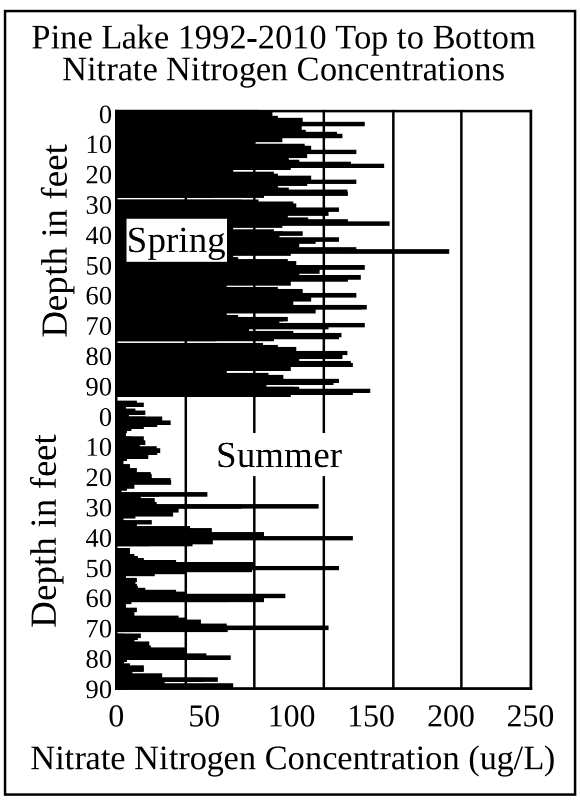
In summer the lake appears to be nitrogen limited, so any nitrogen added to the lake or areas (lawns) surrounding the lake during the year is not recommended.

Lawn fertilizers containing either nitrogen or phosphorus should not be used on lawns near (within 400 feet) of the lake or the lagoon/canal.



The graph of 1992-2010 Pine Lake surface spring, summer and lagoon/canal nitrates shows the variance in the spring and summer lake samples, and the large variation in the canal and lagoon samples. The canal and lagoon samples have some very high nitrates, the highest being over 1200 ug/L at Station 12 in the lagoon.

TOP TO BOTTOM NITRATE NITROGEN CONCENTRATIONS



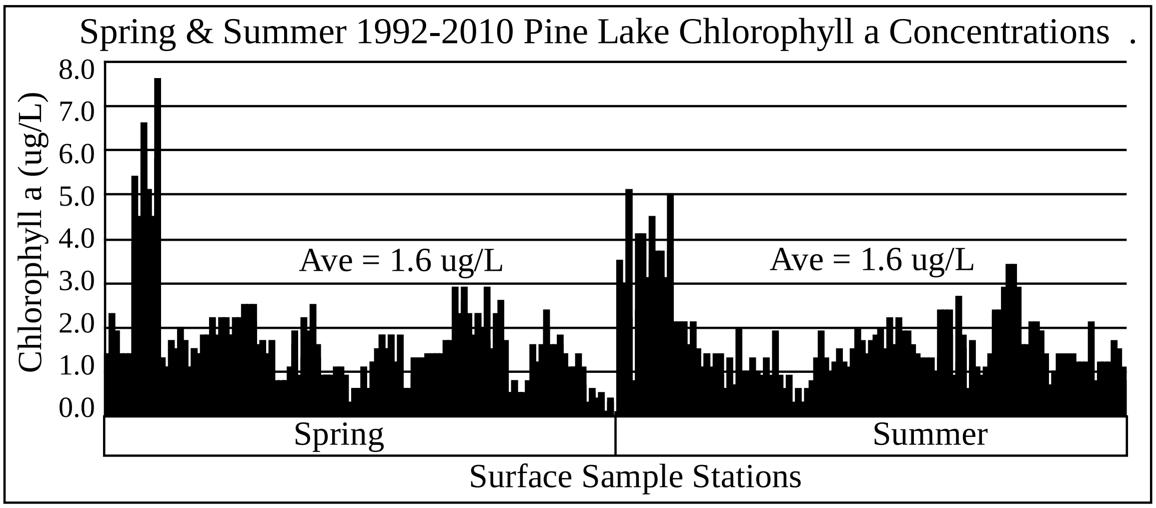
Top to bottom (every 10 feet) samples were collected every time the lake was sampled in both spring and summer. The graph shows the 1992 through 2010 data. The data are first grouped by spring and summer, then by depth, and finally by year.

The graph shows what we normally expect in a Michigan inland lake. Spring nitrate nitrogen concentrations (top to bottom because the lake is mixed at this time) are uniform, and considerably higher than summer nitrate nitrogen concentrations most of the time.

The summer data shows lower nitrate nitrogen concentrations top to bottom and an increase in nitrate nitrogen concentration in some of the mid-depth samples. This is normal for Pine Lake, but unusual for most Michigan inland lakes. The cause for this increase in nitrate nitrogen concentration the mid-depth of the lake is unknown at this time.

CHLOROPHYLL A

Chlorophyll a, reported in micrograms per liter (or parts per billion) generally gives an estimate of algal densities. Best is less than 1 microgram per liter.



The graph of 1992-2010 chlorophylls by year shows early on Pine Lake had significant algal blooms. Since then Pine Lake has small algal blooms from time to time. The graph also shows some chlorophyll a concentrations are below 1 microgram per liter. This is good.

In 2010, spring chlorophylls ranged from 0.1 to 0.6 ug/L (very good) and in summer they ranged from 0.8 to 1.7 ug/L (good).

pH (Hydrogen ion concentration) (No graph)

pH has traditionally been a measure of water quality. Today it is an excellent indicator of the effects of acid rain on lakes. About 99% of the rain events in southeastern Michigan are below a pH of 5.6 and are thus considered acid. However, there seems to be no lakes in southern Michigan which are being affected by acid rain. Most lakes have pH values between 7.5 and 9.0.

pH values for Pine Lake ranged between 7.9 and 9.0. These are normal values for a high quality Michigan inland lake.

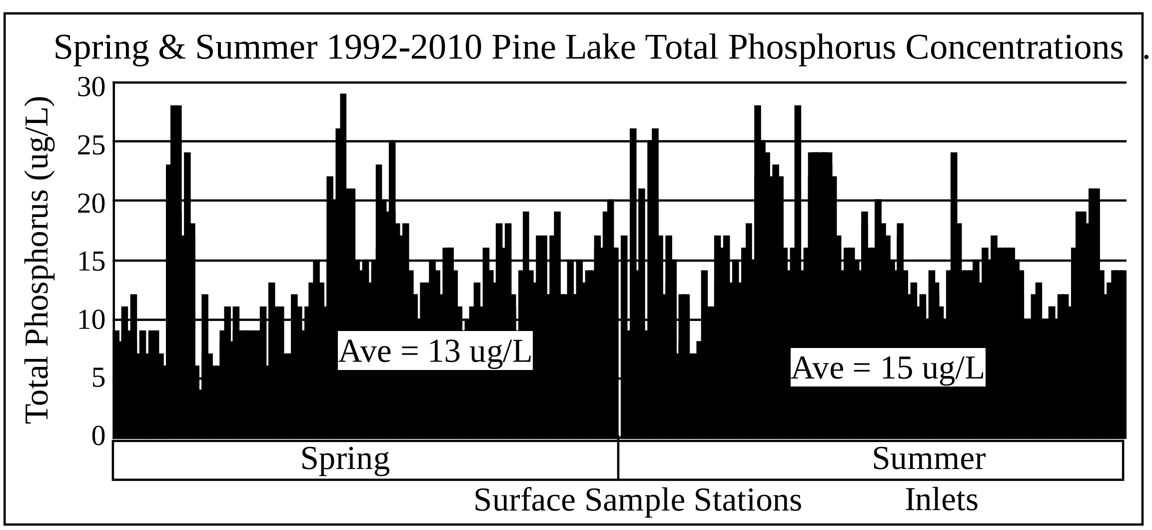
Lakes with extensive plant communities often have high summer pH values (greater than 9) because the plants use the carbonates in the water as a carbon source. This causes a decrease in the buffering capacity of the water, and allows the pH to rise.

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).

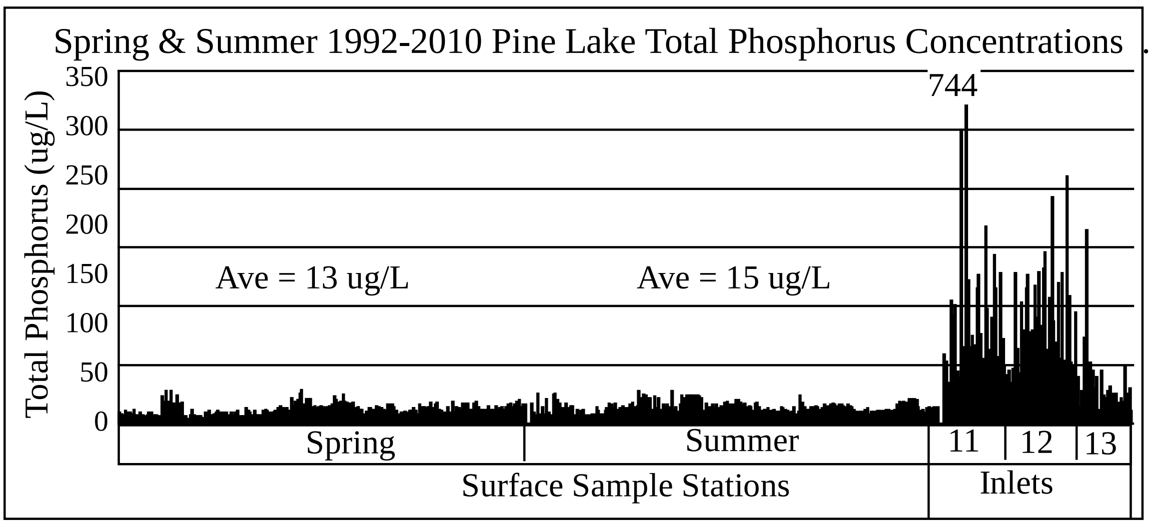
10 parts per billion is considered a low concentration of phosphorus in a lake



and 50 parts per billion is considered a high value in a lake by many limnologists.

The graph of 1992-2010 surface phosphorus data shows Pine Lake has surface phosphorus concentrations in the 5 to 29 micrograms per liter range. Best is below 10 micrograms per liter.

The graph shows spring phosphorus concentrations vary more than summer phosphorus concentrations, but the spring average (13 ug/L) is slightly lower than the summer average (15 ug/L) The graph seems to show phosphorus concentrations are increasing in spring, but not in summer.

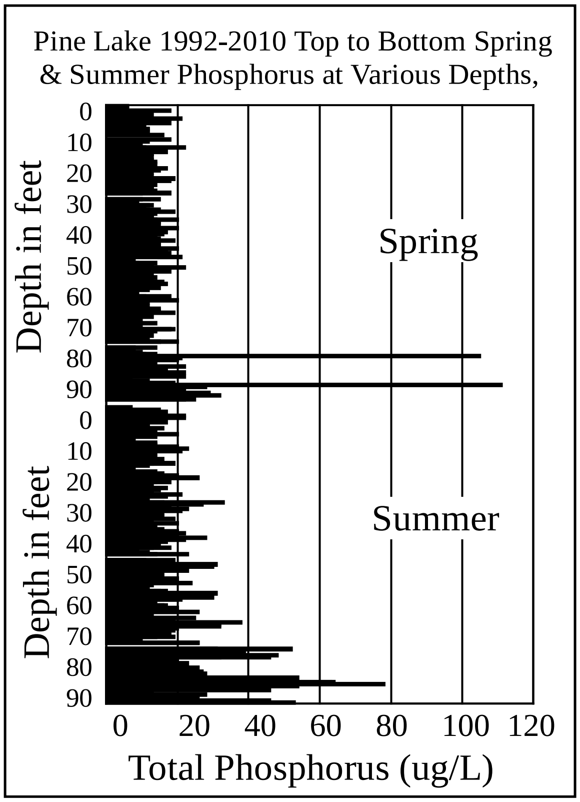


The graph of spring, summer, and canal/lagoon surface phosphorus concentrations shows how much higher the canal/lagoon phosphorus concentrations are than the lake. Pine Lake does not need these high phosphorus concentrations.

However these high phosphorus concentrations show up because they are concentrated by the small amount of water in the canal and lagoon system. Similar amounts of phosphorus are probably washed into the lake from fertilized riparian lawns, but are diluted by the larger amount of water in the lake so they are harder to detect.

The data on the graph of top to bottom 1992-2010 phosphorus concentrations is shown first by spring and summer, then by depth, then by date.

The graph shows in spring the phosphorus concentration is fairly uniform top to bottom. The reason for the two high values at 80 and 90 feet is unknown. These data are not what we usually see, but are not unexpected.



On the other hand, the graph shows in summer, phosphorus concentrations almost always increase near the bottom. This is phosphorus which was precipitated with iron during the time when the lake had dissolved oxygen top to bottom. Once the lake ran out of dissolved oxygen in the bottom water, the iron came back into solution, and released the phosphorus which had been carried down with it earlier.

The graph shows phosphorus is being released from the bottom sediments (see summer 80 foot and 90 foot bars on graph) during anoxic (no dissolved oxygen) conditions.

SECCHI DISK TRANSPARENCY (originally Secchi's disk)

In 1865, Angelo Secchi, the Pope's astronomer in 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. 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.

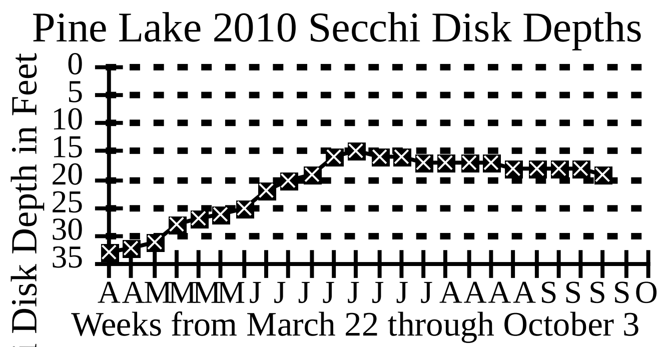
We do it slightly differently. We lower the disk on the shaded side of an anchored boat until the disk disappears, and note the depth, then report the depth to the next deepest foot. For example if the disk disappears at six and a half feet, we report the Secchi disk depth as 7 feet. The reason we do 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 grandchildren see it disappear 3-4 feet deeper than grandparents.

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.

2010 PINE LAKE SECCHI DISK DATA

Dirk Dzierzawski did a good job taking Secchi disk readings through the warm months in 2010. The graph shows his data.

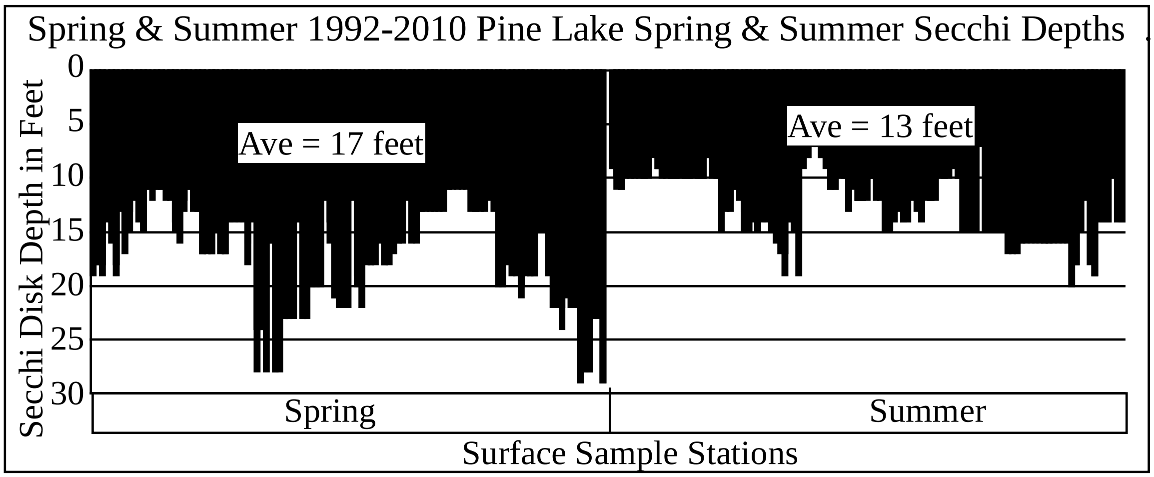


MAR	.	.	.	33	.
APR	.	32	.	31	.
MAY	.	28	27	26	.
JUN	25	22	20	19	
JUL	16	15	16	16	17
AUG	17	17	17	18	.
SEP	18	18	18	.	.
OCT	19	.			

The 2010 Secchi disk data shows in early spring, Secchi disk readings were 33 feet. They gradually decreased to between 15 and 19 feet the rest of the summer.

Secchi disk readings should continue being taken regularly on a weekly basis through the warm months to follow what is happening in the lake.

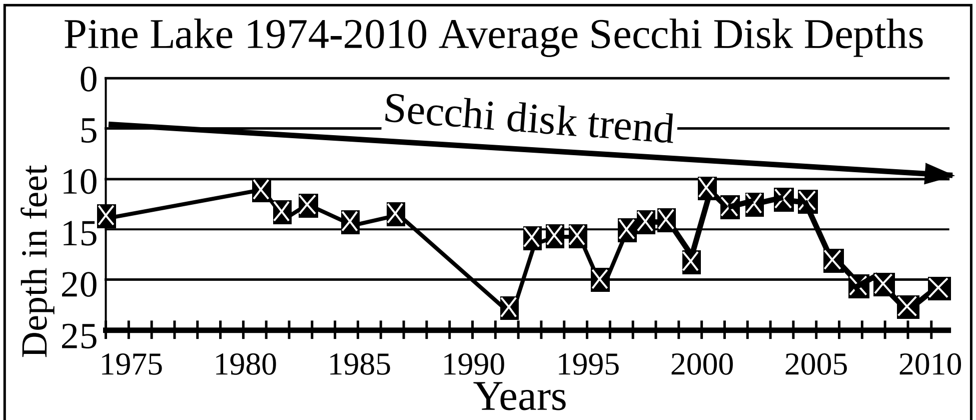
SECCHI DISK READINGS TAKEN WITH THE SAMPLES



The graph shows Secchi disk readings taken with the samples were deepest in spring, 28 feet and 29 feet. Spring readings varied more than summer readings and had an average of 17 feet. Summer readings were more uniform and averaged 13 feet. The graph does not show any specific trend in either spring or summer other than that spring readings may be deeper than summer readings.

SECCHI DISK TREND GRAPH

The graph shows the trend of average Secchi disk data collected from 1974



Data:

Year	1974	1981	1982	1983	1985	1987	1992	1993	1994	1995	1996	1997
Depth	14.0	11.0	14.0	12.5	14.6	13.6	23.5	16.4	15.8	15.8	20.9	15.7

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Depth	14.3	12.8	18.0	10.8	12.4	12.3	12.0	12.1	18.0	20.4	20.3	22.9	21.1

through 2010.

The graph shows from 1974 through 1992 Pine Lake was getting clearer. Between 1992 and 2005, the trend seems to be that the lake was getting less clear. Since 2005 the clarity is getting better. That’s a plus. Let’s hope this trend continues.

THE LAKE WATER QUALITY INDEX

The Lake Water Quality Index used in this study to define the water quality of Pine 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 — Total alkalinity
Chlorophyll a — Temperature

Secchi disk depth	Conductivity
Total nitrate nitrogen	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 was 16 at an Ottawa County lake.

THE LAKE WATER QUALITY INDEX CALCULATION SHEETS

The Lake Water Quality Index calculation sheets which follow were developed to show graphically what the results of the nine different lake water quality tests mean in terms of lake water quality.

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 2010 SPRING AND SUMMER LAKE WATER QUALITY INDICES

SPRING LAKE WATER QUALITY

2010 spring Lake Water Quality Indices for the ten Pine Lake surface samples ranged from 95 to 97 and averaged 96.

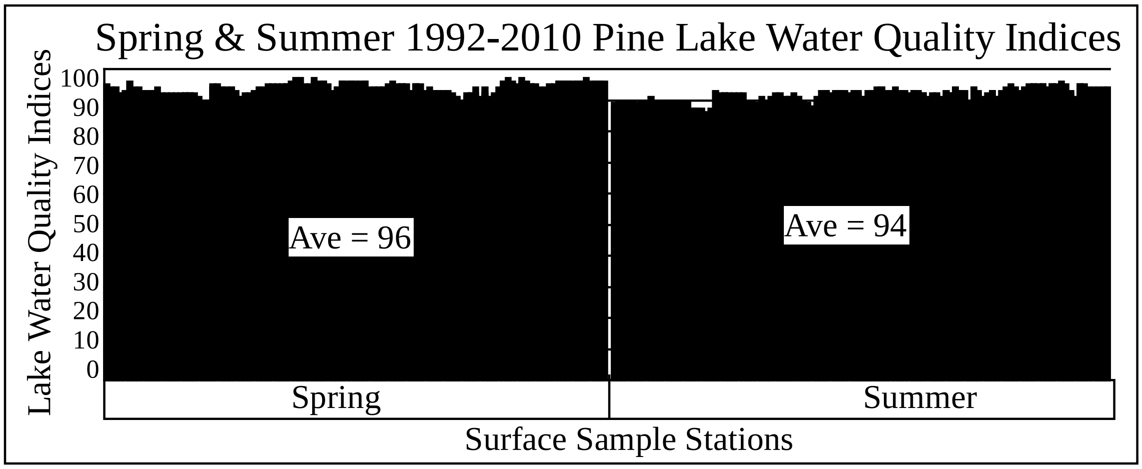
SUMMER LAKE WATER QUALITY

2010 summer LWQIs for the ten Pine Lake surface samples ranged from 92 to 94 and averaged 94.

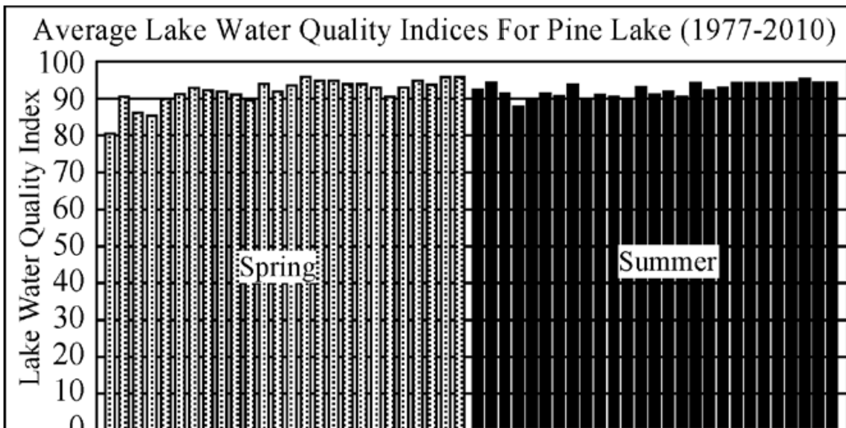
These data indicate in spring and summer 2010 the Lake Water Quality Indices for Pine Lake were all above 90, or in the A range.

1992-2010 LAKE WATER QUALITY INDICES

The graph shows the spring and summer Lake Water Quality Indices for Pine Lake from 1992 through 2010. It shows the spring and summer water quality of Pine Lake appears to be getting better. This is good. Keep it up.



THE AVERAGE WATER QUALITY OF PINE LAKE (1977-2010)



Year	1977	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	
Spring	82	---	91	87	86	91	93	94	93	93	92	91	94	
Summer	92	94	90	86	89	91	90	93	89	90	90	87	92	
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Spring	92	94	96	95	96	96	94	92	91	92	96	94	96	96
Summer	90	90	91	93	92	93	92	92	92	92	94	95	94	94

The graph shows the average Lake Water Quality Indices of Pine Lake since 1977. As in the prior graph, it too shows the water quality of Pine Lake appears to be getting better in both spring and summer. That's a plus.

THE LAKE WATER QUALITY INDEX CALCULATION SHEETS

Because the spring and summer Lake Water Quality Indices in 2010 were relatively uniform, only two Lake Water Quality Index calculation sheets are included in this report, one for the ten spring 2010 surface samples, using averaged data and a second for the ten summer 2010 surface samples, using averaged data.

In the report marked MASTER, all 20 of the 2010 LWQI calculation sheets are included. That is the only difference between the MASTER and the rest of the reports.

PINE LAKE 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.

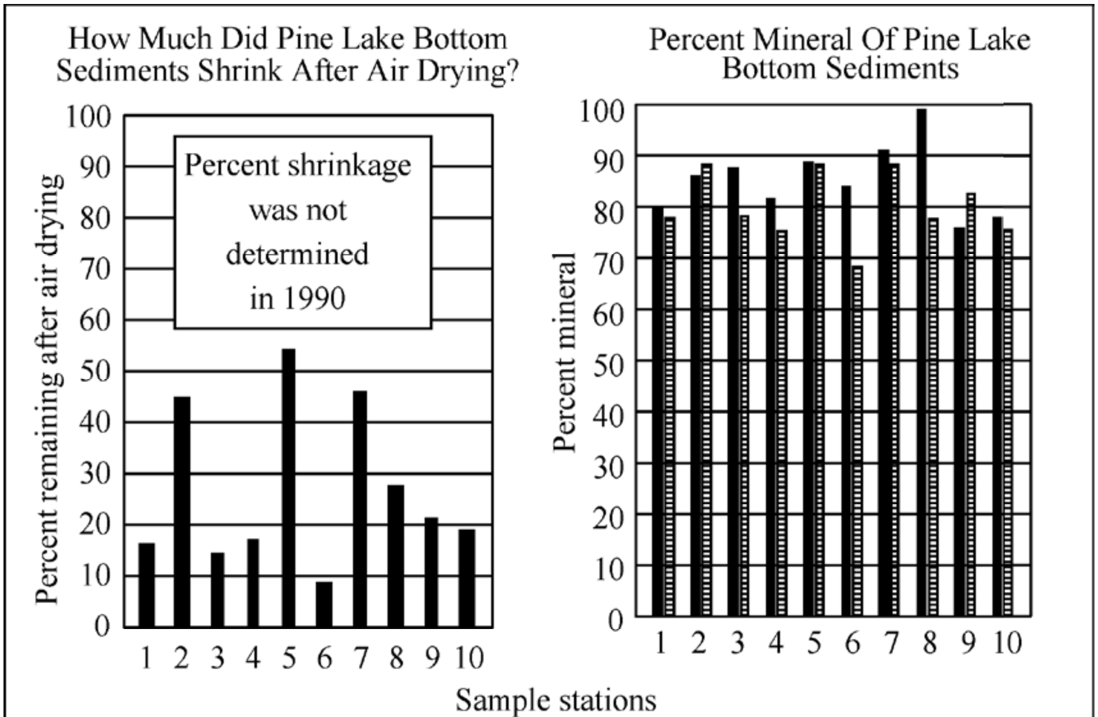
I consider high quality bottom sediments from natural lakes to be above 85 percent mineral. And I consider bottom sediments less than 50 percent mineral to be muck.

PINE LAKE BOTTOM SEDIMENTS

Ten bottom sediment samples were collected in at the sample stations shown on the map in 1990 and again in 2002. The graph shows the data.

All 1990 sediments turned gray after air-drying except three (Stations 8, 9 & 10). Of those, two remained black and one turned tan. After burning at 550 degrees C, nine 1990 sediment samples remained gray and one turned tan. That indicated the lake is filling with carbonates and bicarbonates, which is what is happening in most Michigan inland lakes.

In the 1990 samples, the mineral content ranged from 76 to 99 percent, and averaged 85 percent. This is good, and indicates Pine Lake was not accumulating organic material at a faster than normal rate except in waters deeper than 50 feet.



1990 — Characteristics of Pine Lake Bottom Sediments — 2002

Sample I.D.	Shrinkage	Percent Mineral		Dried at 100°C Color		Color after burning at 550°C		Depth of water (feet)	
	2002	1990	2002	1990	2002	1990	2002	1990	2002
1	84	80	78	Gray	Gray	Gray	Red gray	33	26
2	55	86	89	Gray	Gray	Gray	Gray	36	28
3	86	88	79	Gray	Gray	Gray	Red gray	23	32
4	83	81	76	Gray	Gray	Gray	Gray	14	23
5	46	89	89	Gray	Gray	Gray	Gray	5	7
6	91	84	69	Gray	Gray	Gray	Red gray	22	20
7	56	91	89	Gray	Gray	Gray	Gray	3	5
8	72	99	78	Tan sand	Gray	Tan	Gray	34	30
9	79	76	82	Black	Gray	Gray	Gray	56	30
10	81	78	76	Black	Gray	Gray	Red gray	94	90
		85%	81%	Average mineral content of bottom sediments					

In 2002 all of the sediments turned gray after air drying, and a majority remained gray after burning at 550 degrees C. However, four of the ten 2002 sediments turned red gray after burning. The red color indicated the presence of clay, which is not a normal constituent of sediments in most Michigan inland lakes. The source of the clay is probably home building and road building activities around the lake.

The mineral content of the 2002 samples ranged from 69 to 89 percent, and averaged 81 percent. This indicates Pine Lake is starting to accumulate organic material.

The amount of shrinkage was not determined in the 1990 samples. The 2002 samples shrunk a normal amount, between 55 and 91 percent. Other than the 91 percent shrinkage at Station 6, this is normal shrinkage for a Michigan inland lake.

One of the most important things Pine Lake homeowners can do is to make sure the mineral content doesn't change, and organic material starts to build up in the bottom sediments. If the mineral content of the bottom sediments doesn't change, it means the homeowners around the lake are taking proper care of their lake.

Wallace E. Fusilier, Ph.D.
Consulting Limnologist
Water Quality Investigators
Dexter, Michigan 48130
April 2011