

PORTAGE LAKE

WASHTENAW AND

LIVINGSTON COUNTIES

1994 - 2006 WATER QUALITY STUDIES

PORTAGE LAKE DATA

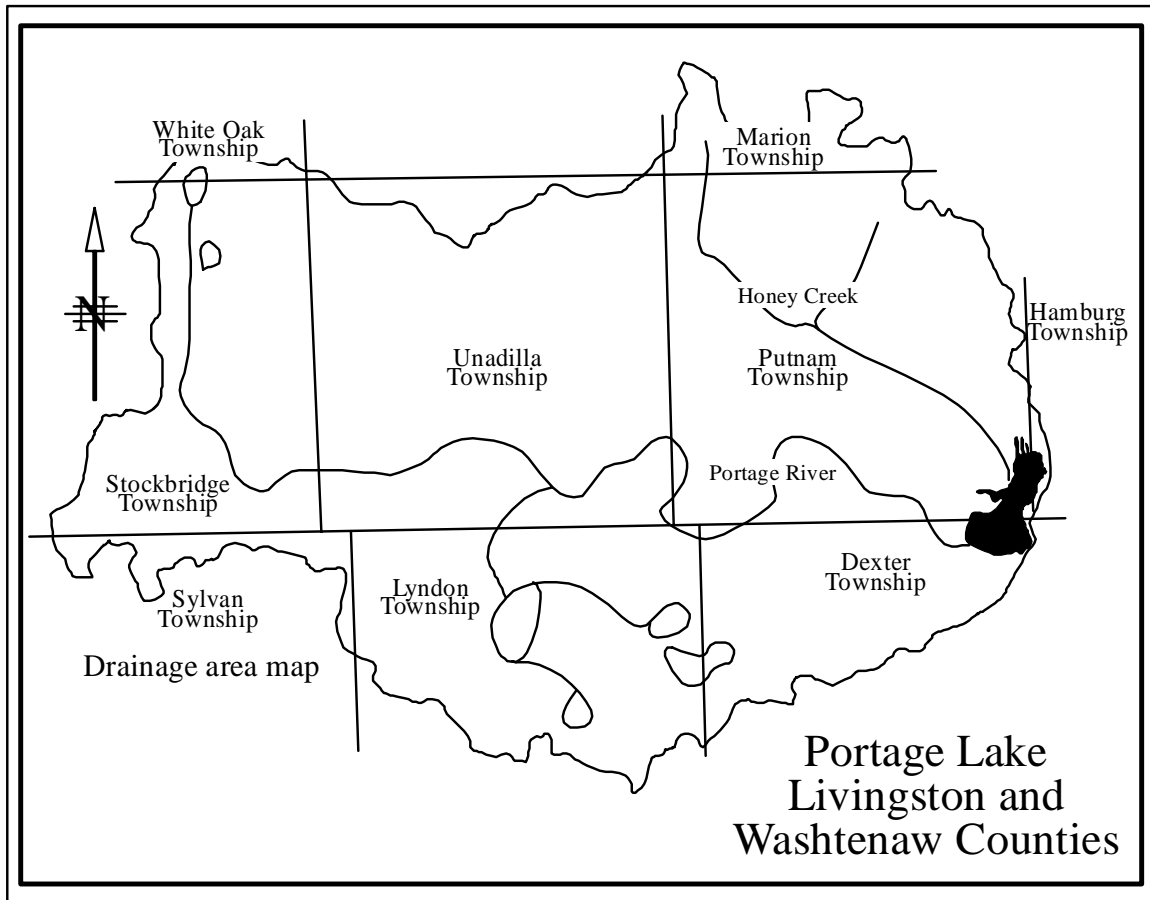
Portage Lake, also called Big Portage Lake, is a 725-acre natural hard-water kettle lake located in Sections 25 and 36, Putnam Township (T1N R4E), Section 31, Hamburg Township (T1N R5E) Livingston County, and Sections 1 and 2, Dexter Township (T1S R4E), Washtenaw County, Michigan. The lake consists of a north and south basin separated by a bar one to two feet under the surface. The northern basin makes up about one quarter of the lake and has a maximum depth of 50 feet. The southern basin, which makes up about three-quarters of the lake, has a maximum depth of 84 feet. The lake has a single 7-acre island on the northwest side of the south basin. Hence the surface area of the lake is 718 acres.

The hypsographic (depth-area) graph shows about 30 percent of the north basin and 25 percent of the south basin is five feet deep or less.

The lake contains 19,567 acre-feet of water, and has a mean depth of 27.3 feet. The shoreline length is 53,094 feet. However this includes the shoreline lengths of Wynn's and Colony canals located on the north end, and Camelot canal, which flows into Mud Bay, and then into the lake at the west end of the sand bar, plus several other bays. It does not however, include the shoreline of the island.

The lake has two inlets. Honey Creek, which drains 17,792 acres, flows into the north basin. The Portage River, which drains 54,784 acres, flows into Little Portage Lake, then under the Dexter Pinckney Road bridge and into

Portage Lake. The longitude and latitude of the 84-foot deep hole is 83° 53.384W and 42° 25.234N.



The lake was formed when two blocks of ice broke off the retreating glacier about 10,000 years ago and were then surrounded by the debris released as the glacier melted. Finally the blocks of ice melted, forming the present lake basins.

The John Flook dam on the Huron River below Portage Lake causes water from the Huron River to flow both into and out of the lake through the Gulf Canal and through the Portage River outlet, depending on time of year (and water volume). Hence, the entire Huron River watershed upstream of Portage Lake may from time to time be included in the Portage Lake watershed. The Huron River watershed above the Flook dam is 259,840 acres.

The watershed of Portage Lake is large, 74,795 acres. The drainage area, which includes the watershed plus the surface area of Portage Lake, is

75,520 acres. The watershed to lake ratio is large, 103 to 1. Because of this large ratio the flushing rate of the lake is about 0.36 years or 131 days.

The Flook dam can divert water from the upper Huron River watershed into the lake so although it is not part of the flushing rate calculations, it must be considered when lake levels are concerned.

THE SAMPLE DATES

Portage Lake residents took three spring surface samples for water quality testing plus Secchi disk readings at the three sites shown on the map June 1, 1994 and June 14, 1995.

WQI limnologists collected three spring surface samples for water quality testing plus Secchi disk readings June 9, 1996, May 12, 1997, April 19, 1998, April 26, 1999, April 15, 2000, May 13, 2001, April 15, 2002, April 28, 2003, April 16, 2004, April 18, 2005 and April 19, 2006.

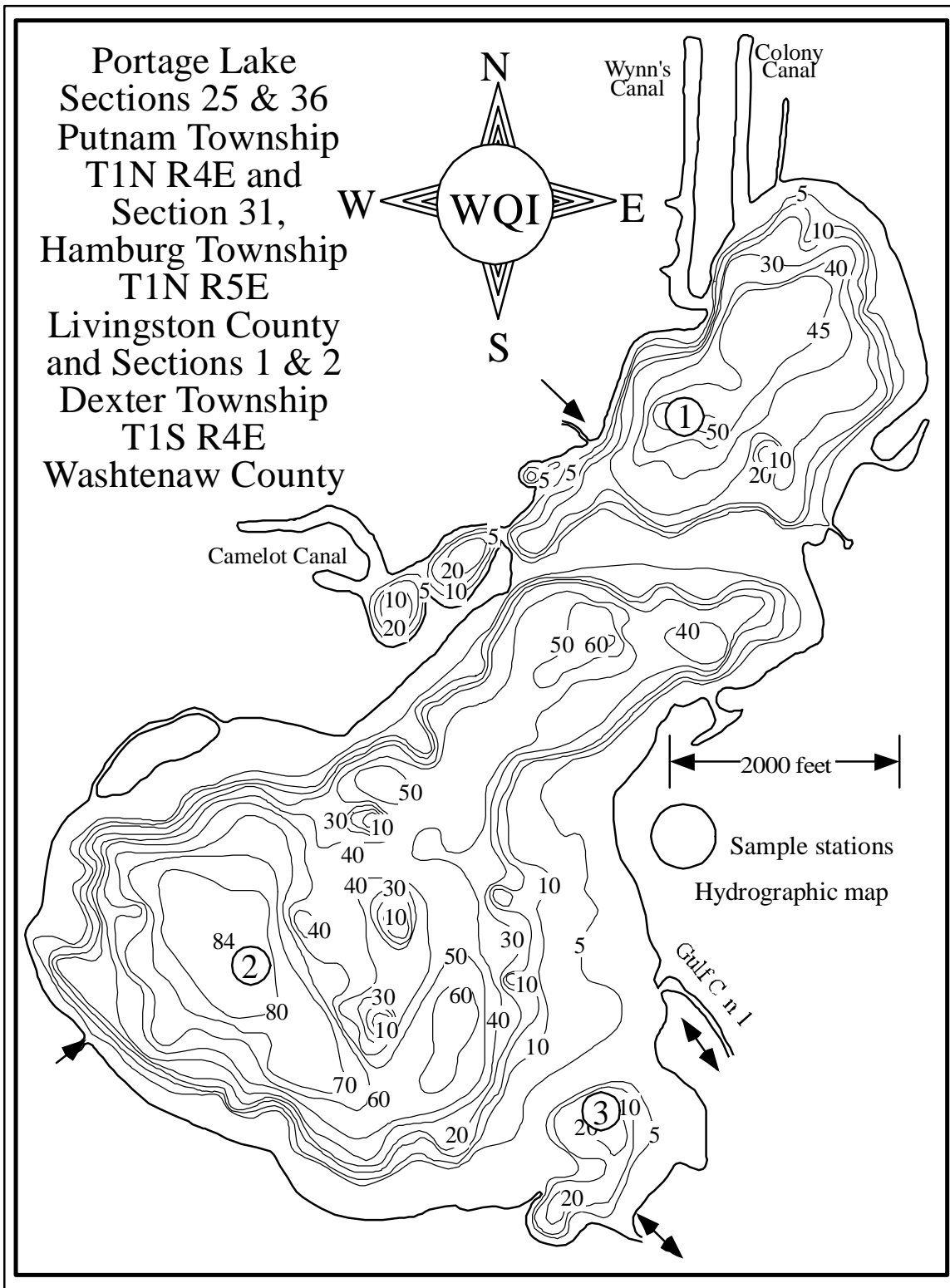
They also collected late summer surface samples for water quality testing plus Secchi disk readings at the stations shown on the map August 1, 1994, August 14, 1995, August 7, 1996, August 25, 1997, August 10, 1998, August 27, 1999, August 4, 2000, August 1, 2001, August 2, 2002, August 1, 2003, August 2, 2004, August 3, 2005 and August 1, 2006. Top to bottom temperature and dissolved oxygen profile data were collected each time the lake was sampled in late summer at the deepest part of the north and south basins. Bottom sediment samples were collected in 1995 in the north and south basins, and in the three canals. Bottom sediment samples from the three in-lake stations were collected in 2005.

The Portage River and Honey Creek were sampled monthly May 2004 through April 2005.

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 SAMPLE STATIONS

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

The Portage River was sampled just before it flowed into Little Portage Lake. Honey Creek was sampled where it crossed under Darwin Road.

THE TEST RESULTS

The results of the tests are found in the text, in the tables 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 gasses and biological activity.

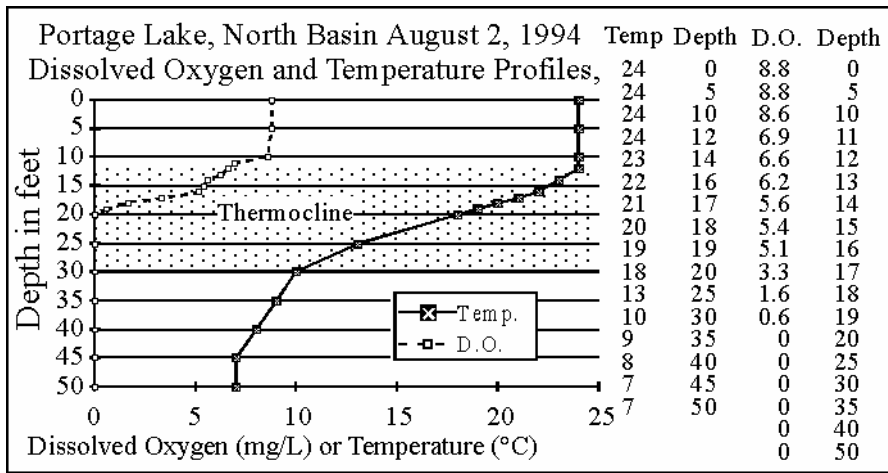
Dissolved oxygen is the test most often selected by lake scientists as being important. Besides providing oxygen for aquatic organisms, in natural lakes oxygen is involved in the capture and release of various chemicals, such as iron and phosphorus.

In spring top to bottom dissolved oxygen concentrations were not measured but since 1996 surface dissolved oxygen concentrations. On the other hand, dissolved oxygen and temperature profile data were collected in both the north and south basins every year when the lake was sampled in late summer.

The late summer data are first shown for the north basin, then for the south basin.

NORTH BASIN

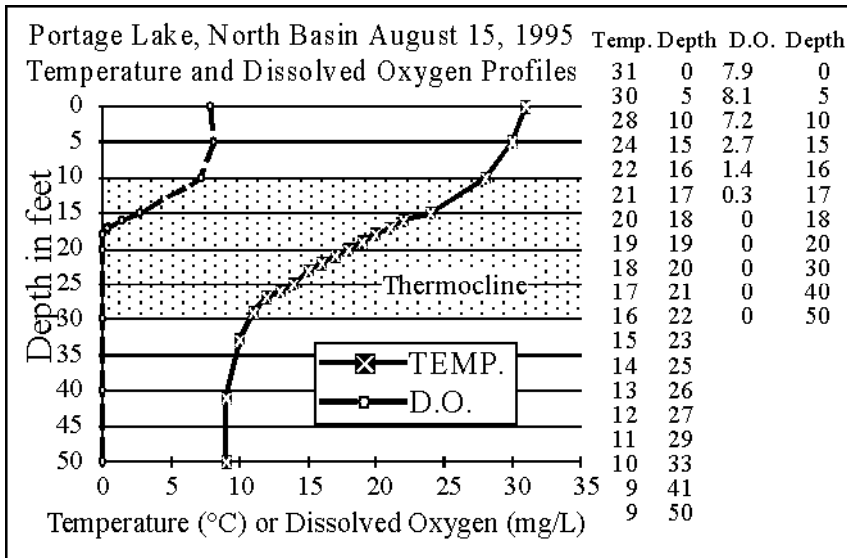
1994



In late summer 1994, the north basin formed a 20-foot-thick thermocline (defined as a layer of water in a lake where the temperature changes rapidly with depth and

shown shaded on the graphs) from 10 to 30 feet. Dissolved oxygen was plentiful above the thermocline.

At the top of the thermocline dissolved oxygen started to decrease. The basin ran out of dissolved oxygen at 20 feet. That condition remained to the bottom. The hypsographic (depth area) graph shows about 48 percent of the north basin is deeper than 20 feet.



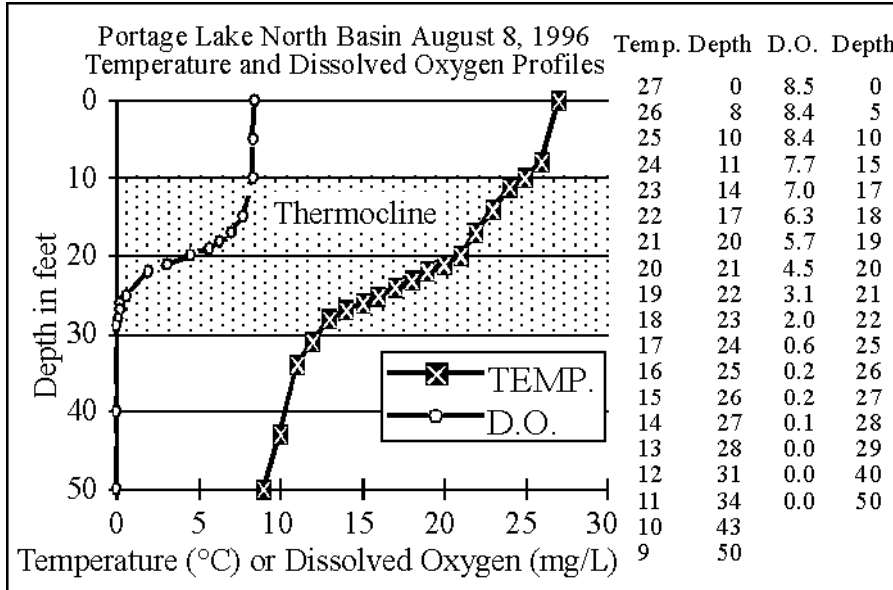
1995

In late summer 1995 the north basin formed a 20-foot-thick thermocline from 10 to 30 feet. Dissolved oxygen was plentiful above the thermocline. This basin ran out of

dissolved oxygen at 18 feet. That condition remained to the bottom. About 50 percent of this basin is deeper than 18 feet.

1996

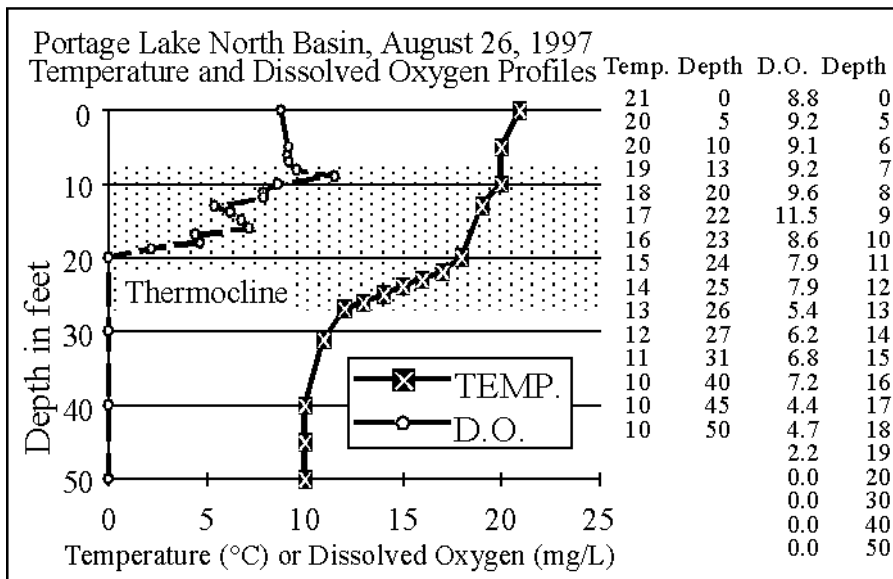
In late summer 1996 the north basin again formed a 20-foot-thick thermocline from 10 to 30 feet. Dissolved oxygen was again plentiful above the thermocline. The basin ran out of dissolved oxygen at 29 feet and that condition remained to the bottom at 50 feet.



About 38 percent of the basin is deeper than 29 feet.

1997

In late summer 1997, the north basin formed a 19-foot thick thermocline from eight to 27 feet. This year dissolved oxygen reached a maximum at the top of the thermocline, 11.5 milligrams per liter. The dissolved oxygen concentration peaked again

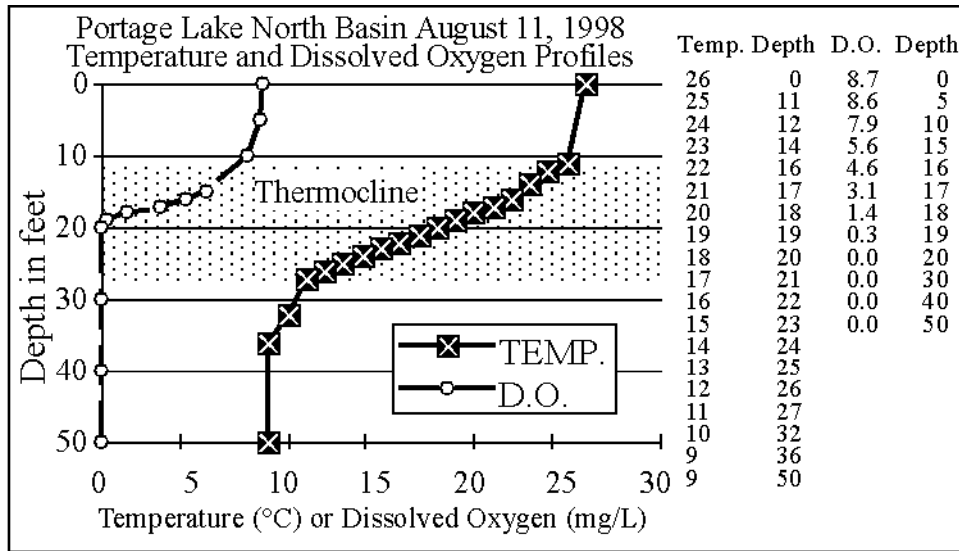


at 15 feet. These dissolved oxygen maximums in the thermocline are often caused by algal blooms which settle there. They are not rare, nor do they indicate anything in particular except there was enough light at that particular depth for algae to grow. The second peak is unusual because the upper algal bloom should have blocked the sunlight needed by the second deeper bloom.

In 1997 the north basin ran out of dissolved oxygen at 20 feet, and that condition again remained to the bottom.

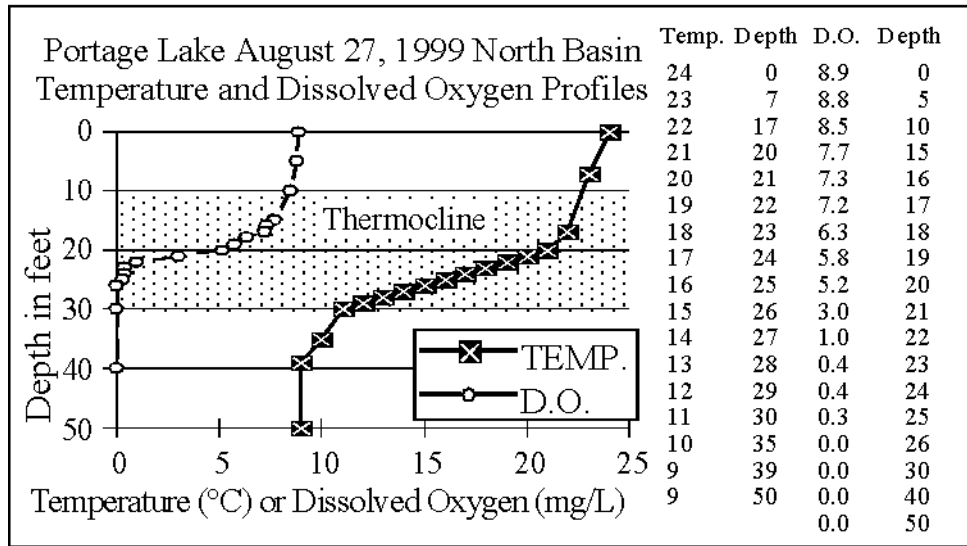
1998

In late summer 1998 the north basin formed an 18-foot-thick thermocline



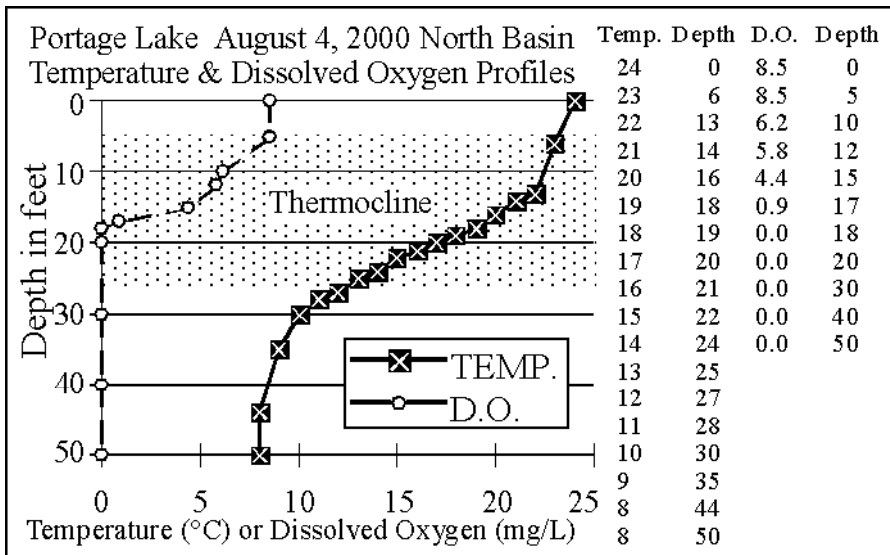
from 10 to 28 feet. The basin again ran out of dissolved oxygen at 20 feet, and that condition remained to the bottom.

1999



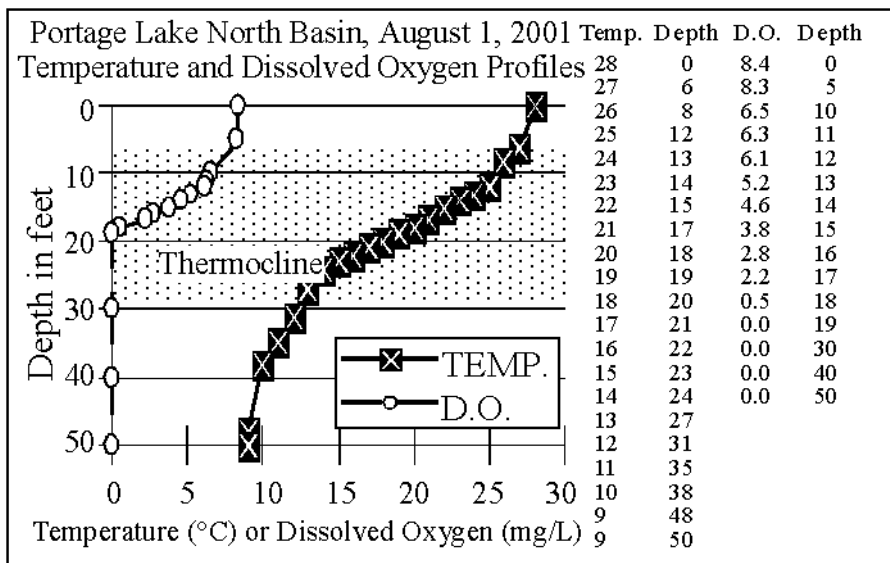
In late summer 1999, the north basin formed a 20-foot-thick thermo-cline from 10 to 30 feet. Dissolved oxygen was plentiful above the thermocline.

This basin ran out of dissolved oxygen at 26 feet. That condition remained to the bottom. About 40 percent of the basin is deeper than 26 feet.



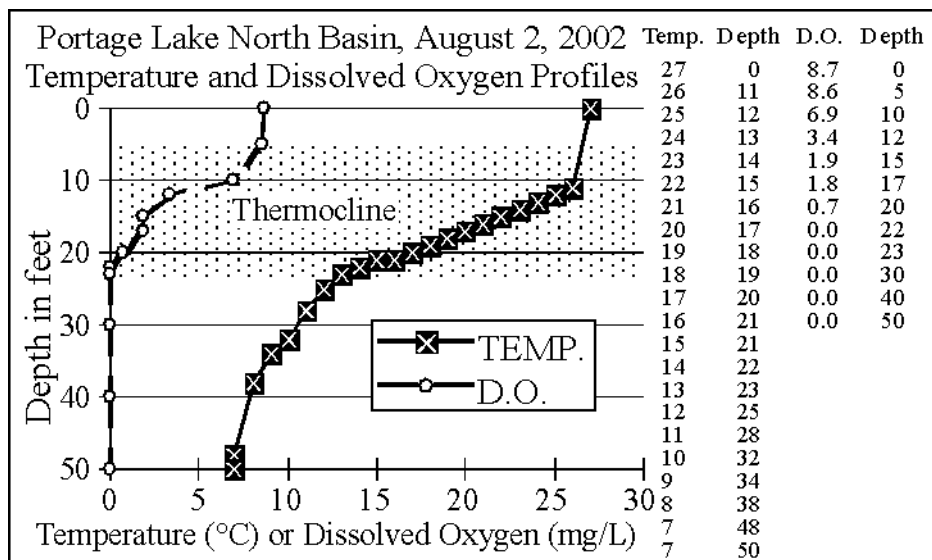
2000

In late summer, 2000, the north basin formed a 22-foot-thick thermocline from 5 to 27 feet. Dissolved oxygen was plentiful above five feet. This basin ran out of dissolved oxygen at 18 feet. That condition remained to the bottom.



2001

In late summer, 2001, the north basin formed a 24-foot-thick

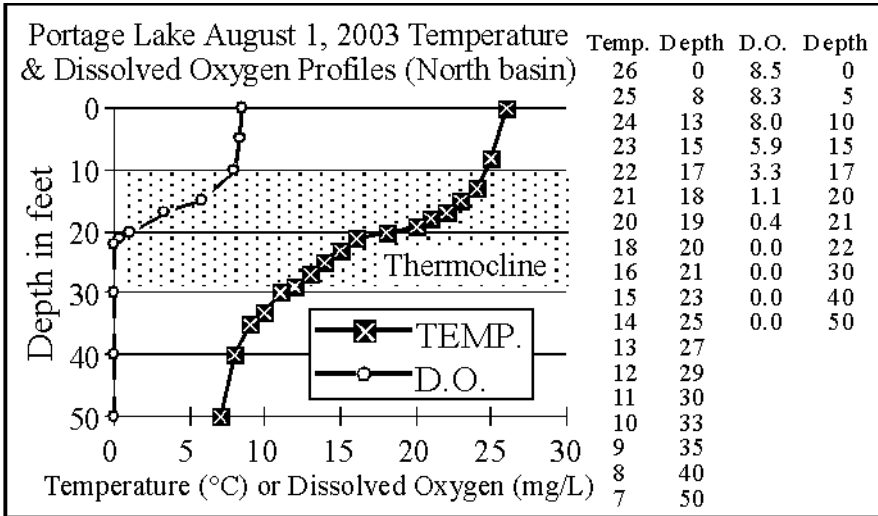


thermocline from 5 to 29 feet. Dissolved oxygen was plentiful above five feet. This year the basin ran out of dissolved oxygen at 19 feet and that condition remained to the

bottom. 49 percent of the basin is deeper than 19 feet.

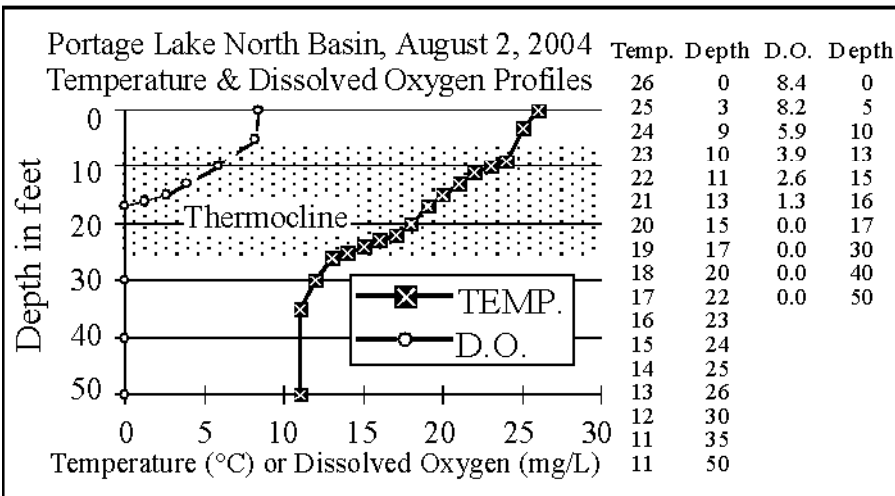
2002

In late summer 2002, the north basin formed a 20-foot-thick thermocline from 5 to 25 feet. Dissolved oxygen was plentiful above five feet. This year the basin ran out of dissolved oxygen at 22 feet and that condition remained to the bottom. 45 percent of the basin is deeper than 22 feet.



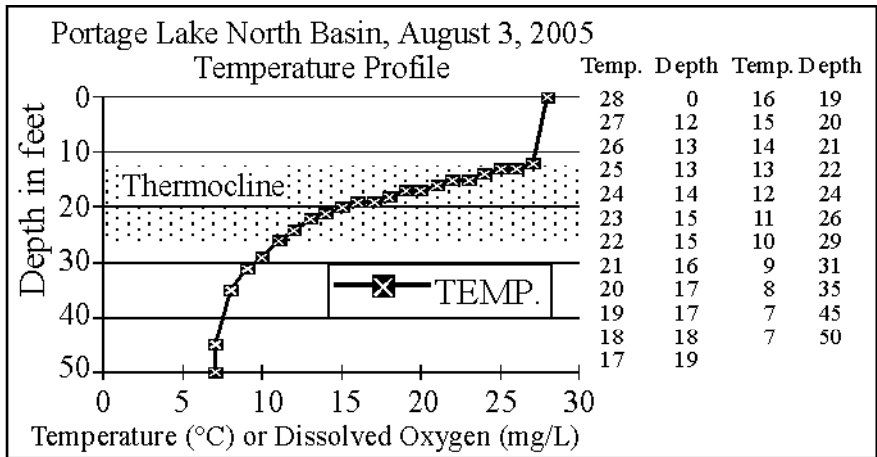
2003

In late summer 2003, the north basin formed a 20-foot-thick thermocline from 10 to 30 feet. Dissolved oxygen was plentiful above the thermocline. This year the basin ran out of dissolved oxygen at 22 feet and that condition remained to the bottom.



2004

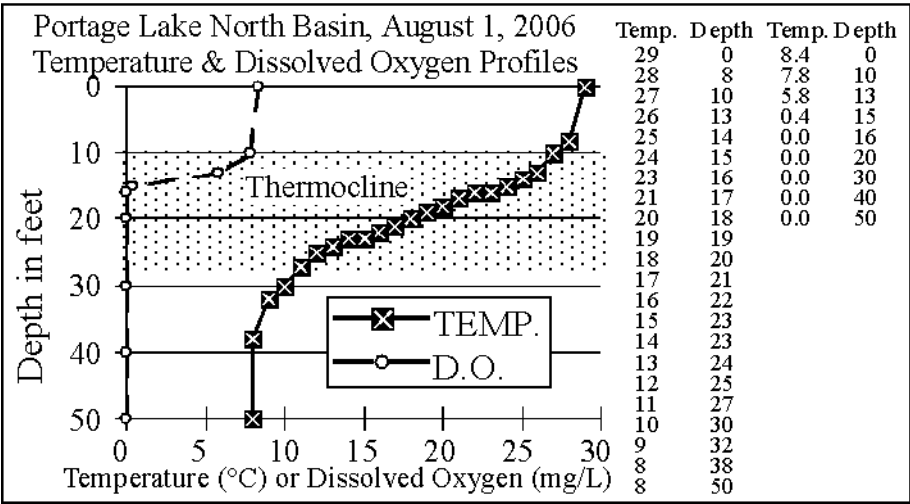
In late summer 2004 the north basin formed a 20-foot-thick thermocline from 5 to 25 feet. Dissolved oxygen was plentiful in the top five feet. It started to decrease at the top of the thermocline, and was zero a 17 feet. About half this basin is deeper than 17 feet.



2005

In late summer 2005 the north basin formed a 15-foot-thick thermocline from 12 to 27 feet.

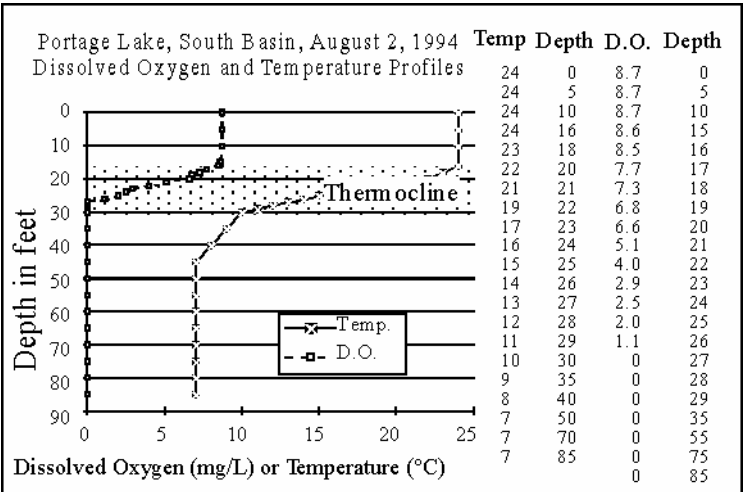
Dissolved oxygen data were not available.



2006

In late summer 2006 the north basin formed a 20-foot-thick thermocline from 10 to 30 feet.

Dissolved oxygen concentrations were adequate to support fish life above 14 feet. This basin ran out of dissolved oxygen at 16 feet and that condition remained to the bottom.

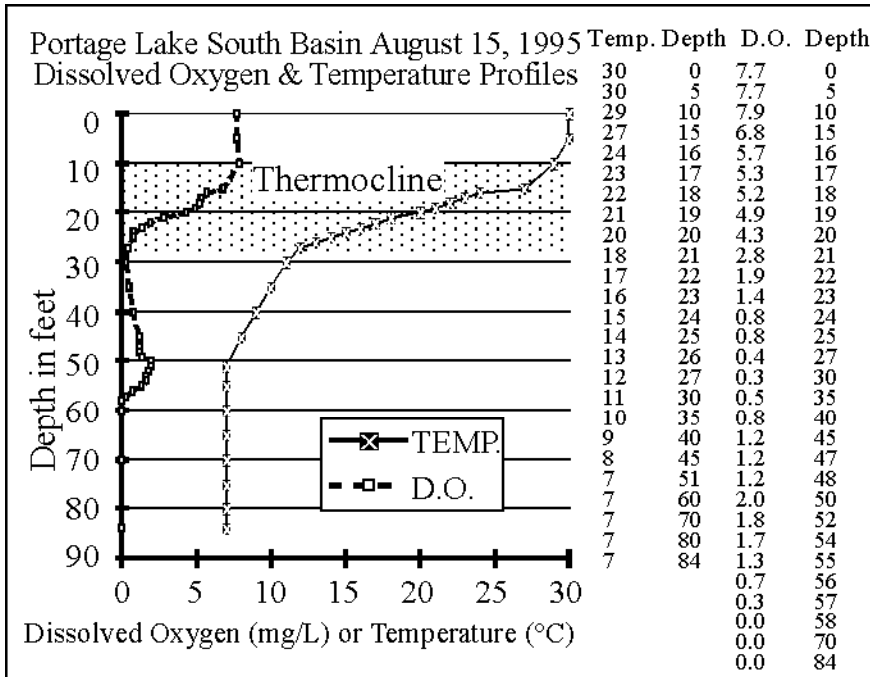


The north basin seems to run out of dissolved oxygen at about 20 feet in late summer, although the range is from 17 feet to 29 feet. There is no consistent pattern, which is good.

SOUTH BASIN

1994

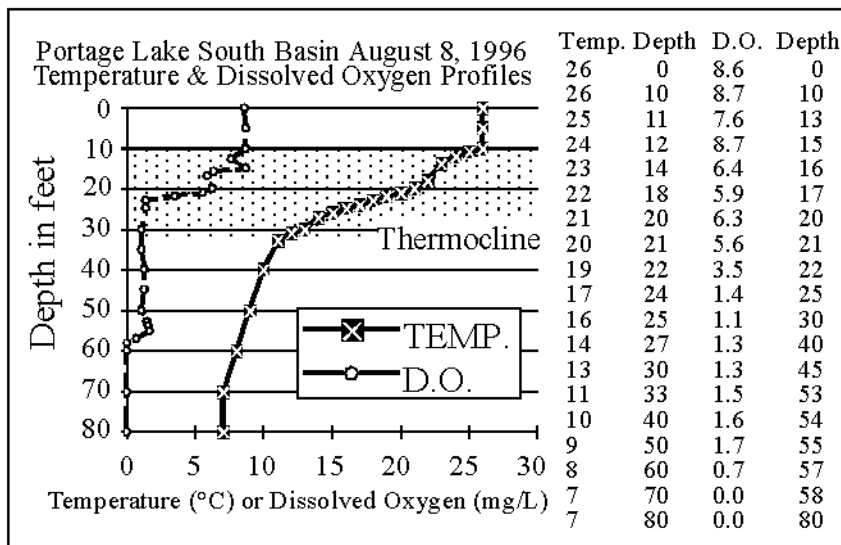
In late summer 1994 the south basin formed a 12-foot-thick thermocline from 18 to 30 feet. Dissolved oxygen was plentiful above the thermocline. This basin ran out of dissolved oxygen at 27 feet. That condition remained to the bottom at 84 feet. 52 percent of this basin is deeper than 27 feet.



1995

In late summer 1995, the south basin formed an 18-foot-thick thermocline from 10 to 28 feet. Dissolved oxygen was plentiful above the thermocline.

The basin started to run out of dissolved oxygen at the top of the thermocline and reached 0.8 milligrams per liter at 24 feet. From that depth to 58 feet, dissolved oxygen concentrations fluctuated between 0.3 and 2.0 milligrams

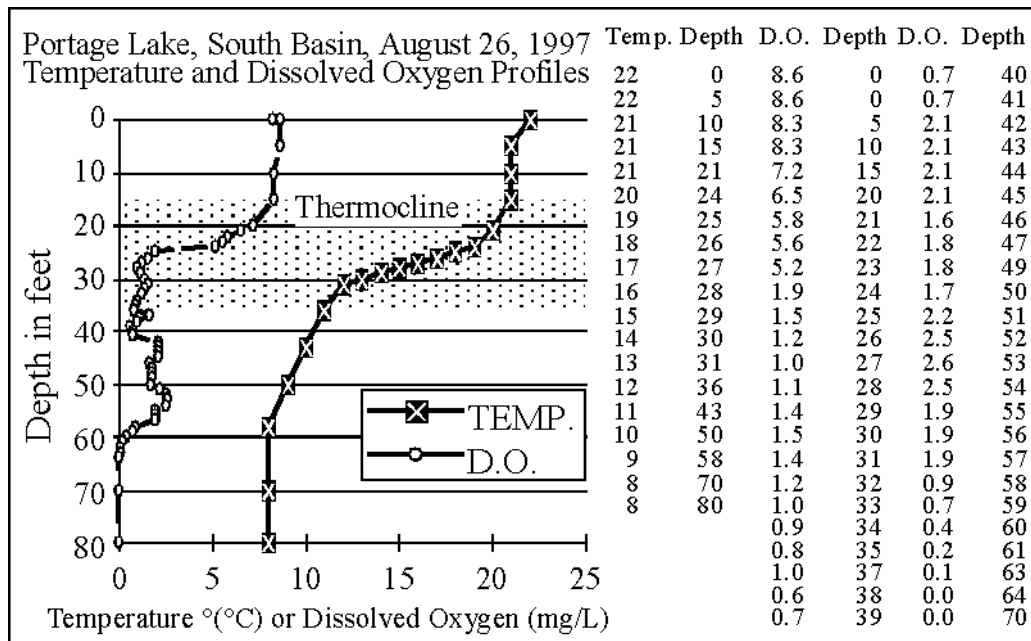


per liter. The south basin ran out of dissolved oxygen at 58 feet and that condition remained to the bottom at 84 feet. 14 percent of this basin is deeper than 58 feet.

1996

In late summer 1996, the south basin formed an 18-foot-thick thermocline from 10 to 28 feet. Dissolved oxygen was plentiful above the thermocline. Dissolved oxygen started to decrease at the top of the thermocline and reached 1.4 milligrams per liter at 25 feet. From that depth to 58 feet, dissolved oxygen concentrations fluctuated between 0.7 and 1.7 milligrams per liter. The south basin ran out of dissolved oxygen at 58 feet and that condition remained to the bottom at 84 feet.

1997



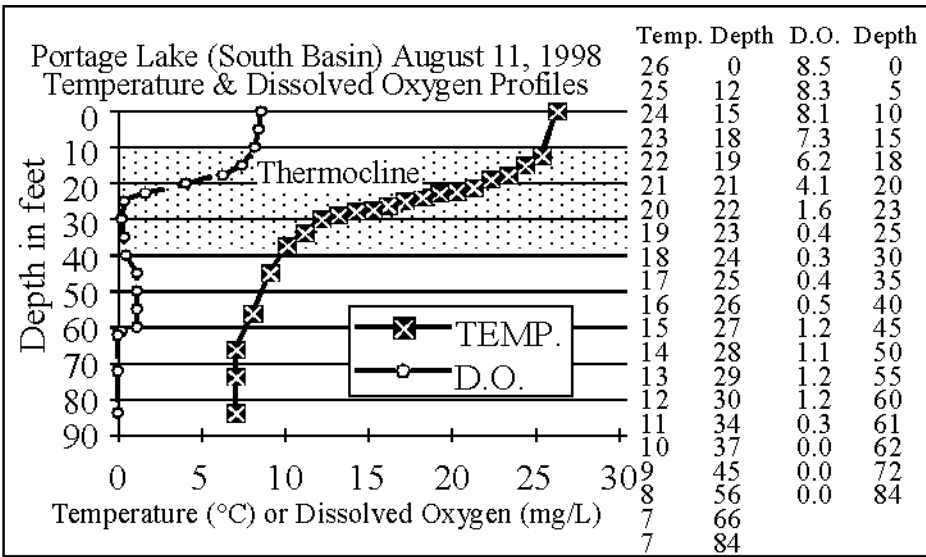
In late summer 1997, the south basin formed a 20-foot-thick thermocline from 15 to 35 feet. Dissolved oxygen was plentiful above the thermocline. The lake started to run out of dissolved oxygen at the top of the thermocline and reached 1.0 milligrams per liter at 27 feet. From that depth to 64 feet, dissolved oxygen concentrations fluctuated between 0.1 and 2.6 milligrams per liter. The south basin ran out of dissolved oxygen at 64 feet that year and that condition remained to the bottom at 84 feet. 10 percent of the basin is deeper than 64 feet.

1998

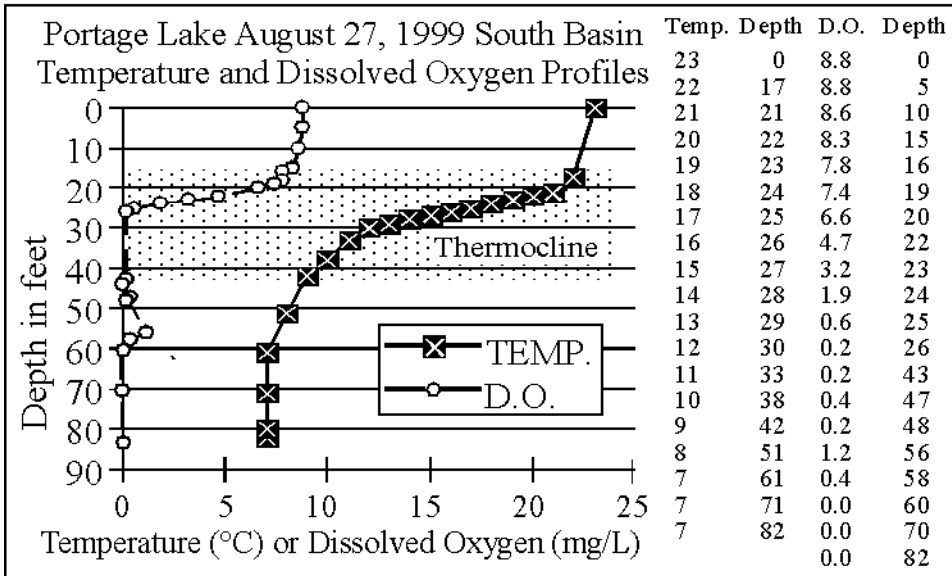
In late summer 1998, the south basin formed a 30-foot-thick thermocline

from 10 to 40 feet. Dissolved oxygen was plentiful in the top ten feet. The lake started to run out of dissolved oxygen at the top of the thermocline and reached a low of 0.3 milligrams per liter at 30 feet. From that depth to 62 feet, dissolved oxygen concentrations fluctuated between 0.3 and 1.2 milligrams per liter. The basin ran out of dissolved oxygen at 62 feet and that condition remained to the bottom at 84 feet.

1999



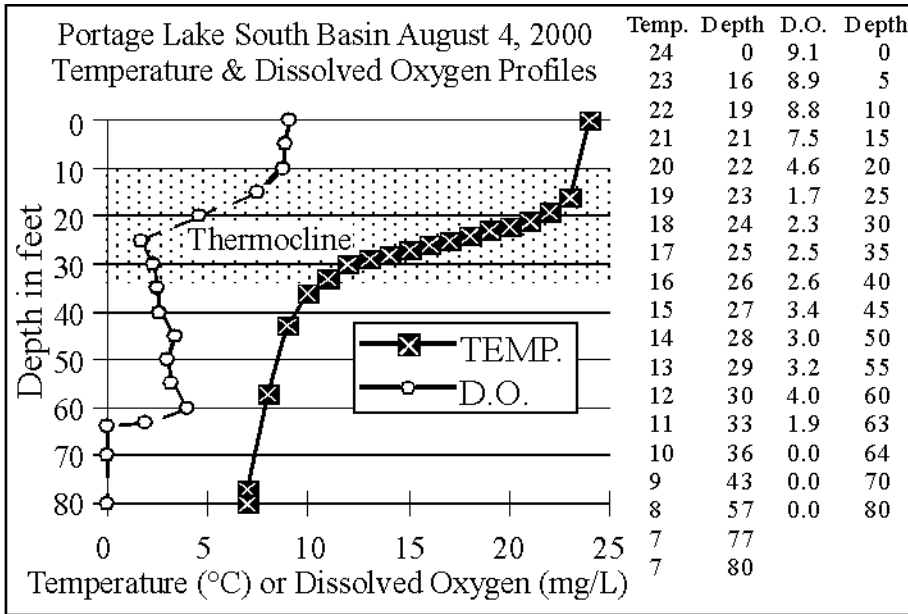
In late summer, 1999, the south basin formed a 27-foot-thick thermo-cline from 15 to 42 feet. Dissolved oxygen was plentiful above the thermocline, and started to decrease at the top of the thermocline, reaching 0.2 milligrams per liter at 26 feet. From that depth to 60 feet, dissolved oxygen concentrations fluctuated at low levels. The lake ran out of dissolved oxygen at 60 feet. That condition remained to the bottom.



concentrations fluctuated at low levels. The lake ran out of dissolved oxygen at 60 feet. That condition remained to the bottom.

2000

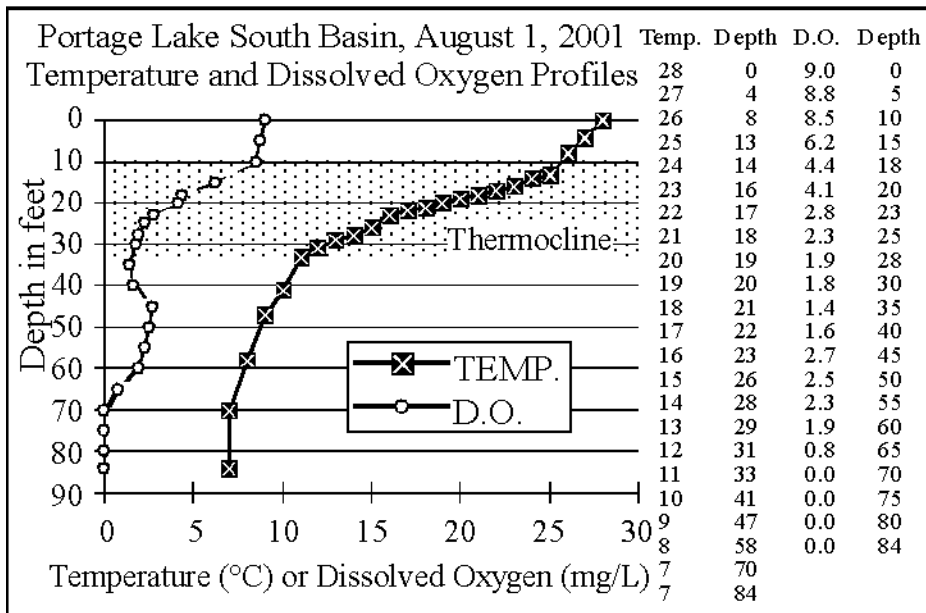
In late summer, 2000, the south basin formed a 22-foot-thick thermocline from 10 to 32 feet. Dissolved oxygen was again plentiful above the thermocline. This basin started to run out of dissolved oxygen at the top of the thermocline. It reached a low of 1.7 milligrams per liter at 25 feet. From that depth to 64 feet, dissolved oxygen fluctuated from 1.9 to 4 milligrams



per liter. The basin ran out of dissolved oxygen at 64 feet. That condition remained to the bottom.

2001

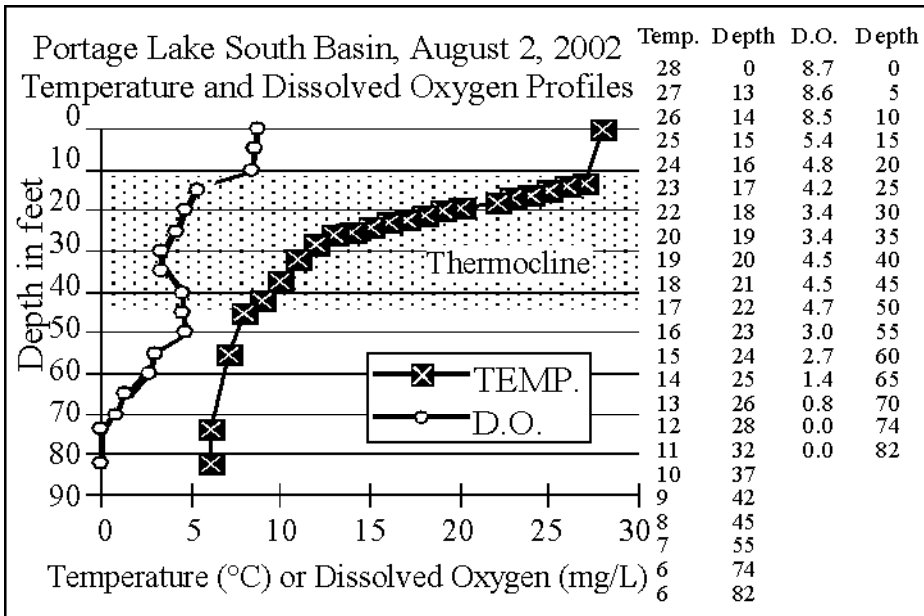
In late summer 2001 the south basin formed a 23-foot-thick thermocline from 10 to 33 feet. Dissolved oxygen was plentiful above the thermocline, and started to drop at the top of the thermocline.



It reached a low of 1.4 milligrams per liter at 35 feet. From that depth to 70 feet, dissolved oxygen concentrations fluctuated at low levels. This basin ran out of dissolved oxygen at 70 feet and that condition remained to the bottom.

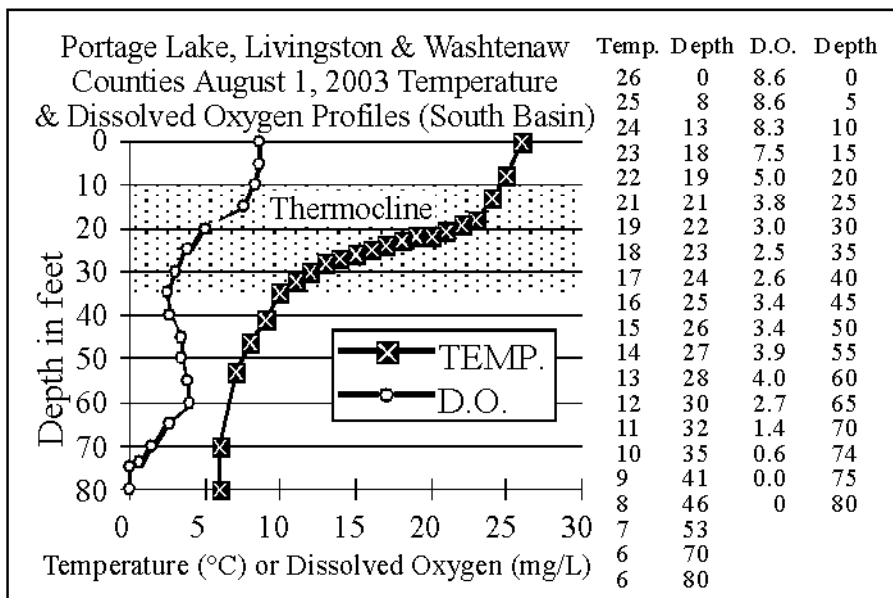
2002

In late summer 2002 the south basin formed a 32-foot-thick thermocline from 10 to 42 feet. Dissolved oxygen was plentiful above the thermocline, and started to drop at the top of the thermocline. It reached a low of 3.4 milligrams per liter at 35 feet. From that depth to 74 feet, dissolved oxygen



concentrations fluctuated at low levels. This basin ran out of dissolved oxygen at 74 feet and that condition remained to the bottom.

2003



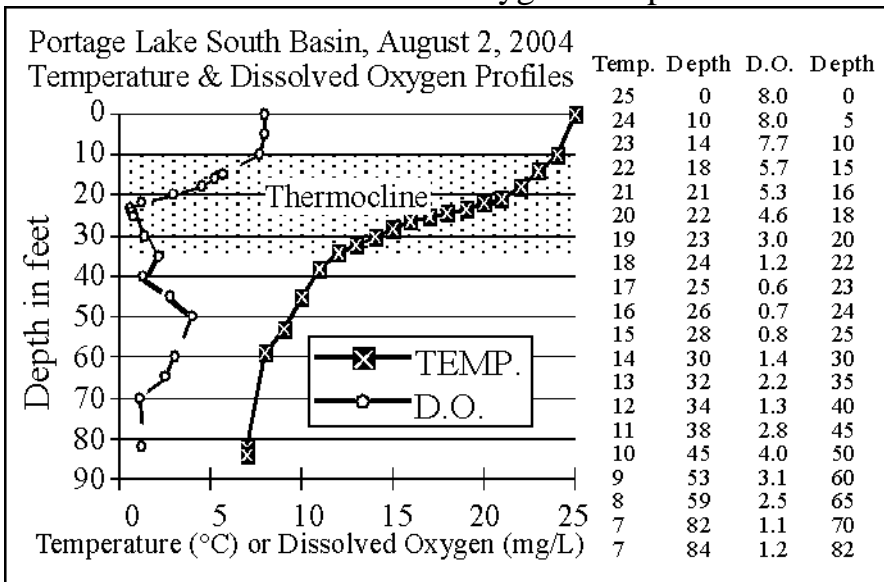
In late summer 2003 the south basin formed a 24-foot-thick thermocline from 10 to 34 feet. Dissolved oxygen was plentiful above the thermocline, and started to drop at the

top of the thermocline. It reached a low of 2.5 milligrams per liter at 35 feet. From that depth to 74 feet, dissolved oxygen concentrations fluctuated at low levels. This basin ran out of dissolved oxygen at 75 feet and that condition remained to the bottom.

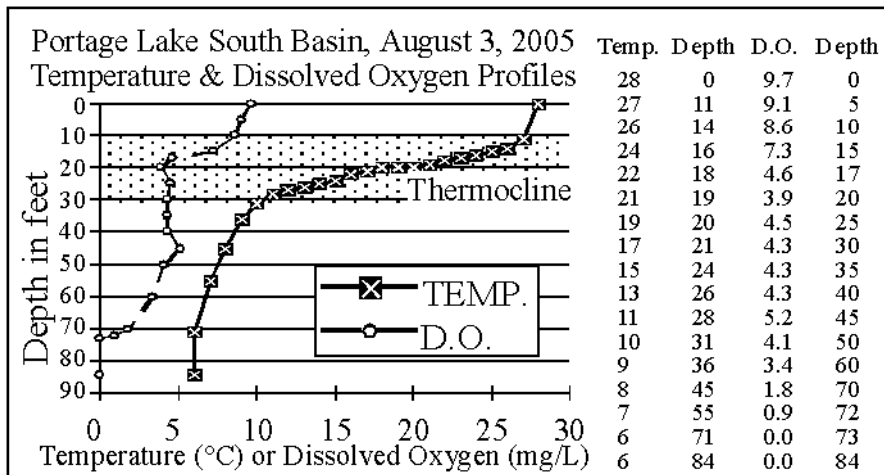
About 5 percent of the basin is deeper than 75 feet.

2004

In late summer 2004 the south basin formed a 24-foot-thick thermocline from 10 to 34 feet. Dissolved oxygen was plentiful above the thermocline, and started to drop at the top of the thermocline. It reached a low of 0.6



and started to drop at the top of the thermocline. It reached a low of 0.6 milligrams per liter at 23 feet. From that depth to the bottom, dissolved oxygen concentrations fluctuated at low levels.

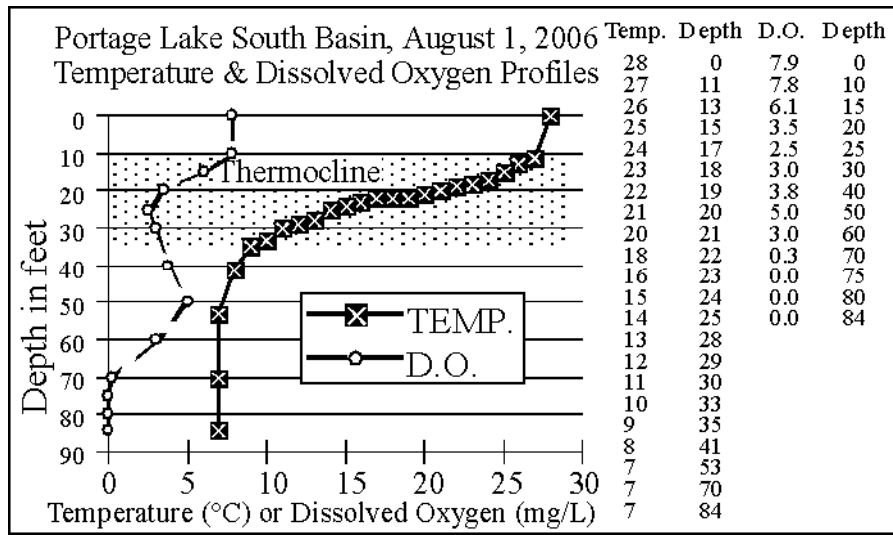


This basin did not run out of dissolved oxygen at any depth in 2004.

2005

In late summer 2005 the south

basin formed a 21-foot-thick thermocline from 10 to 31 feet. Dissolved oxygen was plentiful above the thermocline, and started to drop at the top of the thermocline. It reached a low of 3.9 milligrams per liter at 20 feet. From that depth to the bottom, dissolved oxygen concentrations fluctuated at low levels. This basin ran out of dissolved oxygen at 73 feet in 2005.



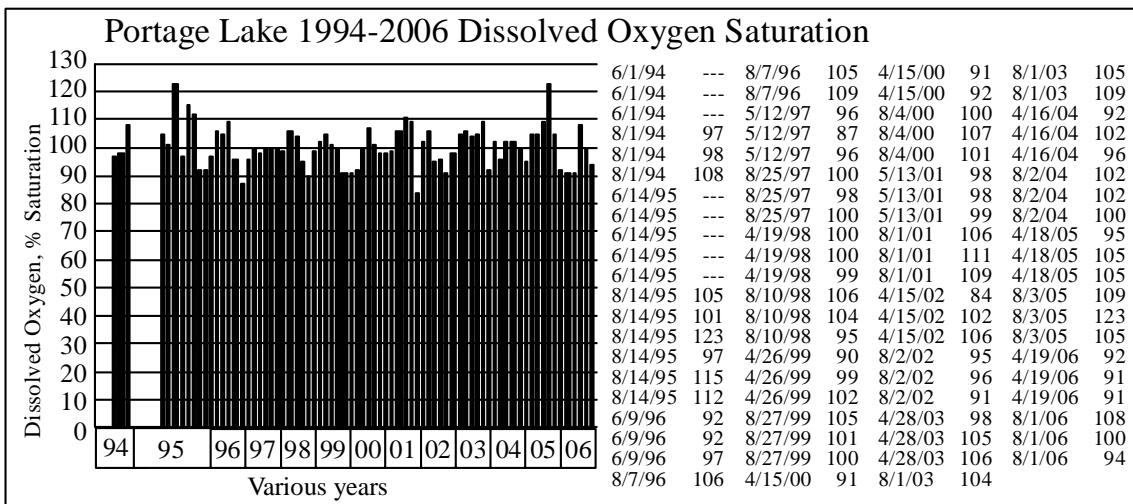
2006

In late summer 2006 the south basin formed a 25-foot-thick thermocline from 10 to 35 feet. Dissolved oxygen was plentiful above the thermocline,

and started to drop at the top of the thermocline. It reached a low of 2.5 milligrams per liter at 25 feet, then increased to 4.0 mg/L at 50 feet. From that depth dissolved oxygen concentrations gradually decreased. This basin ran out of dissolved oxygen at 75 feet in 2006.

It is unusual (but not rare) for a lake to have low levels of dissolved oxygen for a considerable depth under the thermocline. There are several other lakes we study with the same conditions. This is better than when the lake runs out of dissolved oxygen in or just below the thermocline and stays that way.

DISSOLVED OXYGEN SATURATION

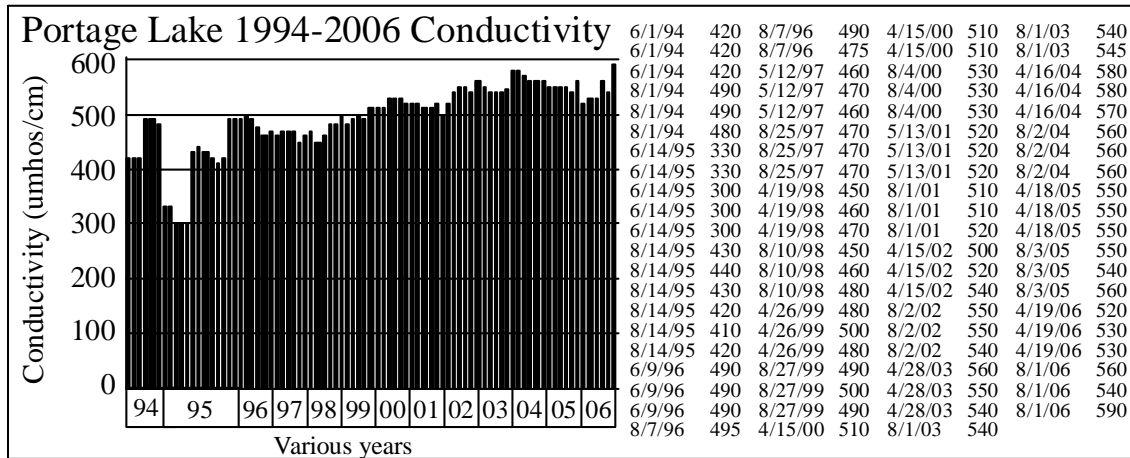


Because the amount of dissolved oxygen a water can hold is temperature dependent, with cold water holding more than warm water, dissolved oxygen saturation is often a better way to determine if dissolved oxygen supplies are adequate.

The graph shows the dissolved oxygen saturation values of surface samples generally range between 90 and 110 percent, which is good.

CONDUCTIVITY

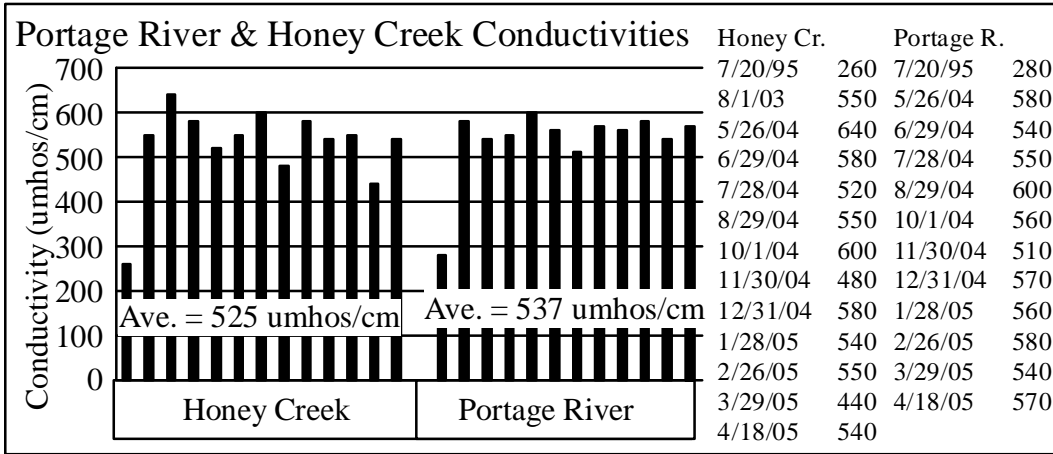
Conductivity, measured with a meter, detects the capacity of a water to conduct an electric current. More importantly however, it measures the amount of materials dissolved in the water, since only dissolved materials (salts) will permit an electric current to flow. Theoretically, pure water will not 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 spring and summer conductivities range from 300 micromhos/cm (in June 1995) to 590 umhos/cm in summer 2006. These are on the high end of normal for conductivities in a Michigan inland lake. The graph shows conductivity is increasing. This indicates salts are entering the lake from near-shore areas. And this will only increase as more and more riparian water softeners dump salt into the lake.

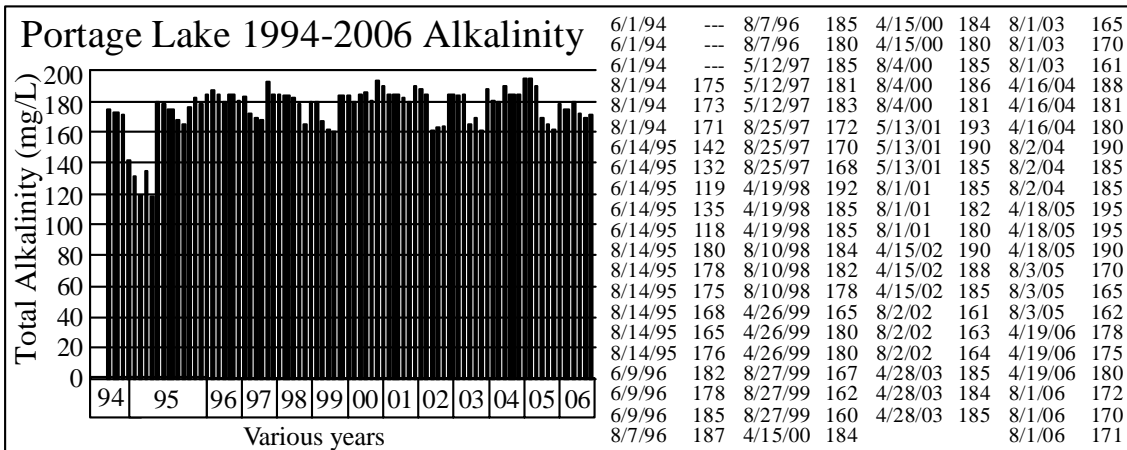
Normal conductivities in Michigan inland lakes range from 75 to 450 micromhos per centimeter.

The graph shows the results of the year-long (2004-5) study of Honey Creek and the Portage River. It shows the conductivities of these two inlets are about the same as the lake.



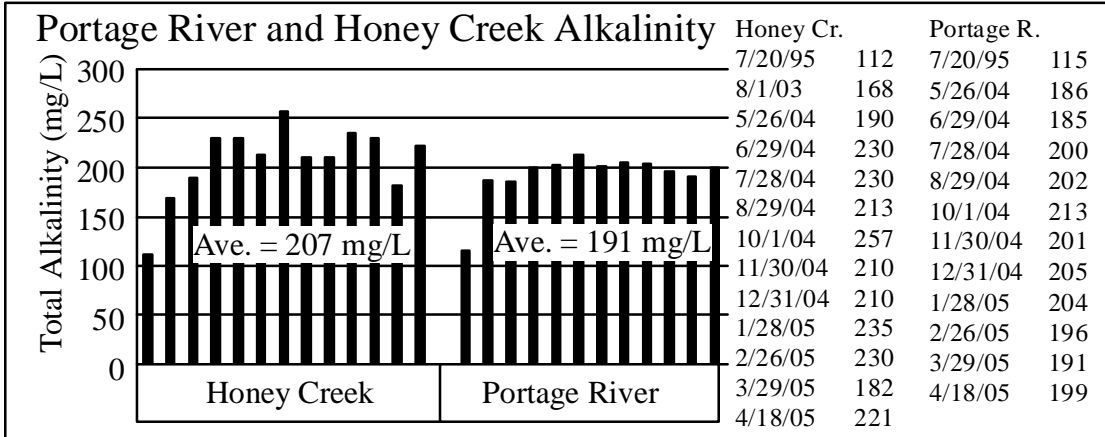
TOTAL ALKALINITY

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.



The spring and summer surface alkalinity of Portage Lake ranges from 118 to 195 milligrams per liter. These data indicate the lake is a hard water lake. The graph seems to show a lot of variability in the alkalinity concentrations, but no specific trend.

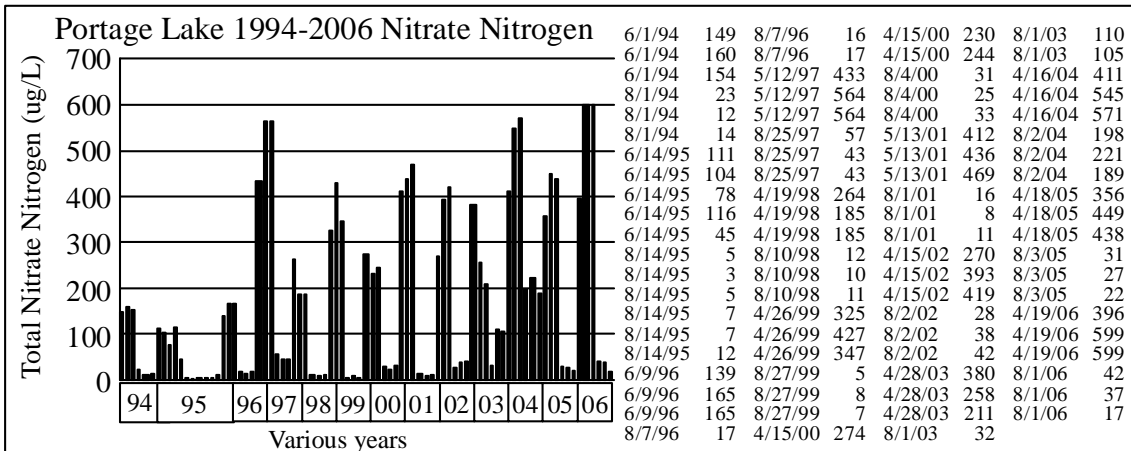
The 2004-5 alkalinities of the two inlets are higher than the lake, but this is normal. Streams usually have higher alkalinities than lakes, because the carbonates and bicarbonates, which are what the alkalinity test measures, enter streams with the groundwater but precipitate in lakes.



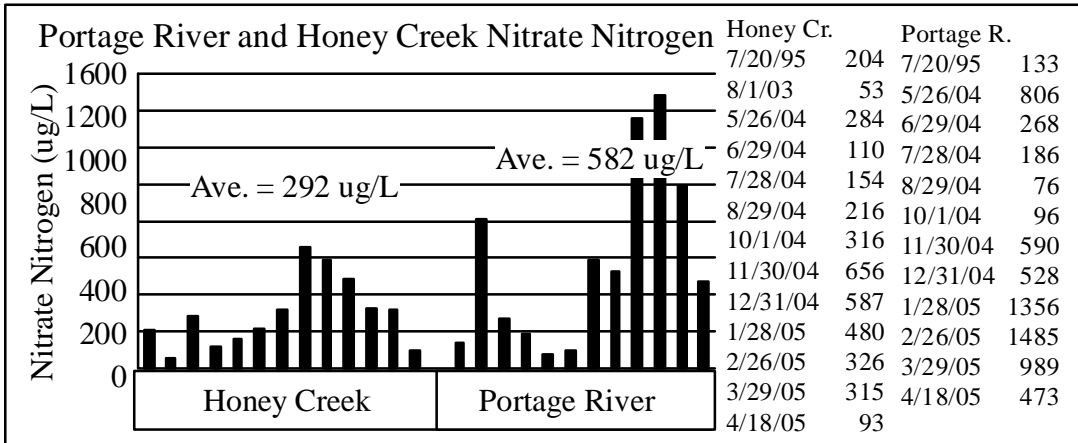
Hard water lakes are tougher than soft water lakes because they have the ability to precipitate some phosphorus to the bottom sediments as calcium phosphate where it is permanently tied up.

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 range from a low of 78 micrograms per liter (in 1995) to a high of 599 micrograms per liter in 2006. Summer values are lower, ranging from 3 to 221 micrograms per liter. These data indicate Portage Lake is probably nitrate rather than phosphorus limited, especially in summer. It also means no fertilizers containing either nitrogen or phosphorus should be used on near-lake areas.



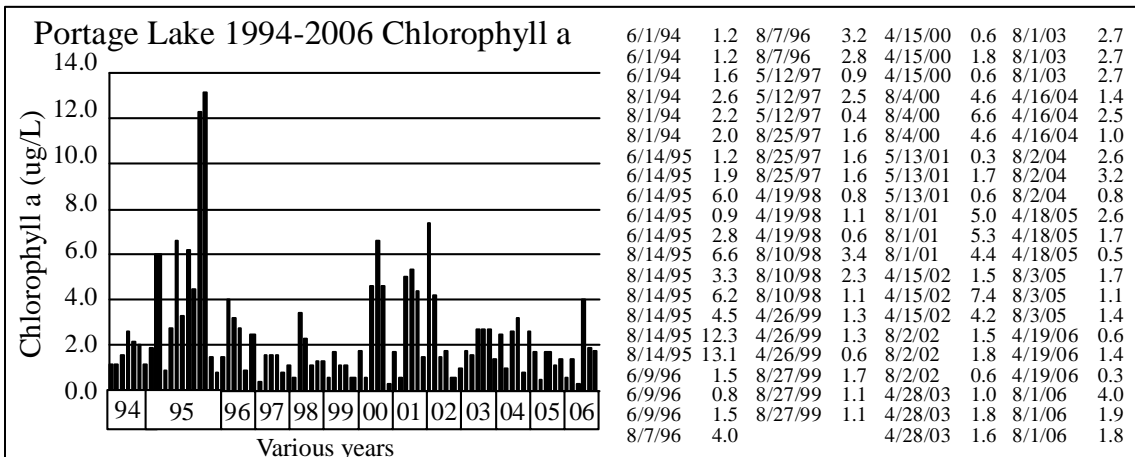
The graph shows the results of the 2004-5 year-long stream study. It shows nitrates in 13 Honey Creek samples range from 53 to 656 micrograms per liter and average 292 micrograms per liter. The nitrate nitrogen concentrations of the 12 Portage River samples range from 76 to 1485 micrograms per liter, and average 582 micrograms per liter.

So in the case of nitrates, the Portage River has nitrate concentrations twice as high as Honey Creek. Plus the flow of the Portage River is three times larger than that of Honey Creek, so the Portage River actually adds six times more nitrate nitrogen to Portage Lake each year compared to Honey Creek.

CHLOROPHYLL A

Chlorophyll a, reported in micrograms per liter (or parts per billion) generally gives an estimate of algal densities. Best is below 1 ug/L

The chlorophyll data shows Portage Lake had significant algal blooms in 1995, 2000, 2001 and 2002 especially when compared to 1994, 1997, 1998, 1999, 2003, 2004 and 2005. The graph shows summer chlorophylls are generally higher than spring chlorophylls. The lower than average chlorophylls in 2003, 2004, 2005 and 2006 are encouraging.



pH (Hydrogen ion concentration) (no graph)

1994 through 2006 spring and summer surface pH values ranged from 7.8 to 8.8. These are normal pH values for a Michigan inland lake fed by a river.

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.

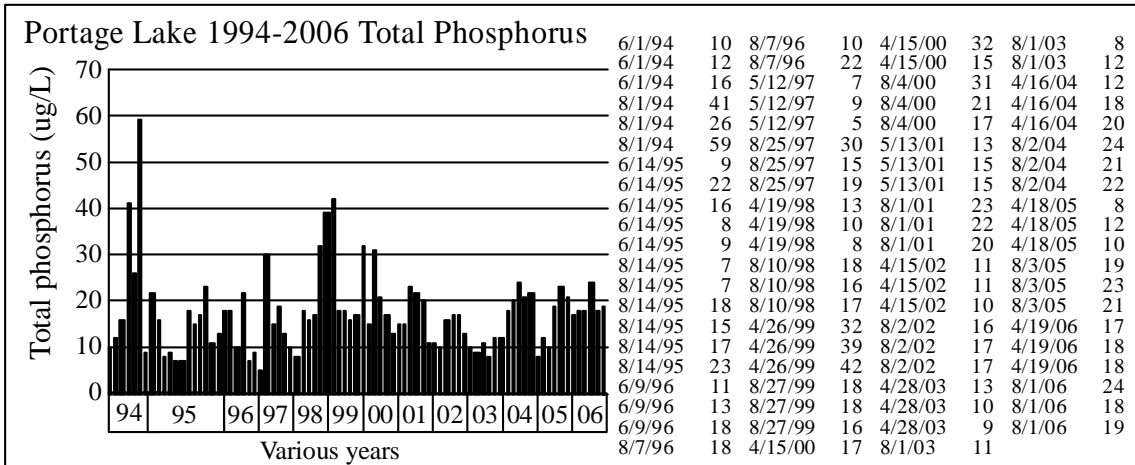
TOTAL PHOSPHORUS

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.

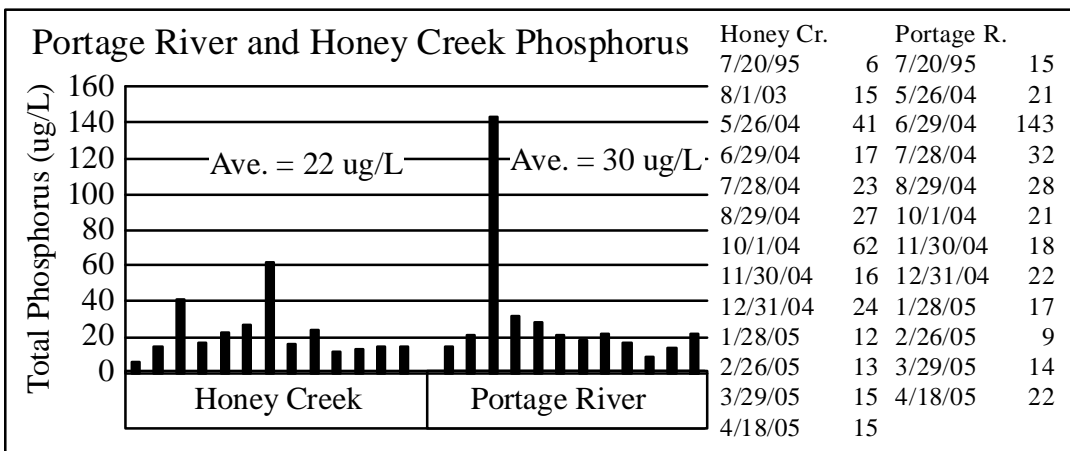
However, based on our studies of many Michigan inland lakes, we've found many lakes were phosphorus limited in spring (so don't add phosphorus) and nitrate limited in summer (so don't add nitrogen).

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

The graph shows phosphorus concentrations range from 5 to 60 micrograms per liter, but are generally in the 10 to 20 microgram per liter range. The graph seems to show since 1999, phosphorus concentrations may be



decreasing. In spring 2005 phosphorus concentrations ranged from 8 to 12 micrograms per liter. These are very acceptable phosphorus concentrations.



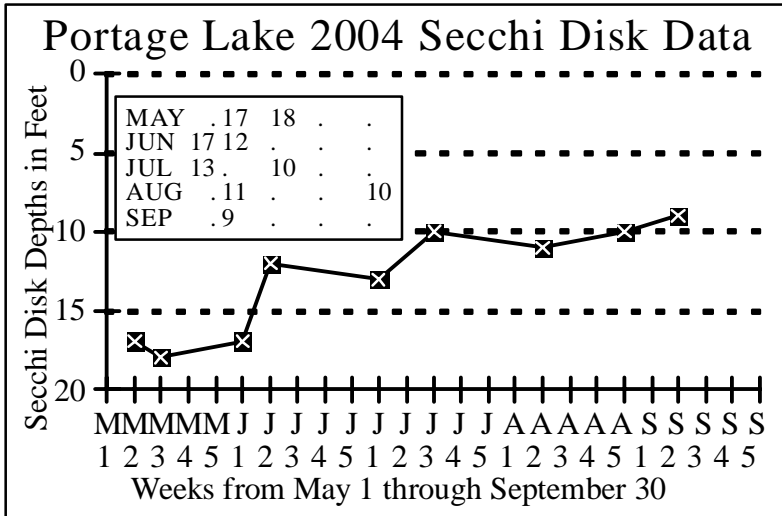
The 2004-5 year-long study of Honey Creek and the Portage River found phosphorus concentrations in Honey Creek ranged from 6 to 62 micrograms per liter, and averaged 22 micrograms per liter, while the phosphorus concentrations of the Portage River ranged from 9 to 143 micrograms per liter, and averaged 30 micrograms per liter.

The average phosphorus concentration of Portage Lake, based on 84 samples is 17 micrograms per liter.

It appears the Portage River adds about twice the amount phosphorus to the lake than Honey Creek does.

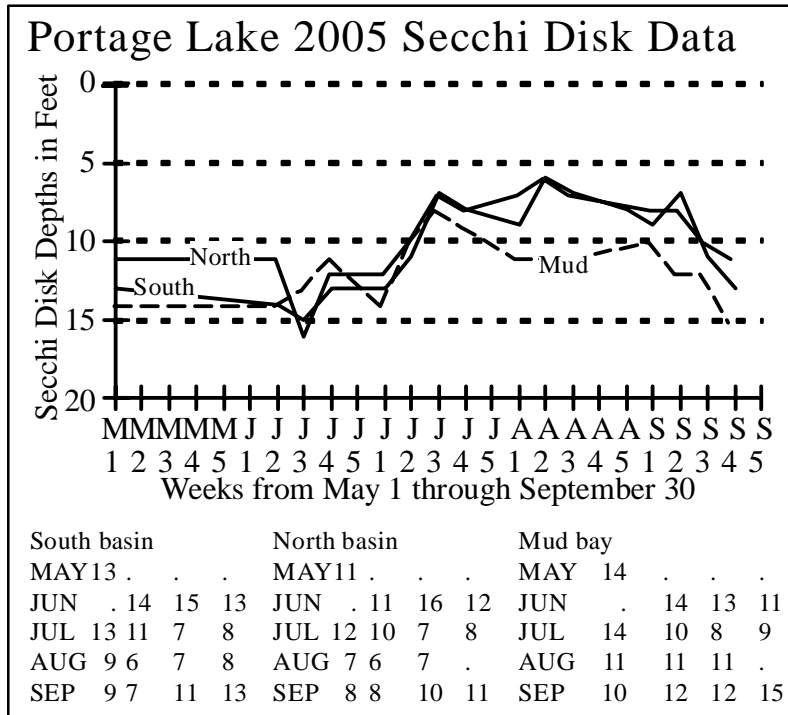
PORTAGE LAKE SECCHI DISK DATA

2004



Jim Meier took Secchi disk readings in Portage Lake in 2004. The graph shows his data. It shows 17-18 foot readings when the water was cool in spring, and then as the water warmed, the clarity decreased to 9 to 11 feet.

2005



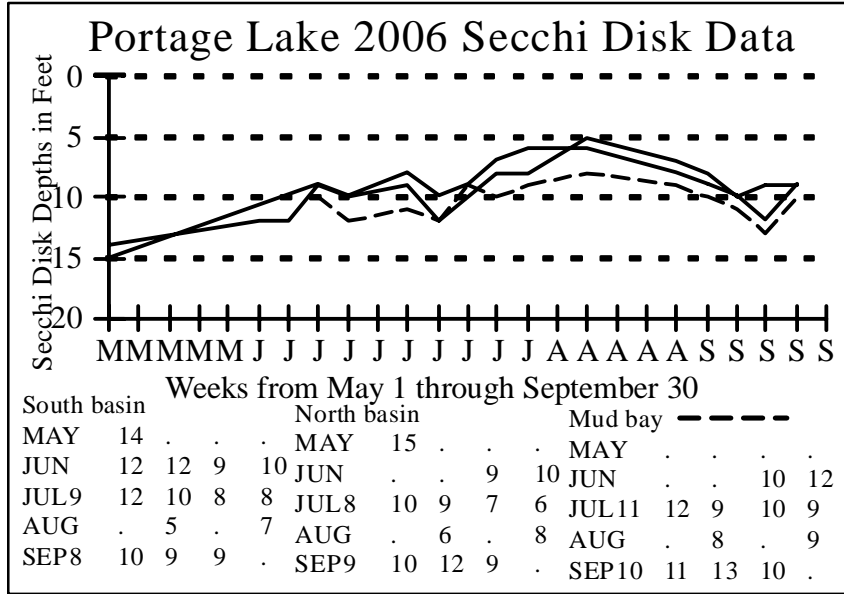
Bill Ferrington did a good job taking Secchi disk readings at three sites in the lake in 2005, the north basin, the south basin and Mud Bay. The graph shows his data.

It shows deeper spring readings and shallower summer readings, as did the 2004 and 2005 data. Surprisingly, Mud Bay had deeper

August and September readings than either the north or south basins.

2006

Bill Ferrington did a good job taking Secchi disk readings at three sites in the lake in 2006, the north basin, the south basin and Mud Bay. The graph shows his data.

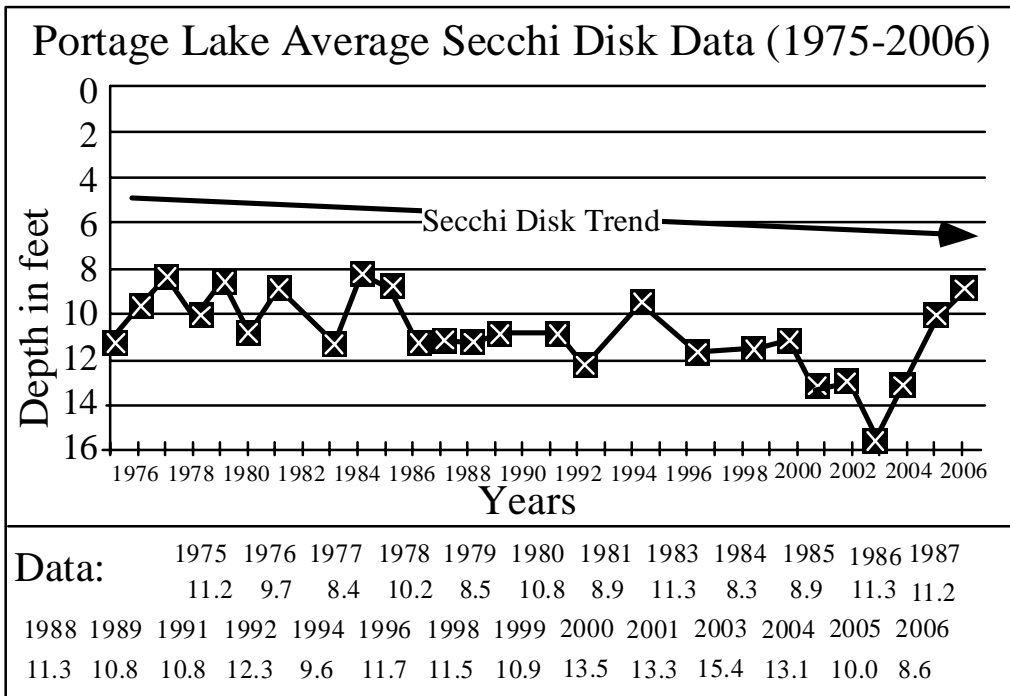


shows his data.

It shows deeper spring readings and shallower summer readings, as did Meier's 2004 data.

Surprisingly, Mud Bay had deeper readings than did either the north or south basins in 2006.

THE SECCHI DISK TREND GRAPH

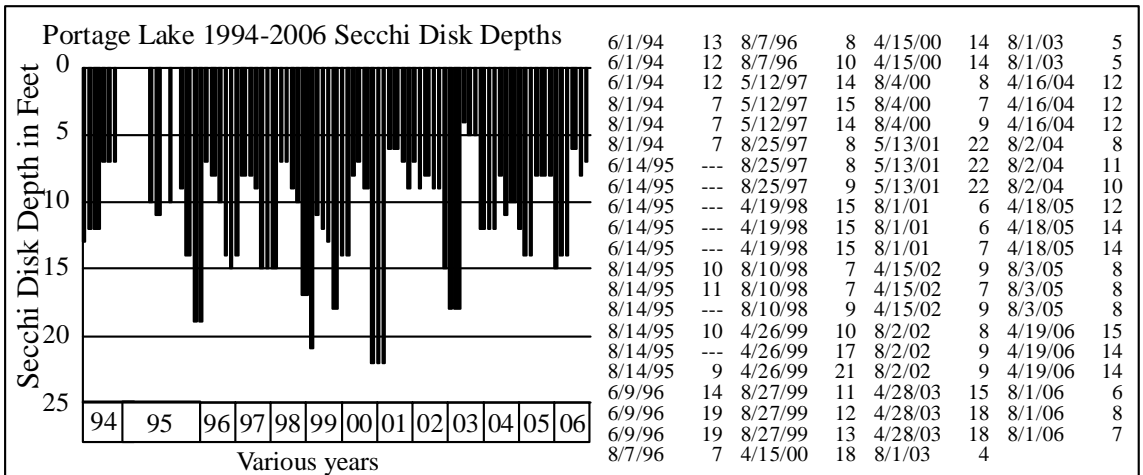


Because Portage Lake residents have been taking Secchi disk readings on a regular basis since 1975, we were able to construct a Secchi Disk Trend Graph.

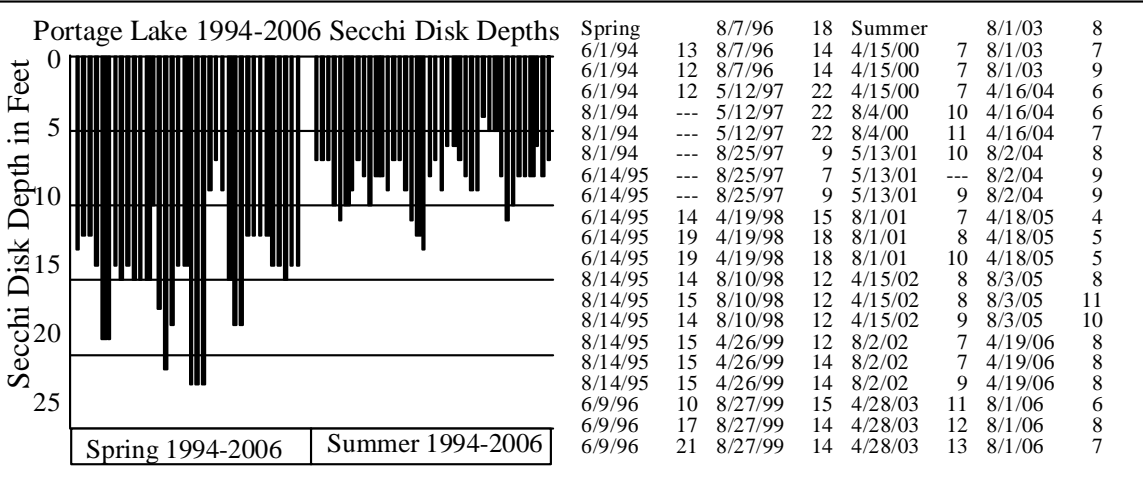
The graph shows Portage Lake had been getting clearer as the years pass. However, in 2004, 2005 and 2006 average Secchi disk readings decreased. Let's hope this trend doesn't continue.

SECCHI DISK READINGS TAKEN WITH THE SAMPLES

The graph shows the Secchi disk readings taken with the samples, sorted by year.



It shows spring 2001 was best at 22 feet. Since that time the water clarity in spring has been decreasing



The above graph shows the same data, but this time sorted first by spring and summer, then by years. The reason this was done was to see whether spring or summer readings, or both, were changing over the years. It shows spring values are changing more than summer values.

THE LAKE WATER QUALITY INDEX

The Lake Water Quality Index used in this study to define the water quality of Portage 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 involved 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.

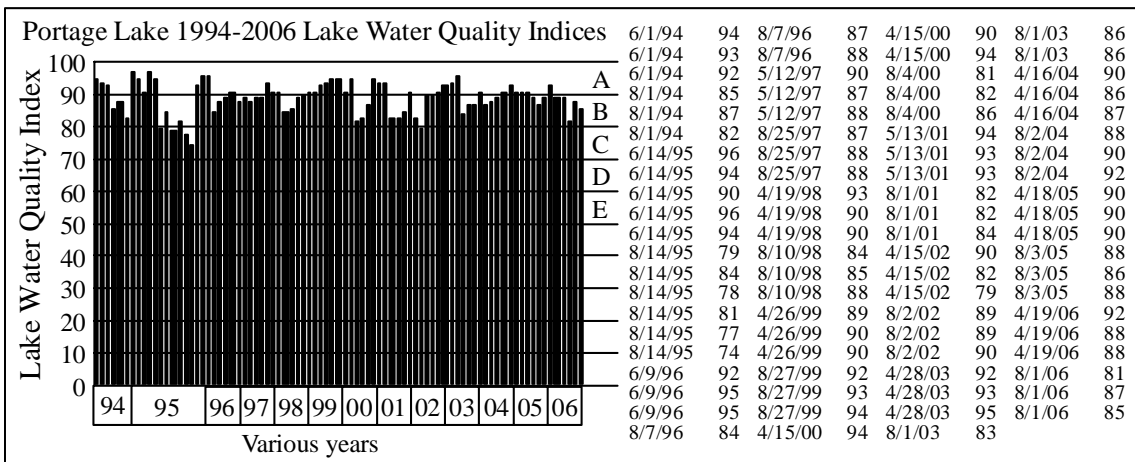
The position of the red lines across the thermometer indicates how the results of each test compare in terms of lake water quality. Test results indicating excellent water quality are indicated by red lines near the top of the thermometer. Test results indicating poor water quality are indicated by red 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 1994-2006 PORTAGE LAKE WATER QUALITY INDICES

The graph shows the Lake Water Quality Indices for Portage Lake range from a low of 74 in summer 1995 to a high of 96 in spring 1995. The graph does not seem to show any specific trend.



The graph shows in 2006, the spring Lake Water Quality Indices for Portage Lake were 88 or 90, or in the B to A range. In summer 2006 the lake water quality indices were 81, 87 and 85, or in the B range.

One of the things the graph doesn't show is any change in the water quality of the lake since the sewers were installed.

THE LAKE WATER QUALITY INDEX CALCULATION SHEETS

Because the spring 2006 Lake Water Quality Indices at the three surface stations were similar (90 88 88), one LWQI calculation sheet is included in this report for the three spring surface samples, using averaged data.

In summer 2006 the LWQIs were similar (81, 87, 85) so a second LWQI calculation sheet is included for the three summer surface samples, using averaged data.

In the report marked MASTER, all 6 of the 2006 LWQI calculation sheets are included. That is the only difference between the MASTER and the rest of the reports.

PORTAGE LAKES 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.

PORTAGE LAKE BOTTOM SEDIMENTS

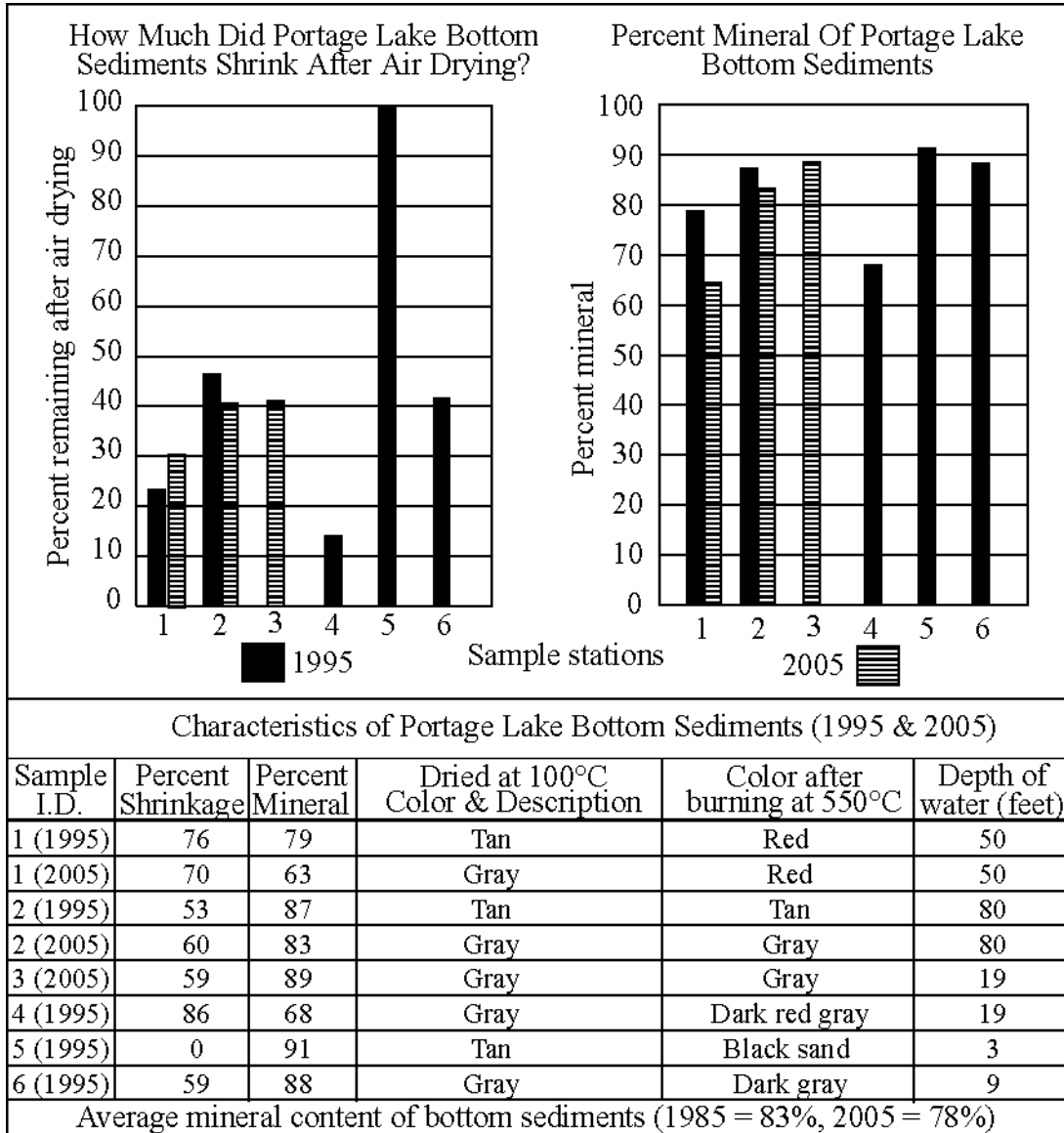
Five bottom sediment samples were collected from Portage Lake and associated canals in 1995. Three bottom sediment samples were collected from the in-lake stations in 2005. The graph below shows the data.

The 1995 sample from Station 1 (the north basin) collected in 50 feet of water shrunk 76 percent, and was 79 percent mineral. It turned tan after air drying and red after burning at 550 degrees C.

The 2005 sample from Station 1 (the north basin), again collected in 50 feet of water, was black when recovered, shrunk 70 percent, turned gray after air drying, and red after burning at 550 degrees C. It was 63 percent mineral.

The red color is the result of clay entering the lake from near shore activities such as home building and road building. Clay is not a normal constituent of lake bottom sediments.

Sample 2 collected from the south basin in 1995 from 80 feet of water, shrunk 53 percent, and was 87 percent mineral. It turned tan after air-drying and remained tan after burning at 550 degrees C.



The 2005 sample from Station 2 (the south basin), collected in 80 feet of water, was black when recovered, shrunk 60 percent, turned gray after air drying, and remained gray after burning at 550 degrees C. It was 83 percent mineral.

These are very good bottom sediments collected from the deepest hole in the lake.

The 2005 sample from Station 3 (the south basin), collected in 19 feet of water, was black when recovered, shrunk 59 percent, turned gray after air drying, and remained gray after burning at 550 degrees C. It was 89 percent mineral.

The 2005 samples from stations 1 & 2 both have lower mineral contents than the 1995 samples from the same stations. This indicates the lake is building up organic material in the sediments at a faster than normal rate.

In 1995, Sample 4 was collected from 19 feet of water in Mud Bay. It shrunk the most, 86 percent, and had the lowest mineral content of the 1995 samples, 68 percent. It also turned dark red gray indicating clay was present. This was probably the result of the recent home building activity along the canal.

In 1995, Sample 5, taken from Wynn's Canal in 3 feet of water had the highest mineral content (91%), and shrunk the least (0%). The sample was essentially sand. And these are characteristics of sandy bottom sediments.

In 1995, Sample 6 was collected from 9 feet of water in Colony Canal. It shrunk 59 percent and was 88 percent mineral. It turned gray after air-drying and remained gray after burning at 550°C.

The 1995 Sample 5 and 6 canal sediments collected in shallow water show the canals were recently dug, and have not had a lot of time to accumulate organics.

Wallace E. Fusilier, Ph.D.
Consulting Limnologist
Water Quality Investigators
Dexter, Michigan
May 2007

Surface Lake Water Quality Data

Date	Sample Station Number	Temperature °C	Dissolved Oxygen		Chlorophyll a ug/L	Secchi Disk Depth (feet)	Total Nitrate Nitrogen ug/L	Alkalinity mg/L	pH	Conductivity umhos/cm@25°C	Total Phosphorus ug/L	Lake Water Quality Index	Grade
			(m g/L)	Percent Saturation									
6/1/94	1	---	---	---	1.2	13	149	---	8.2	420	10	94	A
6/1/94	2	---	---	---	1.2	12	160	---	8.2	420	12	93	A
6/1/94	3	---	---	---	1.6	12	154	---	8.3	420	16	92	A
8/1/94	1	24	8.8	97	2.6	7	23	175	8.3	490	41	85	B
8/1/94	2	24	8.7	98	2.2	7	12	173	8.3	490	26	87	B
8/1/94	3	24	9.2	108	2.0	7	14	171	8.3	480	59	82	B
6/14/95	1	---	---	---	1.2	---	111	142	7.9	330	9	96	A
6/14/95	2	---	---	---	1.9	---	104	132	7.7	330	22	94	A
6/14/95	3	---	---	---	6.0	---	78	119	8.0	300	16	90	A
6/14/95	4	---	---	---	0.9	---	116	135	7.7	300	8	96	A
6/14/95	5	---	---	---	2.8	---	45	118	7.8	300	9	94	A
8/14/95	1	31	7.9	105	6.6	10	5	180	8.8	430	7	79	C
8/14/95	2	30	7.7	101	3.3	11	3	178	8.8	440	7	84	B
8/14/95	3	31	9.2	123	6.2	---	5	175	8.8	430	18	78	C
8/14/95	4	32	7.2	97	4.5	10	7	168	8.6	420	15	81	B
8/14/95	5	32	8.5	115	12.3	---	7	165	8.3	410	17	77	C
8/14/95	6	32	8.3	112	13.1	9	12	176	8.7	420	23	74	C
6/9/96	1	21	8.3	92	1.5	14	139	182	8.4	490	11	92	A
6/9/96	2	21	8.3	92	0.8	19	165	178	8.3	490	13	95	A
6/9/96	3	22	8.5	97	1.5	19	165	185	8.2	490	18	95	A
8/7/96	1	27	8.5	106	4.0	7	17	187	8.4	495	18	84	B
8/7/96	2	26	8.6	105	3.2	8	16	185	8.4	490	10	87	B
8/7/96	3	27	8.7	109	2.8	10	17	180	8.3	475	22	88	B
5/12/97	1	12	10.4	96	0.9	14	433	185	8.3	460	7	90	A
5/12/97	2	11	9.7	87	2.5	15	564	181	8.2	470	9	87	B
5/12/97	3	12	10.4	96	0.4	14	564	183	8.3	460	5	88	B
8/25/97	1	21	9.0	100	1.6	8	57	172	8.5	470	30	87	B
8/25/97	2	22	8.6	98	1.6	8	43	170	8.6	470	15	88	B
8/25/97	3	21	9.1	100	1.6	9	43	168	8.6	470	19	88	B
4/19/98	1	13	10.6	100	0.8	15	264	192	8.3	450	13	93	A
4/19/98	2	12	10.8	100	1.1	15	185	185	8.3	460	10	90	A
4/19/98	3	12	10.7	99	0.6	15	185	185	8.3	470	8	90	A
8/10/98	1	26	8.7	106	3.4	7	12	184	8.8	450	18	84	B
8/10/98	2	26	8.5	104	2.3	7	10	182	8.8	460	16	85	B
8/10/98	3	26	7.8	95	1.1	9	11	178	8.7	480	17	88	B
4/26/99	1	14	9.4	90	1.3	10	325	165	8.0	480	32	89	B
4/26/99	2	13	10.5	99	1.3	17	427	180	8.2	500	39	90	A
4/26/99	3	14	10.6	102	0.6	21	347	180	8.3	480	42	90	A
8/27/99	1	24	8.9	105	1.7	11	5	167	8.4	490	18	92	A
8/27/99	2	23	8.8	101	1.1	12	8	162	8.4	500	18	93	A
8/27/99	3	24	8.5	100	1.1	13	7	160	8.3	490	16	94	A
4/15/00	1	9	10.5	91	0.6	18	274	184	8.4	510	17	94	A
4/15/00	2	9	10.6	91	1.8	14	230	184	8.3	510	32	90	A
4/15/00	3	10	10.4	92	0.6	14	244	180	8.3	510	15	94	A
8/4/00	1	24	8.5	100	4.6	8	31	185	8.8	530	31	81	B
8/4/00	2	24	9.1	107	6.6	7	25	186	8.7	530	21	82	B
8/4/00	3	24	8.6	101	4.6	9	33	181	8.6	530	17	86	B
5/13/01	1	19	9.2	98	0.3	22	412	193	8.5	520	13	94	A
5/13/01	2	19	9.2	98	1.7	22	436	190	8.4	520	15	93	A
5/13/01	3	19	9.3	99	0.6	22	469	185	8.4	520	15	93	A
8/1/01	1	28	8.4	106	5.0	6	16	185	8.3	510	23	82	B
8/1/01	2	28	8.8	111	5.3	6	8	182	8.2	510	22	82	B
8/1/01	3	28	8.6	109	4.4	7	11	180	8.1	520	20	84	B
4/15/02	1	10	9.5	84	1.5	9	270	190	8.3	500	11	90	A
4/15/02	2	12	11.0	102	7.4	7	393	188	8.4	520	11	82	B
4/15/02	3	12	11.4	106	4.2	9	419	185	8.3	540	10	79	C
8/2/02	1	27	7.6	95	1.5	8	28	161	8.6	550	16	89	B
8/2/02	2	28	7.6	96	1.8	9	38	163	8.7	550	17	89	B
8/2/02	3	28	7.2	91	0.6	9	42	164	8.6	540	17	90	A
4/28/03	1	14	10.2	98	1.0	15	380	185	8.3	560	13	92	A
4/28/03	2	13	11.1	105	1.8	18	258	184	8.2	550	10	94	A
4/28/03	3	13	11.2	106	1.6	18	211	185	8.2	540	9	94	A
8/1/03	1	26	8.5	104	2.7	4	32	165	8.7	540	11	83	B
8/1/03	2	26	8.6	105	2.7	5	110	170	8.6	540	8	86	B
8/1/03	3	26	8.9	109	2.7	5	105	161	8.6	545	12	86	B

Surface Lake Water Quality Data

Date	Sample Station Number	Temperature °C	Dissolved Oxygen		Chlorophyll a ug/L	Secchi Disk Depth (feet)	Total Nitrate Nitrogen ug/L	Alkalinity mg/L	pH	Conductivity umhos/cm@25°C	Total Phosphorus ug/L	Lake Water Quality Index	Grade
			(mg/L)	Percent Saturation									
4/16/04	1	9	10.7	92	1.4	12	411	188	8.1	580	45	86	B
4/16/04	2	9	11.8	102	2.5	12	545	181	8.2	580	84	75	C
4/16/04	3	9	11.1	96	1.0	12	571	180	8.1	570	107	52	E
8/2/04	1	26	8.4	102	2.6	8	198	190	8.2	560	24	88	B
8/2/04	2	25	8.5	102	3.2	11	221	185	8.3	560	21	90	A
8/2/04	3	25	8.3	100	0.8	10	189	185	8.2	560	22	92	A
4/18/05	1	16	9.5	95	2.6	12	356	195	8.2	550	8	90	A
4/18/05	2	14	10.9	105	1.7	14	449	195	8.2	550	12	90	A
4/18/05	3	15	10.4	105	0.5	14	438	190	8.2	550	10	90	A
8/3/05	1	28	8.6	109	1.7	8	31	170	8.5	550	19	88	B
8/3/05	2	28	9.7	123	1.1	8	27	165	8.4	540	23	86	B
8/3/05	3	28	8.3	105	1.4	8	22	162	8.4	560	21	88	B
4/19/06	1	13	9.8	92	0.6	15	396	178	8.1	520	17	92	A
4/19/06	2	13	9.7	91	1.4	14	599	175	8.2	530	18	88	B
4/19/06	3	13	9.7	91	0.3	14	599	180	8.1	530	18	88	B
8/1/06	1	29	8.4	108	4.0	6	42	172	8.7	560	24	81	B
8/1/06	2	28	7.9	100	1.9	8	37	170	8.6	540	18	87	B
8/1/06	3	28	7.3	94	1.8	7	17	171	8.6	590	19	85	B
7/20/95	Honey Cr.	---	---	---	---	---	204	112	8.1	260	6	---	---
8/1/03	Honey Cr.	---	---	---	---	---	53	168	8.7	550	15	---	---
5/26/04	Honey Cr.	---	---	---	---	---	284	190	7.8	640	41	---	---
6/29/04	Honey Cr.	---	---	---	---	---	110	230	8.1	580	17	---	---
7/28/04	Honey Cr.	---	---	---	---	---	154	230	8.0	520	23	---	---
8/29/04	Honey Cr.	---	---	---	---	---	216	213	7.9	550	27	---	---
10/1/04	Honey Cr.	---	---	---	---	---	316	257	7.9	600	62	---	---
11/30/04	Honey Cr.	---	---	---	---	---	656	210	7.8	480	16	---	---
12/31/04	Honey Cr.	---	---	---	---	---	587	210	7.7	580	24	---	---
1/28/05	Honey Cr.	---	---	---	---	---	480	235	7.7	540	12	---	---
2/26/05	Honey Cr.	---	---	---	---	---	326	230	7.8	550	13	---	---
3/29/05	Honey Cr.	---	---	---	---	---	315	182	7.8	440	15	---	---
4/18/05	Honey Cr.	---	---	---	---	---	93	221	8.3	540	15	---	---
7/20/95	Portage R.	---	---	---	---	---	133	115	8.1	280	15	---	---
5/26/04	Portage R.	---	---	---	---	---	806	186	7.9	580	21	---	---
6/29/04	Portage R.	---	---	---	---	---	268	185	8.6	540	143	---	---
7/28/04	Portage R.	---	---	---	---	---	186	200	8.0	550	32	---	---
8/29/04	Portage R.	---	---	---	---	---	76	202	8.1	600	28	---	---
10/1/04	Portage R.	---	---	---	---	---	96	213	7.9	560	21	---	---
11/30/04	Portage R.	---	---	---	---	---	590	201	8.0	510	18	---	---
12/31/04	Portage R.	---	---	---	---	---	528	205	8.0	570	22	---	---
1/28/05	Portage R.	---	---	---	---	---	1356	204	7.8	560	17	---	---
2/26/05	Portage R.	---	---	---	---	---	1485	196	7.9	580	9	---	---
3/29/05	Portage R.	---	---	---	---	---	989	191	8.0	540	14	---	---
4/18/05	Portage R.	---	---	---	---	---	473	199	8.2	570	22	---	---