Water Quality Summary: Dissolved Oxygen

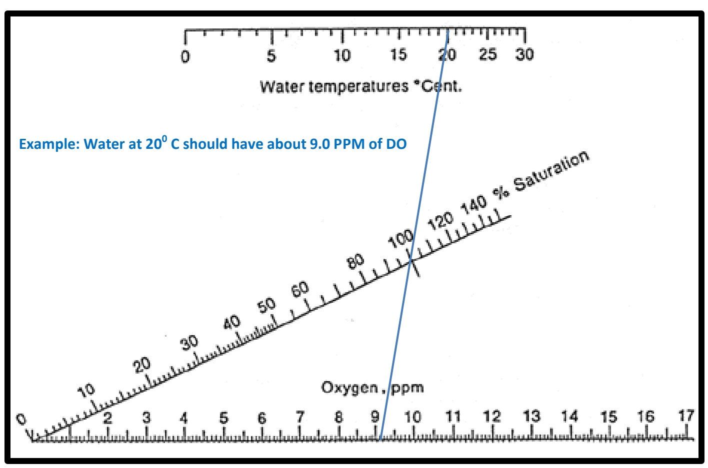
2019 Barr Lake & Milton Reservoir

Twenty times a year since 2003, **Barr Lake** and **Milton Reservoir** have been sampled for water quality. These 340 trips to both reservoirs have produced an abundance of data and information. This is Part 3 of 8 of a water quality summary series for 2019 calendar year for both reservoirs. The first two summaries focused on pH and Chlorophyll-a; this one discusses dissolved oxygen (DO).

The Big Picture – Eutrophication is the addition of nutrients to water bodies resulting in nuisance algae growth and sedimentation. This natural process usually occurs over a long geological period of time. Many lakes, reservoirs, and even estuaries and bays throughout the world experience "*cultural eutrophication*". This term means that water bodies tend to become more productive and shallower over relatively short periods of time due to increased inputs of nutrients and sediments from human activities. Accelerated aging of lakes causes a quick biological response – severe algae growth. This response then leads to other chemical and physical changes within the water – pH, oxygen, water clarity and color, fish, plants, and aesthetics can all change.

DO – Oxygen is the most fundamental parameter of lakes aside from water itself. All aquatic organisms, from fish to microscopic bacteria, need oxygen. DO is the measurement of how much oxygen gas is dissolved in water. The two mechanisms that control oxygen dissolution are diffusion from the atmosphere and photosynthesis. DO concentrations are typically expressed in units of milligrams per liter (mg/L) or parts per million (ppm). Concentrations below 1 mg/L are considered anoxic – void of oxygen and allowing internal loading of ammonia and dissolved phosphorus to occur.

Water temperature, pressure (atmospheric and hydrostatic), and the amount of dissolved salts determine the solubility of oxygen. The colder the water the more oxygen it can hold. At 32º F, one liter of water can hold about 14 mg of oxygen. The same liter of water at 80º F can hold about 8 mg – *lakes during the summer have less DO*. The higher the pressure, the less likely bubbles will form so it holds the oxygen in solution better – *lakes at higher elevation have less DO*. Water with more dissolved salts has less room for oxygen molecules – *lakes in drier areas have less DO*. At a given temperature, pressure, and salt content, there is a limited amount of DO that water can keep soluble. This is the 100% DO level. Percent DO saturation (%DO) is another way of looking at oxygen.



Quick Saturation Chart – draw a straight line from a water temperature to a DO concentration. The %DO is where the line crosses the % saturation line (note: this nonogram is for sea level).

DO or %DO can change quickly and exhibit large differences between the top, middle, and bottom water in productive lakes. Algae and wave action occur near the surface of a lake allowing for %DO to be 100% or more when in equilibrium. If it is >100%, it is often because of additional oxygen from photosynthesis. At the bottom of a lake there is no photosynthesis and the water is not in contact with the atmosphere, but at the same time it is colder and there is more hydrostatic pressure. Bottom water DO can be less than 100% due to decomposition and chemical reactions. Fish are able to avoid low DO areas and swim to where there is an acceptable amount. This is why the DO water quality standard for Colorado lakes (deeper than 5 meters) only applies to the top water (0.5 – 2.0 meters). The DO standard for **Barr Lake** and **Milton Reservoir** is 5.0 mg/L or higher at all times.

2019 DO Data – DO profile data are collected throughout the entire water column in half meter increments during each visit. DO data from 0.5 to 2.0 meters are averaged for the top water. For 2019, there were 20 DO averages recorded for each reservoir (Table 1). For **Barr Lake**, there were three concentrations below the standard and only one below the standard for **Milton Reservoir**. Both reservoirs typically see a decrease in DO in the spring after the diatom bloom.

Table 1. Barr Lake and Milton Reservoir DO data for 2019 (mg/L and %). Bold values exceed water quality target.

Month	DO (Barr)	DO (Milton)
Jan	23.9 (213%)	15.5 (136%)
Feb	18.6 (163%)	17.0 (149%)
Mar	15.8 (147%)	18.5 (170%)
Mar	14.8 (145%)	19.7 (197%)
Apr	16.1(179%)	15.7 (177%)
Apr	5.4 (62%)	9.7 (114%)
May	**4.5 (51%)**	**4.4 (52%)**
May	6.1 (71%)	6.0 (71%)
Jun	6.9 (91%)	6.6 (86%)
Jun	6.3 (85%)	6.4 (84%)
Jul	6.6 (93%)	6.2 (86%)
Jul	9.4 (137%)	6.2 (89%)
Aug	**4.6 (66%)**	6.3 (89%)
Aug	**4.8 (66%)**	7.3 (103%)
Sep	5.5 (76%)	6.0 (83%)
Sep	7.8 (100%)	6.4 (80%)
Oct	10.7 (128%)	10.5 (123%)
Oct	12.1 (128%)	9.3 (95%)
Nov	16.1 (153%)	13.4 (129%)
Dec	14.6 (126%)	16.7 (150%)

Because of year-round algal growth, both reservoirs tend to have sufficient DO – 10 of the 20 averages in 2019 were over 100% DO for both **Barr Lake** and **Milton Reservoir**. Barr had low oxygen in August after the lake-wide cyanobacteria bloom. Decomposition happens quickly after blooms creating a large oxygen demand in shallow waters. It seems to take 2-4 weeks to breakdown the organic matter and re-oxygenate the surface water.

For **Barr Lake**, Chl-a was greater than 100 µg/L from January to early April. During this period, %DO was over 100%. Then algae growth ended and decomposition followed to cause low DO in late April/early May. The winter/spring diatom bloom caused an increase in pH, DO, and Chl-a.

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The growing season (July 1 – September 30) average for **Barr Lake** was 6.5 mg/L and 6.4 mg/L for **Milton Reservoir**. In general, there is plenty of oxygen except for isolated situations when consumption is faster than supply.

Figure 1. 2019 DO data compared to water quality standard and 2003-2019 annual average.

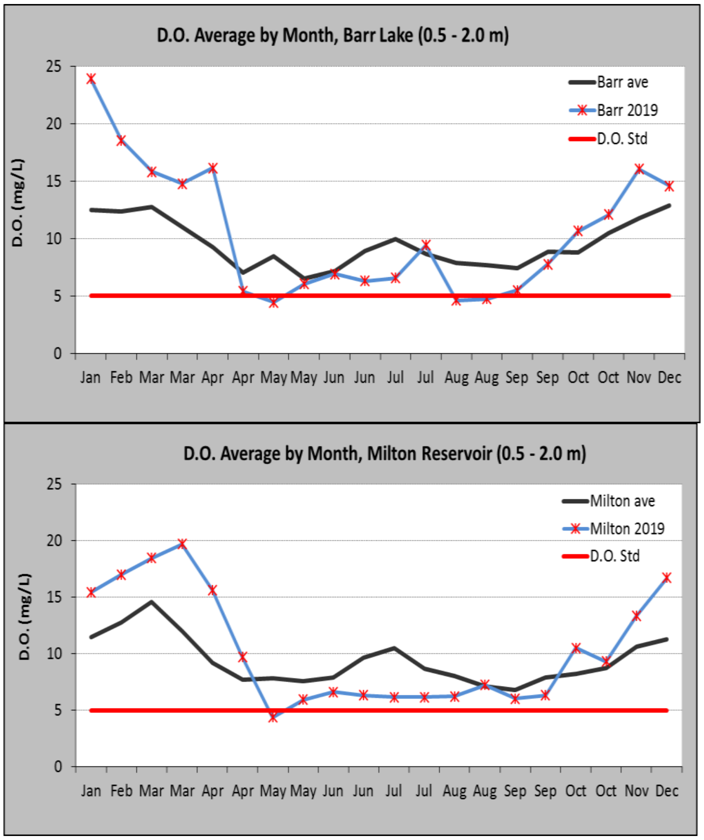

Figure 1 shows the average annual cycle of DO along with 2019 data for both reservoirs. **Barr Lake** followed the annual patterns of highs and lows. **Milton Reservoir** had a typical DO year as well with higher than average values in the winter and fall.

Oxygen Deficit Rate – Figure 2 shows the average DO for each level in Barr Lake (top, middle, and bottom). The Oxygen Deficit Rate (ODR) is the slope of the line when DO declines. It tells you how many milligrams of oxygen are being consumed over a given period of time per unit area. The ODR for **Barr Lake** from March to June 2019 was 1,317 mg of DO/m^2-day. The oxygen consumption rate is the ODR applied to the sediment area of the bottom water (the bottom 2 meters). The consumption rate was 8,280 Kg of oxygen per day. This information is useful when considering in-lake aeration systems.

The reservoir is fully mixing when all three DO lines are the same. As soon as the bottom water is not mixing, respiration starts to consume the DO. When there is an increase in top water DO, this is caused either by photosynthesis or wave action. When middle and bottom water DO increases, this is usually caused by wind mixing or algal growth in shallow conditions.

Figure 2