MIDSUMMER RENEWAL OF OXYGEN WITHIN THE HYPOLIMNION[1]

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ABSTRACT

Following a very rainy period in the summer of 1950, oxygen temporarily reappeared in the hypolimnion of Lake Mendota. It is postulated that the oxygen was introduced there by density currents of cold, silt laden, well oxygenated runoff water.

In the well known annual march of stratification in our northern lakes, the content of dissolved oxygen within the hypolimnion approaches nil soon after the onset of summer stratification (2), and the division between well oxygenated water above the thermocline and less oxygenated water below normally persists until the fall overturn. This reduction of oxygen in the hypolimnion occurred in Lake Mendota in the early part of the summer of 1950 as usual. However, in mid-July of 1950 there occurred in this region the rainiest five-day period recorded in the 85-year history of the Madison Weather Bureau Office, about 10 inches of rain falling on the Mendota watershed. Immediately following the period of rain, the Lake rose about 15 inches, and unusually high values of dissolved oxygen were measured at several levels within the hypolimnion.

DISOLVED OXYGEN (ppm)

Depth (m)	*July 11*	*July 17–18*	*July 21*	*July 26*	*August 10*
0–8	5	8.2	5.7–7.3	6.8–8.6	12.0–12.5
14–20	0–2.2	0.4–*9.5*	0.2–*7.7*	0–3.3	0– 0.5

Within a week after the rain, the oxygen values below the thermocline had returned to their normal low values. Evidently the abnormal appearance of oxygen in the lower strata of Lake Mendota was associated with the excessive rainfall. It is the purpose of this paper

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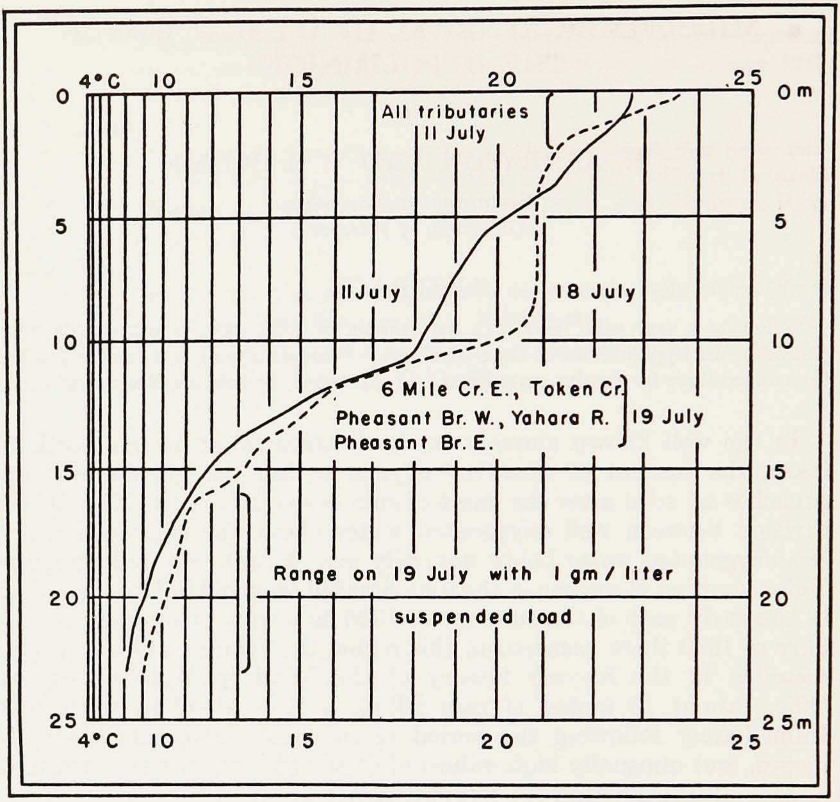

Figure 1. Change in level at which tributary waters spread due to cooling and addition of suspended load following heavy rains. The horizontal ordinate is linear with respect to density.

to suggest a mechanism whereby this renewal of oxygen could be accomplished.

Byers, et al. (1) have shown that rain temperatures in thunderstorms range from just above freezing to about the wet bulb temperature of the air. During the period in question, the wet bulb temperature of the air varied between 55° and 60° F and water temperatures within the hypolimnion ranged from 50° to 60° F. Thus the range in density of the rainwater was well below that found in the epilimnion, where temperatures of 70° to 72° F were observed. Even if the rainwater mixed with a considerable amount of this warm upper layer it might still be cold enough to sink below the epilimnion, carrying oxygen with it.

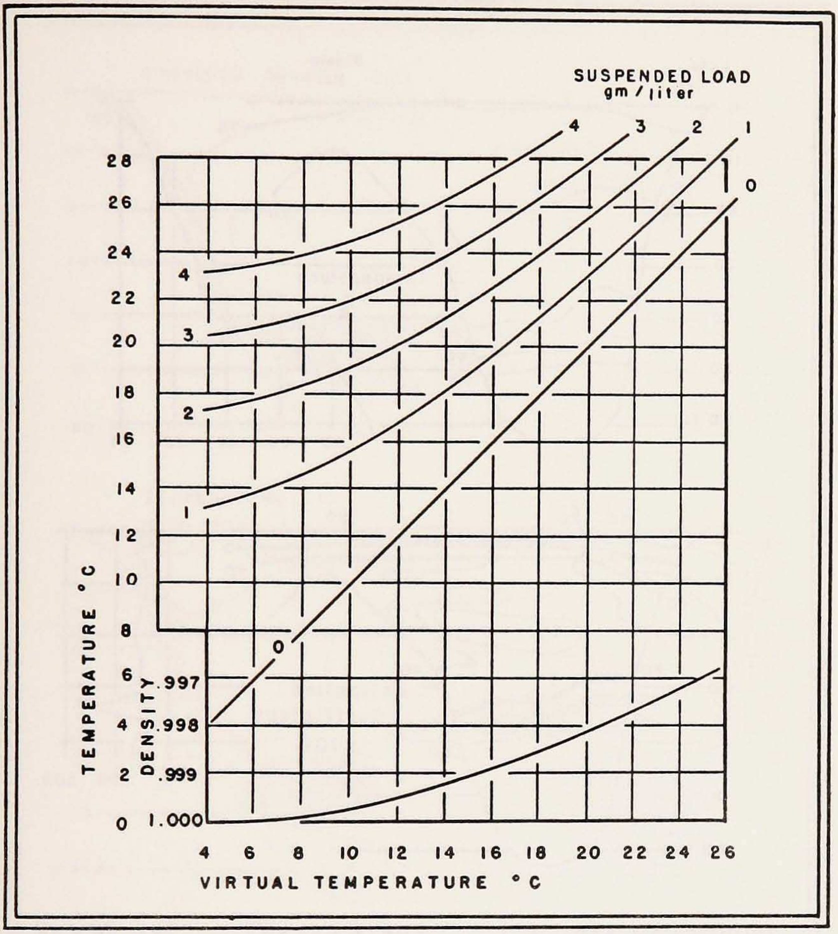

Figure 2. Graph of suspended load as a function of temperature and density. Note that a virtual temperature may be used to express the increase in density due to the suspensoids.

There are several reasons to believe that this was not the case. Before the rain, the water leaving Lake Mendota through the Yahara Locks had an alkalinity of 154 ppm., after the rain only 120 ppm. This outflow, from the upper meter, indicates that the rain actually mixed with and diluted the upper epilimnion.

On the other hand, the streams tributary to Lake Mendota provided a mechanism for carrying dissolved oxygen into the hypolimnion. Prior to the rain, the water from the tributaries, warmer than the

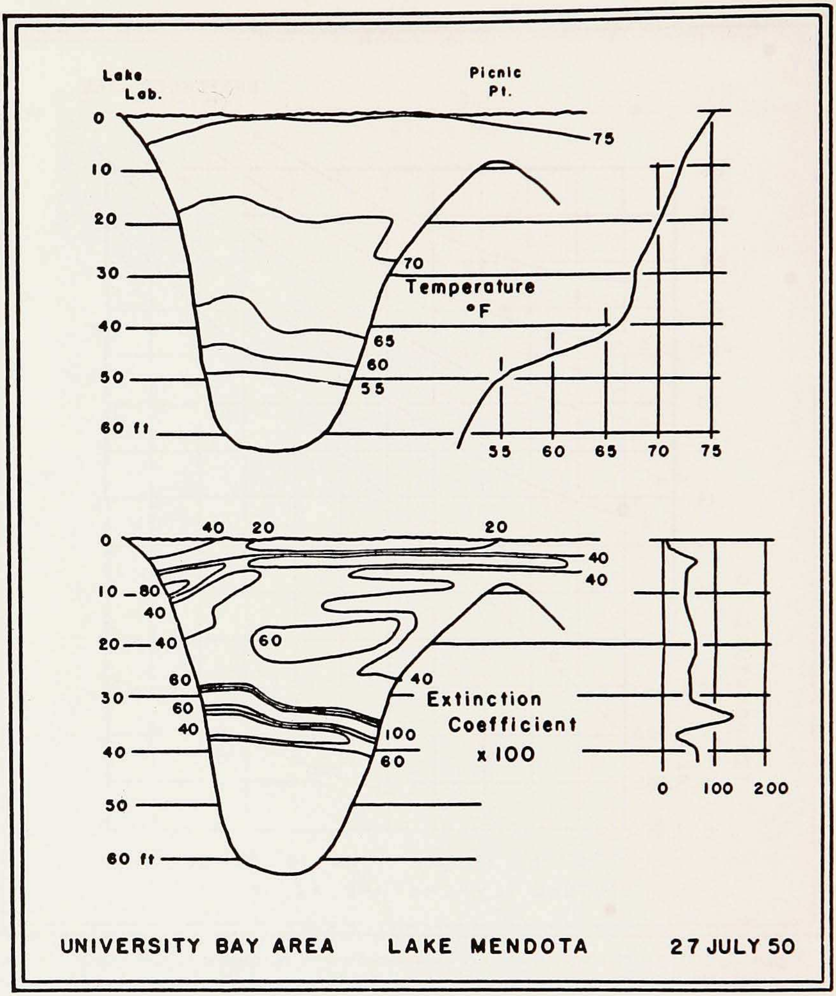

Figure 3. Distribution of temperature and extinction coefficient along a section across the mouth of University Bay, Lake Mendota. Length of section approximately one mile.

warmest lake water, would be expected to spread on the surface. After the rain, the muddy and well-aerated runoff water was cold. The density level in the Lake corresponding to this temperature was within the thermocline and upper hypolimnion (Fig. 1). However, as may be seen from Fig. 2, the effect of suspended load is to increase the density. If a conservative value of suspended load is assumed, a

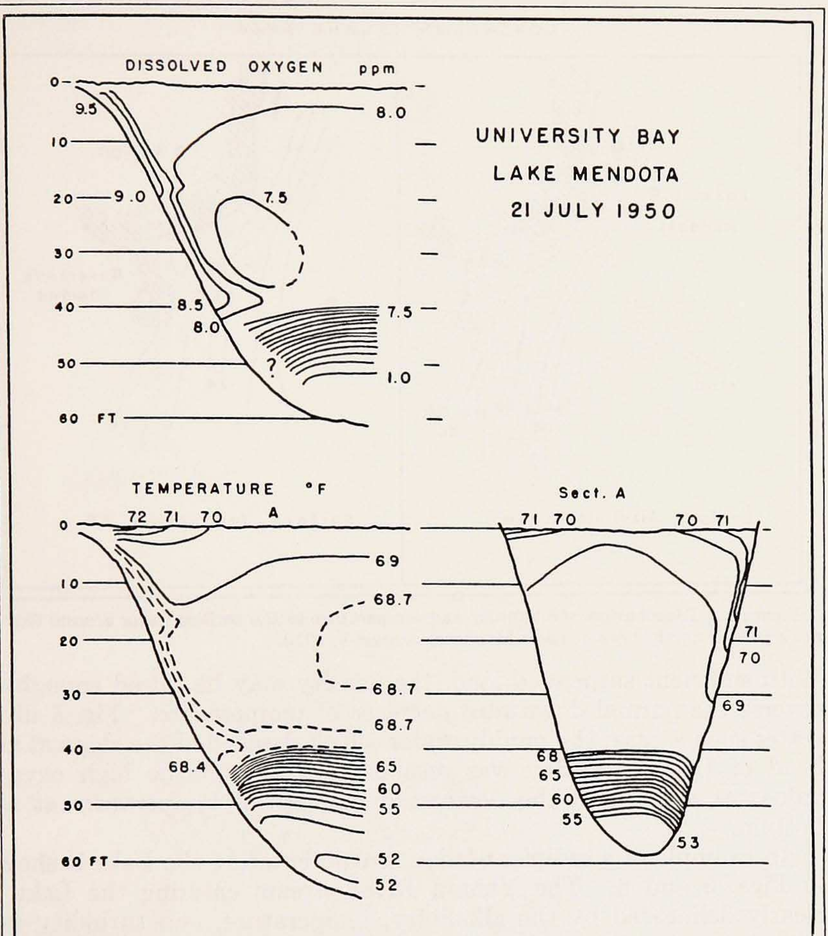

Figure 4. Longitudinal profiles of dissolved oxygen and temperature through University Bay. Section A is a transverse profile at the point marked "A."

density for the runoff water corresponding to a much lower temperature is obtained from the graph. Referring again to Fig. 1, it is clear that this tributary inflow could have descended to the lower part of the hypolimnion to spread.

Since each tributary has its own particular combination of temperature and suspended load, each should find a different density surface over which to spread. Stratification of turbidity results (Fig. 3).

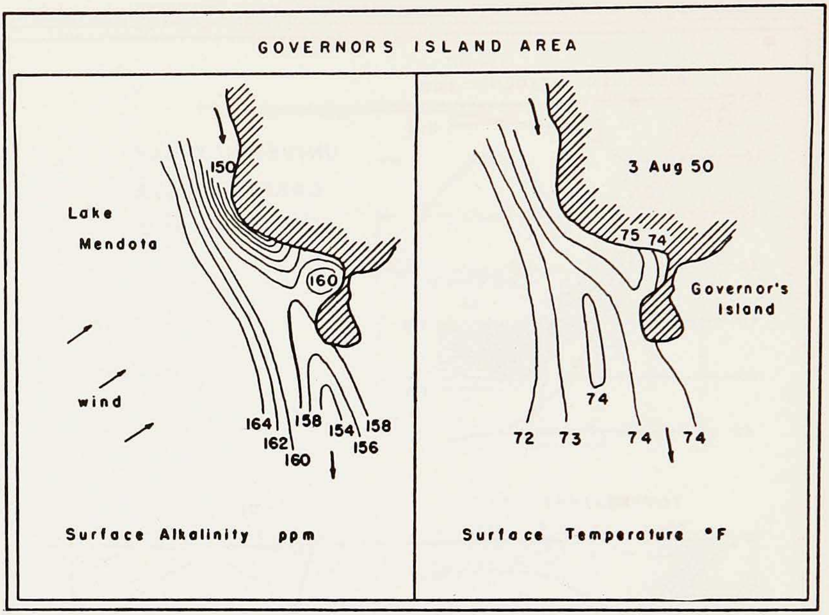

Figure 5. Distribution of alkalinity and temperature in the surface water around Governor's Island, north shore of Lake Mendota, August 3, 1950.

With sufficient suspended load, the density may be raised enough to reverse the normal downward decrease of temperature. Fig. 4 illustrates such a case; the muddy water which descended the slope at the head of University Bay was responsible for both the high oxygen values at depth and the downward increase of temperature at the bottom.

An example of a sediment-laden stream entering the Lake is shown in Figs. 5 and 6. The Yahara River stream entering the Lake is clearly delineated by the alkalinity, temperature, and turbidity distributions at and near the surface, but a cross section shows that the main body of muddy water is flowing along the bottom.

During and immediately following the periods of extremely heavy rain, many of the streams tributary to Lake Mendota ran at flood stage, with cold water carrying a large load of suspended sediment and abnormal amounts of dissolved oxygen. These tributaries provide a mechanism for occasional mid-summer renewal of hypolimnetic oxygen.

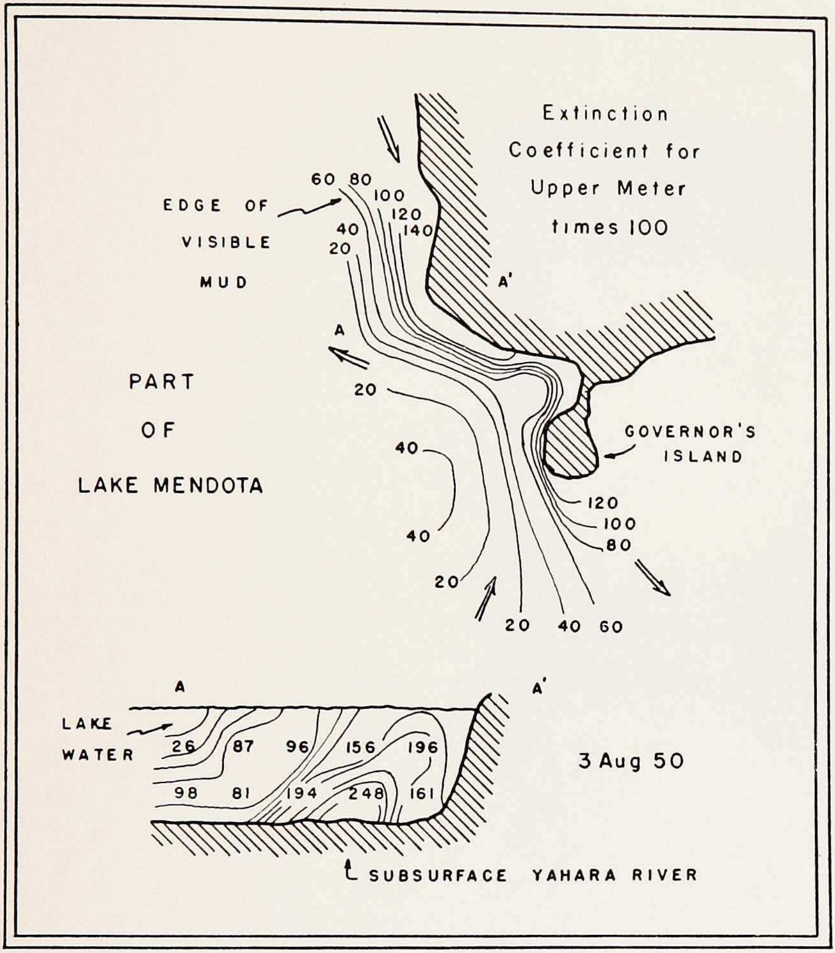

Figure 6. Extinction coefficient in the same area and at the same time as in Fig. 5.

REFERENCES

(1) Byers, H. R., Harry Moses, and P. J. Harney
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(2) Welch, P. S.
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