Eufaula Reservoir Aeration Research — 1968

LOWELL E. LEACH[1]

INTRODUCTION

Eufaula Reservoir has a surface area of 102,500 acres and a storage of 2,800,000 acre-feet at power pool elevation, 585 ft, above m.s.l. The central pool, where the major portion of the research was conducted, has a surface area of 10,800 acres and a volume of about 570,000 acre-feet at 585. Aeration research conducted in 1968 was a continuation of a 1967 "Pilot Study of the Dynamics of Reservoir Destratification" conducted by personnel of the Robert S. Kerr Water Research Center, Federal Water Pollution Control Administration, Ada, Oklahoma. The research and aeration system was modified as a result of the findings of the 1967 pilot study.

ANTECEDENT MONITORING PROCEDURES

In January 1968, 17 sampling stations were located in the central pool by triangulation surveys. Vertical profiles of temperature and dissolved oxygen were taken at 5-ft intervals every two weeks during winter and spring to establish antecedent conditions and to determine the progress of sratification. Two upstream stations, which would be outside the influence of the aeration system, were also monitored and used as control stations. Locations of monitoring stations are shown in Figs. 1 and 2.

STRATIFICATION

Stratification was hampered during the spring months by unusually heavy rainfall and unseasonably cool weather. During May and June,

[1]Research Hydraulic Engineer, Water Quality Control Research Program, Robert S. Kerr Water Research Center, South Central Region, Federal Water Pollution Control Administration, U.S. Department of the Interior, Ada, Oklahoma.

high inflows resulted in the reservoir rising to a record elevation of 590.5 ft. At this elevation, it was necessary to release stored water through the tainter gates, as well as through the power penstocks, for about 10 days. During these high releases, work on installation of the air distribution system had to be suspended for safety reasons, resulting in considerable delay. These tremendous discharges, together with the large inflow, caused the upstream turbid waters to move downstream from the upper reaches of the reservoir, engulfing the central pool. This movement of water through the reservoir mixed the central pool and slowed stratification.

Stratification finally occurred in mid-July and became stable by the end of July with a thermocline at a depth of about 60 ft near the dam, tilting upstream to a depth of about 50 ft at Station 17. This compared with a thermocline depth in 1967 of about 25 ft at all stations in the central pool.

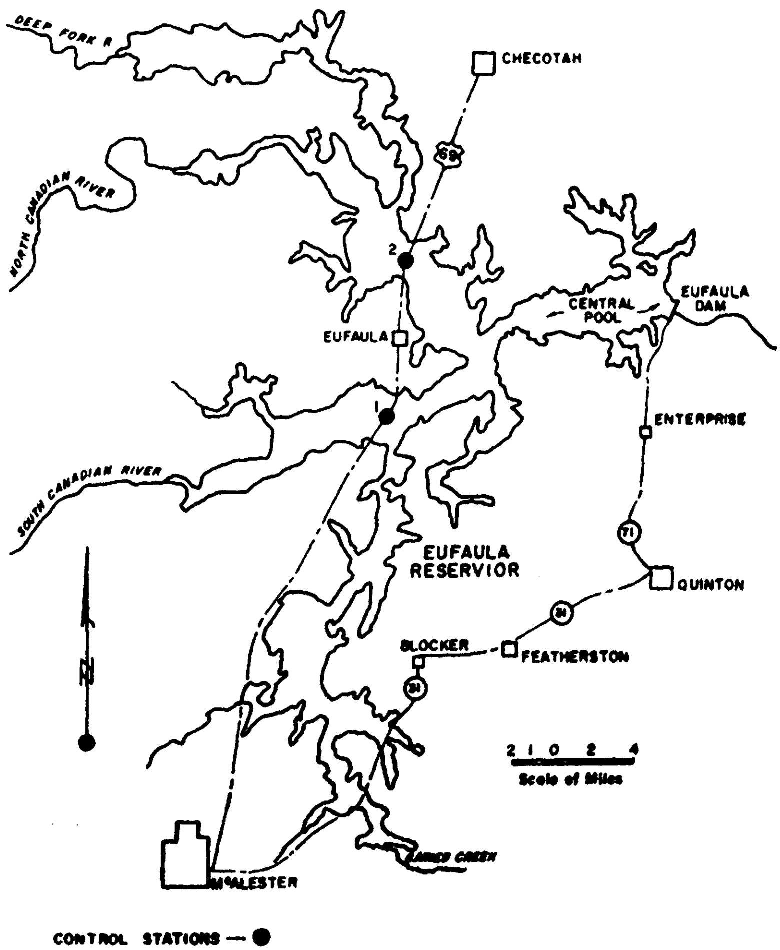

Figure 1 — Vicinity Map

AIR DISTRIBUTION SYSTEM

The air distribution system design was modified for the 1968 research based on the performance of the system used in the 1967 pilot study and the volume of effect desired. The system used in 1967 consisted of four 20-ft lengths of 1-inch hose, each having four equally spaced microporous diffuser stones. The 1968 system consisted of six 40-ft arms of 4-inch diameter pipe, each arm having eight equally spaced microporous diffusers. Diffusers used during both operations were commercially fabricated, microporous porcelain, hollow candles having a length of 8 3/16 inches and an interior diameter of 1½ inches. The bubble-forming microporous capillaries had an average radius of 25×10^{-4} cm resulting in 27% porosity for each candle.

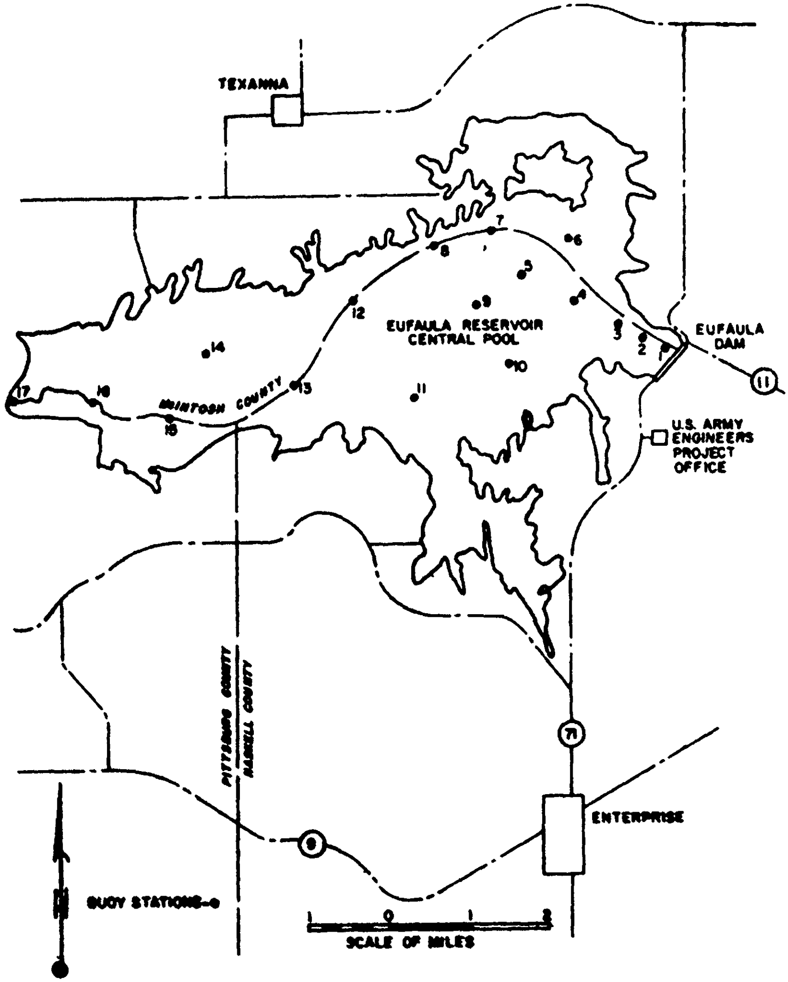

Figure 2 — Project Location Map

Air was supplied to the system through two 750-ft lengths of 2½-inch rubber fire hose extending from the face of Eufaula Dam into the reservoir and down to the bottom at a depth of 95 ft where they were attached to the air distribution system.

Air Compressor Installation

The air compressor used was a 1,200 cfm, electrically powered, rota-screw-type machine that supplied the volume of air at 125 psig and a temperature of approximately 175F. The compressor was placed on the top of Eufaula Dam near the roadway above the power penstocks for convenience of installation and proximity to a high-voltage power source. Air delivered from the compressor was filtered through a scrubber that removed oil and water vapor and passed through a meter run where pressure, temperature, and pressure differential were measured through an orifice plate and recorded on a continuous recording chart. Electrical energy utilized was recorded regularly from an electrical meter.

Aeration Procedures

Aeration started on 2 August with a constant flow of about 1,200 cfm of compressed air being pumped to the air distribution system located on the reservoir bottom at a 95-ft depth. The air pressure at the meter run on top of the dam was 55 psig with a temperature of 150F. The air pressure decreased to about 5 psig at the air distribution system and to a temperature of 75F.

Discussion of Results

The upstream stations were monitored twice weekly after aeration began, and it was noted that a slight increase in dissolved oxygen was occurring between depths of 35 and 60 ft with detectable effects reaching upstream to Station 5, shown on Fig. 2. However, this effect did not expand or become lasting. Also, it was noted that dissolved oxygen concentrations of water released during power generation increased from 3 mg/l immediately before aeration began to a range of 4.0 to 5.5 mg/l, depending on the volume of power release. It was reasoned that aeration was not progressing satisfactorily in the reservoir because the aerated water was pulled through the dam as a result of power generation nearly as fast as aeration was occurring; thus, only during times when power generation was not in progress was any volume of aerated water accumulated in the hypolimnion.

This discovery resulted in the initiation of a period of intense monitoring of the water being drawn into the power penstocks which was correlated with the power discharges and their dissolved oxygen content. This monitoring period began on 29 August and lasted until 15 September. During the first week, vertical profiles of dissolved oxygen and temperature were run at four stations between the dam and the air distribution system. These profiles were determined as air was being pumped and power releases at varying levels were passing through the dam. Each time the power release was increased, decreased, or stopped, profiles were determined for comparison.

It was found by comparison of cross-sections developed from vertical profiles that the flow net of water entering the power penstocks was illustrated by coning of dissolved oxygen levels toward the bottom as discharge increased from 4,000 cfs to a peak of 12,000 cfs (Fig. 3). A corresponding effect was observed in the dissolved oxygen content of the discharges below the dam, which rose from 4.0 mg/l at a release rate of 4,000 cfs to 5.5 mg/l at 12,000 cfs.

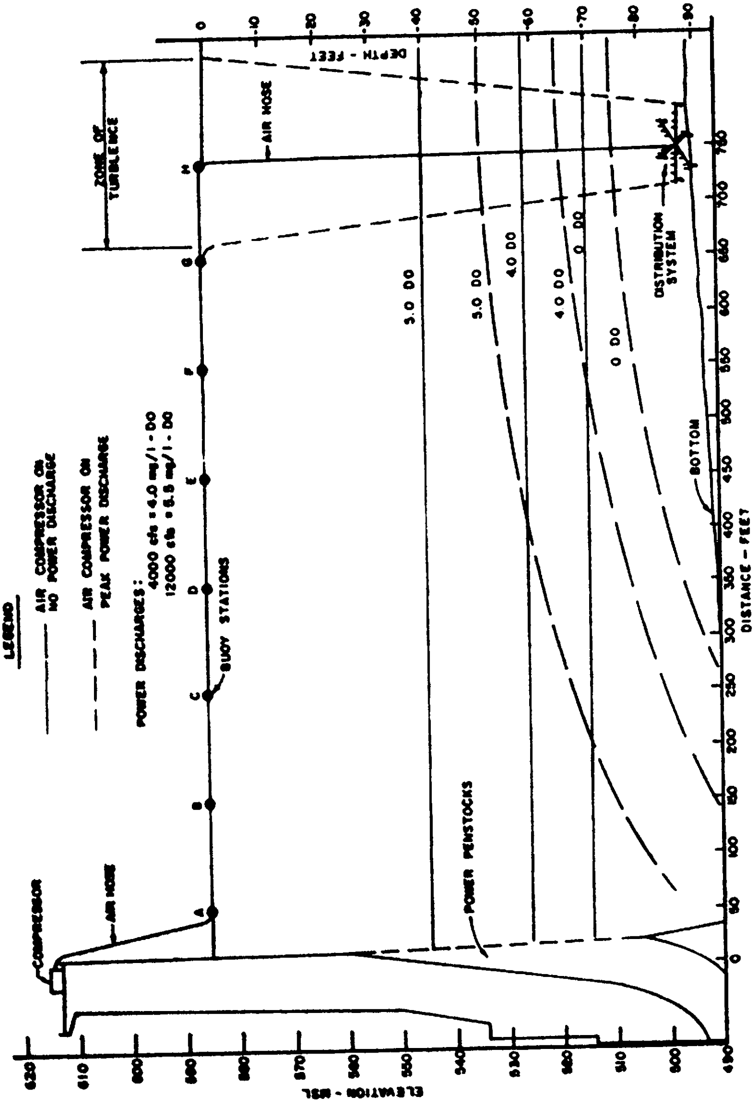

Figure 3 — Oxygen Drawdown Profile

During the time when power generation was not in progress and aeration was continuing, dissolved oxygen concentrations were almost uniform with zero at 70-ft, 4.0 mg/l at 58-ft, and 5.0 mg/l at 40-ft depths. During peak power releases, however, dissolved oxygen levels were coned, having a trajectory of 4.0 mg/l reaching a depth of 95 ft near the dam and rising to 65 ft at the aerator and 5.0 mg/l trajecting from 75 ft at the dam to 50 ft at the aerator. Changes in the trajectory reflected intermediate power discharges by either rising or lowering according to the respective increase or decrease in power discharge.

On 5 September the compressor was turned off and the monitoring schedule was continued to determine the effect of power releases alone in coning the surface or epilimnion water into the penstocks. During periodic power generation over the next five days, dissolved oxygen concentrations of releases were measured and found to have dropped to about 3.5 mg/l at 4,000 cfs discharge and 4.5 mg/l at 12,000 cfs (Fig. 4). The cross-section showed the trajectory of zero dissolved oxygen started at a depth of 85 ft near the dam and rose to 65 ft near the aerator during peak power releases. At the same time, the 4.0 mg/l trajectory rose from 65 ft at the dam to 60 ft at the aerator location, while the 5.0 mg/l trajectory rose from 60 to 58 ft.

Tests were run next without power generation and with the compressor off to determine at what level and at what rate the affected area and central pool would restratify. It was found that after 12 hrs the area under study and the central pool had restratified and become stable with zero dissolved oxygen at a depth of 60 ft, 4.0 mg/l dissolved oxygen at 54 ft, and 6.0 mg/l at 45 ft with horizontal trajectories (Fig. 5).

The compressor was turned on again and run for three final days without power generation. This was done to see what immediate aeration effects could be shown without influence from power releases. Dissolved oxygen concentrations in the area between the aerator and dam continually increased in depth with 5.0 mg/l reaching a depth of 70 ft in the area between the dam and aerator but rising to 60 ft at Station 2 and 50 ft at Station 7 by the end of the third day. Zero dissolved oxygen occurred below 65 ft at all stations upstream from Station 2.

CONCLUSIONS

It is obvious from these effects that the aerator was located too close to the power intakes to have an appreciable effect in the hypolimnion over a large area. However, the location of the compressor and air distribution system was predetermined as the most feasible on economic and available power considerations.

The data evaluation is presently incomplete; therefore, detailed conclusions regarding the effect in the hypolimnion cannot be made at present. It is obvious that the effect of aeration on the power discharges is significant and would result in tremendous benefits in controlling the quality of power discharges and their effects on downstream water quality.

The results of this study indicate that aeration systems, such as those used in this work, can significantly improve the quality of released water during power generation. The application of such a system to conclusively demonstrate its effectiveness and feasibility would now seem appropriate.

Further research is necessary to determine the effectiveness of such aeration systems to control stratification in large reservoirs.

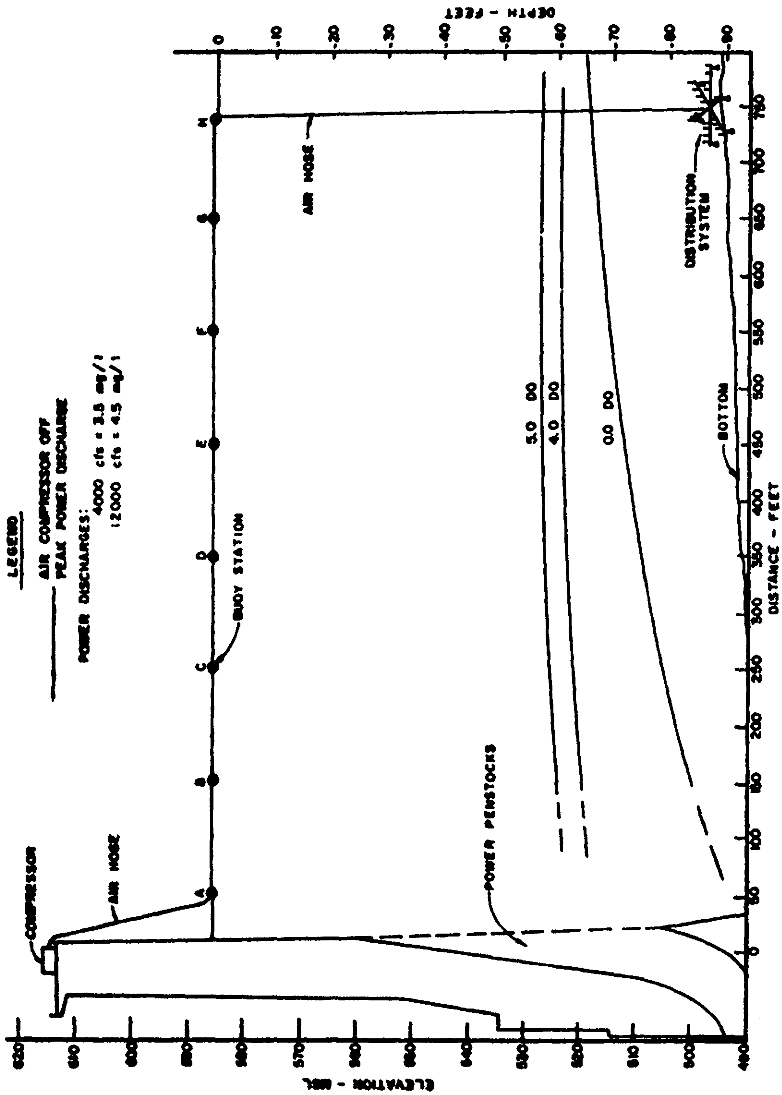

Figure 4 — Oxygen Drawdown Profile

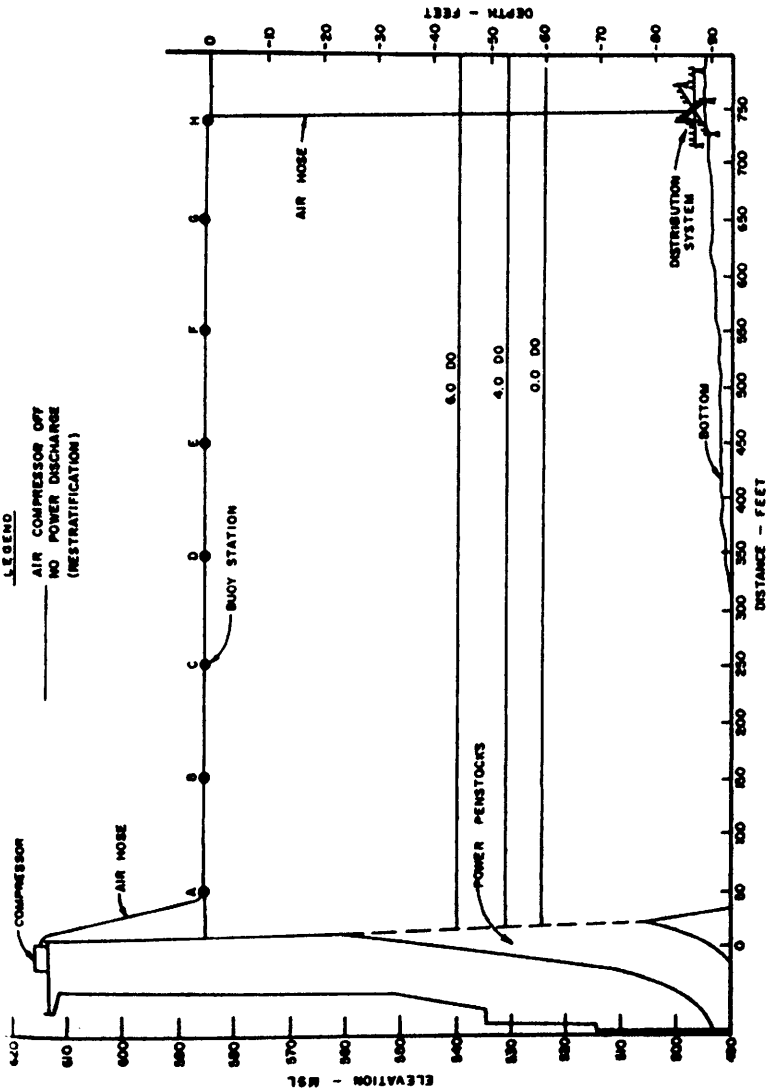

Figure 5 — Oxygen Restratification Profile