Enhancement of Release Water Quality by Localized Mixing Lake Okatibbee, MS

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BACKGROUND

Most lakes thermally stratify in the summer. This density stratification often results in chemical stratification of low or zero dissolved oxygen (DO) in the lake's hypolimnion. When there is zero DO in the hypolimnion, other compounds such as hydrogen sulfide, iron, and manganese are often found in solution. Releasing this water through a low-level outlet usually results in poor water quality downstream which may be hazardous to sensitive aquatic life.

There are several methods of improving the quality of releases from such a lake. If cold water releases are desired, hypolimnion oxygenation or reaeration through the structure will improve the release quality. If warm releases are desired, then artificial destratification, addition of selective withdrawal capabilities, or localized mixing are alternatives for enhancing the downstream quality. Artificial destratification mixes the entire lake redistributing water quality constituents throughout the water column. However, destratifying a large water body can require a large amount of energy. Add-on structural modification for selective withdrawal can provide direct withdrawal of epilimnion water but has a very high first cost. Localized mixing enhances the release quality by forcing epilimnion water downward to be mixed and withdrawn with hypolimnion water. Localized mixing, when applied appropriately, can maintain lake stratification while providing an economically attractive means of improving release quality. Localized mixing will only partially enhance release quality, whereas structural add-ons for selective withdrawal provide maximum improvement by releasing water of desired quality.

PROJECT DESCRIPTION

Lake Okatibbee is a small Corps of Engineers civil works project located on Okatibbee Creek north of Meridian, MS. The lake is shallow with a maximum depth of about 10 m. Water is released from the lake through an outlet works consisting of a fixed low-level intake structure, a horseshoe-shaped conduit, and a stilling basin (Plate 1).

Temperature and chemical stratification develop during the summer. The hypolimnion usually becomes anaerobic causing hydrogen sulfide, iron, and manganese to be in solution. These compounds are released through the low-level outlet with the low-flow summer discharge of about 1.4 m^3/sec.

APPARATUS

The concept of the low-energy mechanical pump (Garton pump) was developed by Dr. James E. Garton* of Oklahoma State University (OSU) for the purpose of destratifying lakes. The Garton pump, furnished and installed by OSU, consisted of a 1.83-m-diam ventilating fan suspended about 1 m below the surface by a 2-m-square raft. The fan was driven by a 1.12-kw electric motor at a design speed of 17 rpm. The pumping rate at this speed was approximately 1.7 m^3/sec.

The pump was attached to the upstream face of the intake structure immediately over the intake (Figure 1). The fan pumps water from the surface toward the bottom, resulting in a turbulent mixing of the surface and bottom water. The excess quantity of mixed water that is not withdrawn rises to neutral buoyancy and spreads as a density current. This phenomenon was observed in laboratory flume tests conducted at WES and is illustrated in Figure 2. It is the mixture of surface and bottom waters within the turbulent mixing zone that is withdrawn through the low-level outlet and contributes to the improved quality of the releases.

Depth, temperature, dissolved oxygen (D.O.), and conductivity measurements were made in the lake with Hydrolab Surveyor Model 6D Water Quality Analyzer. D.O. measurements were also made with a Yellow Springs Instrument (YSI) D.O.-Temperature meter. The sensors were calibrated with the azide modification of the Winkler titration technique. Additionally, D.O. readings were periodically checked against titrations of samples.

TESTS AND RESULTS

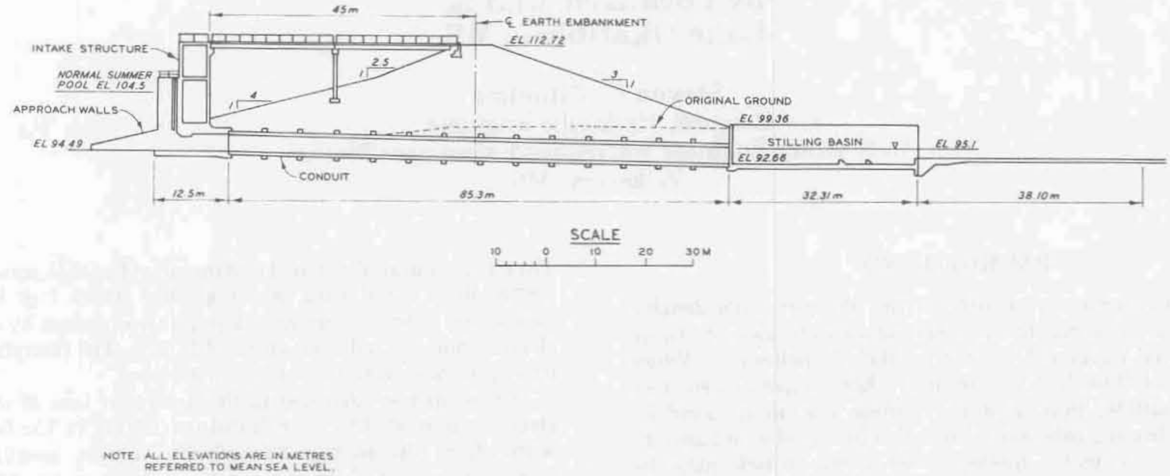
Water quality data were taken in the lake and stilling basin and at various locations in Okatibbee Creek. Profiles of D.O., temperature, and conductivity were taken in the lake at a location about 30 m upstream of the structure. Profiles observed before and after initiating pumping are presented in Plate 2. Data observed along the creek before and after pumping initiation are presented in Plate 3. The "before" data were taken during the morning of 15 June 1977. The pump was started at 3:00 p.m. The "after" data were collected on 16 June 1977.

During the night of 15 June, there was a rainstorm which may have had some influence on the "after" profiles. Considering the

*J. E. Garton and C. E. Rice, "Low Energy Mechanical Methods of Reservoir Destratification," OWRRI Final Technical Completion Report, A-028-OKLA, 1974, Oklahoma State University, Stillwater, Okla.

The Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) conducted tests at Oktibbee Lake, MS during June 1977 to evaluate the effectiveness of a low-energy mixing device in producing sufficient localized mixing to enhance the quality of low flows released from a stratified lake through a fixed low-level outlet works.

Data collected by WES and U. S. Army Engineer District, Mobile, personnel are reported herein. A report, No. MP H-78-1, "Enhancement of Releases from a Stratified Impoundment by Localized Mixing, Okatibbee Lake, MS" by Mark S. Dortch and the writer has been published by the WES.



OKATIBBEE LAKE
OUTLET WORKS

PLATE 1

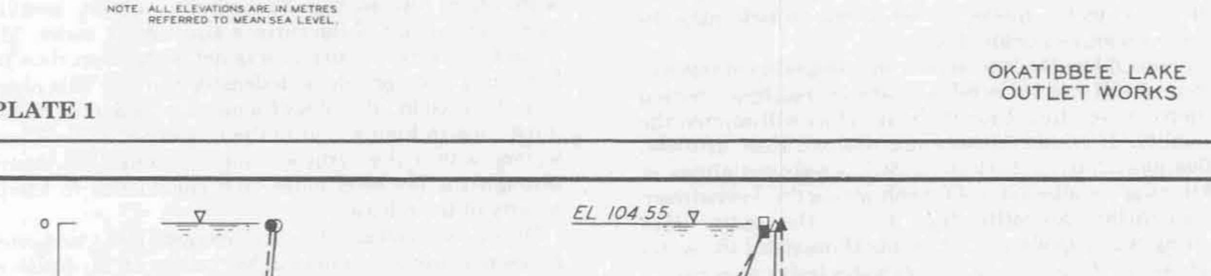


PLATE 2

WATER-QUALITY PROFILES

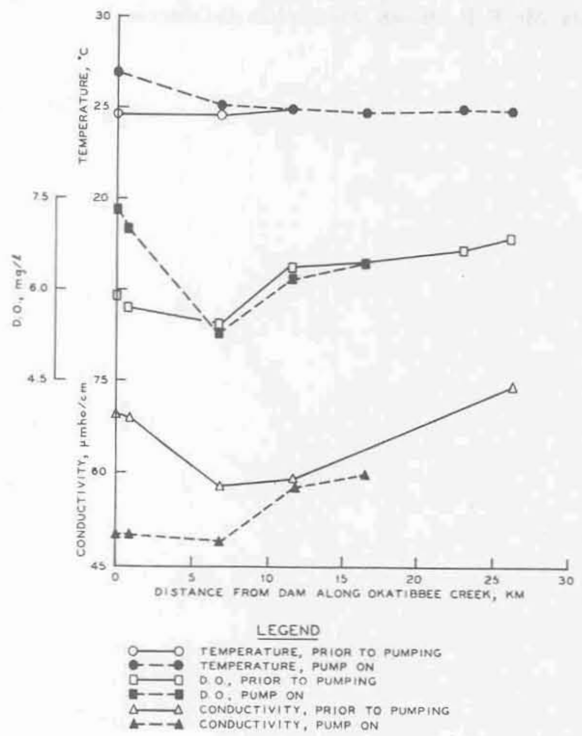


PLATE 3 WATER-QUALITY PROFILES

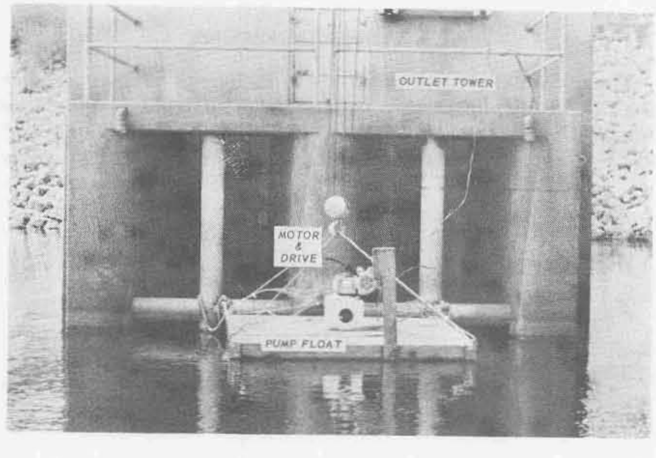


Figure 1. Location of Garton pump

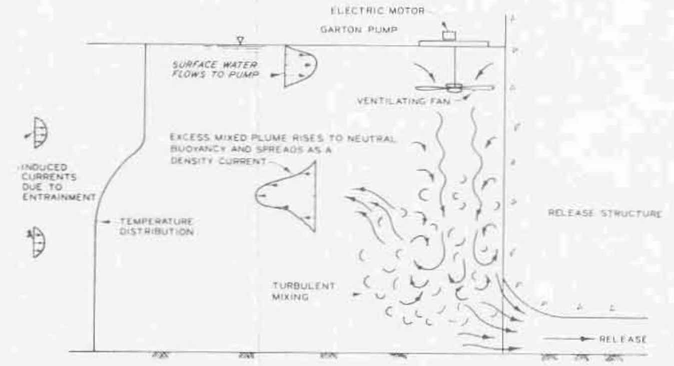


Figure 2. Localized mixing

possibility of measurement error and the occurrence of the storm, the profiles are quite similar. The spreading density current, resulting from the pump-induced mixing, would cause some change within the profiles at the intermediate depths as suggested by the profiles in Plate 2. The pump was not intended to completely mix the lake, so the changes within the lake should be small with respect to the changes in the release quality. However, within the immediate mixing zone of the pump, there should be sharp changes in the quality characteristics. It is not clear why there was an increase in the conductivity (with the pump on) near the bottom. Perhaps the downward flow stirred up sediment on the lake bottom (Plate 2).

Release water quality measurements at the conduit outlet portal prior to pumping and with the pump operating are presented in Table 1. Without localized mixing, water that was void of D.O. was drawn into the intake and was reaerated within the conduit providing a measured release D.O. concentration of about 5.9 mg/ℓ. The temperature and conductivity of the release water were representative of that found in the hypolimnion. Data taken only 15 min after the pump was started indicated a definite effect of the localized mixing on release quality. With the pump on, the temperature and D.O. of the release water were increased by 3.6°C and 1.0 mg/ℓ, and the conductivity was decreased by 20μmho/cm.

The quality of release water was improved by diluting the hypolimnion withdrawal with epilimnion water. Through the conservation of mass and conservation of volume principles it was estimated that 50 percent of the total flow released was epilimnion water. The effects of localized mixing became less apparent farther downstream. Even though the D.O. was

Table 1
Outflow Quality

Condition	Temperature °C	D.O., mg/ℓ	Conductivity μmho/cm
Prior to pumping	23.4	5.9*	65.0
Pump on after 15 min	27.0	6.9	45.0
Pump on after 20 hr	26.7	6.8	50.0

Note: Measurements made at the conduit outlet portal.
*** Water that was void of D.O. was withdrawn and reaerated within the conduit.**

increased at the stilling basin, oxygen demand still caused a typical "sag" downstream. Natural equilibration soon overcame the temperature increase caused by localized mixing.

CONCLUSIONS

These tests demonstrated that localized mixing in the vicinity of the fixed low-level outlet is a feasible method on enhancing the quality of low flow releases. The low energy "Garton" pump is an economical means for inducing localized mixing of stratified water.

In this demonstration, epilimnion water diluted the total release by about 50 percent and it is realistic that this dilution could be much greater. But several design parameters must be evaluated for the development of design and application guidance. The discharge rate of the pump relative to the release rate, the thrust of the pump, the depth of penetration of the pump discharge relative to the outlet depth should be important factors in the design of a localized mixing system.

ACKNOWLEDGEMENT

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