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Design of localized mechanical mixing systems

by
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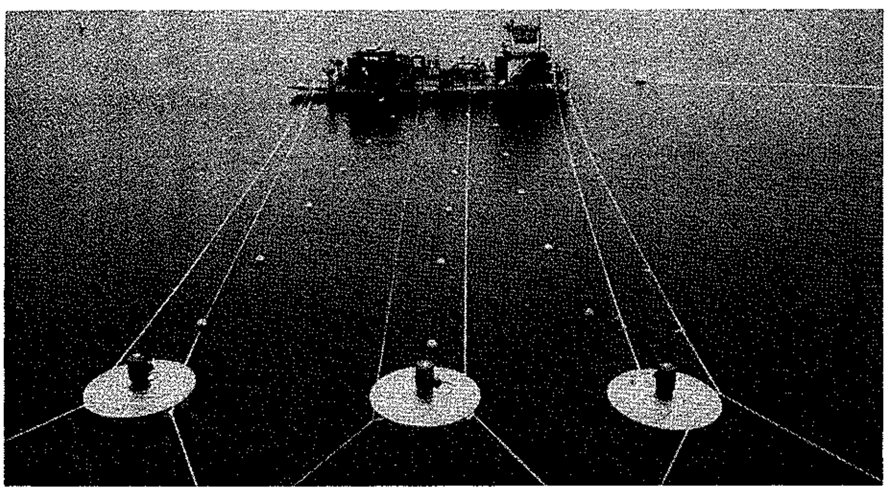

Localized mixing test at J. Percy Priest Reservoir

The thermal stratification that occurs at most reservoir projects can create problems with release water quality. If the hypolimnion becomes isolated from the surface and develops anoxic conditions, reduction of iron, manganese, and hydrogen sulfide may occur. If the release structure withdraws water from the hypolimnion, these soluble constituents as well as low dissolved oxygen (DO) may cause water quality problems downstream. Localized mixing can be used in many cases to improve the release water quality from projects with these characteristics.

Localized mixing

Localized mixing is a technique that provides sufficient mixing in a local area to reduce, if not eliminate, thermal stratification. Reduction of thermal stratification is usually accomplished by pumping surface water downward into the hypolimnion to achieve a locally uniform vertical temperature profile. The jet from a mechanical pump provides the energy needed to entrain epilimnetic water and disrupt the stratification and cause the epilimnetic water to be withdrawn, enhancing release water quality (Figure 1).

The objective of this technique, as indicated by its name, is to mix only a localized area of the reservoir that is subject to withdrawal through the release structure. Only the area near the outlet structure is affected.

Computational procedures

Although the concept of localized mixing is relatively simple, testing of localized mixing at a number of projects has indicated that several factors must be considered before implementation. The strength of thermal stratification will affect the depth of jet penetration and the amount of entrainment. If the system is overdesigned, and the jet penetrates to the reservoir bottom, sediments may be disturbed, resulting in the release of water with poorer quality than before localized mixing.

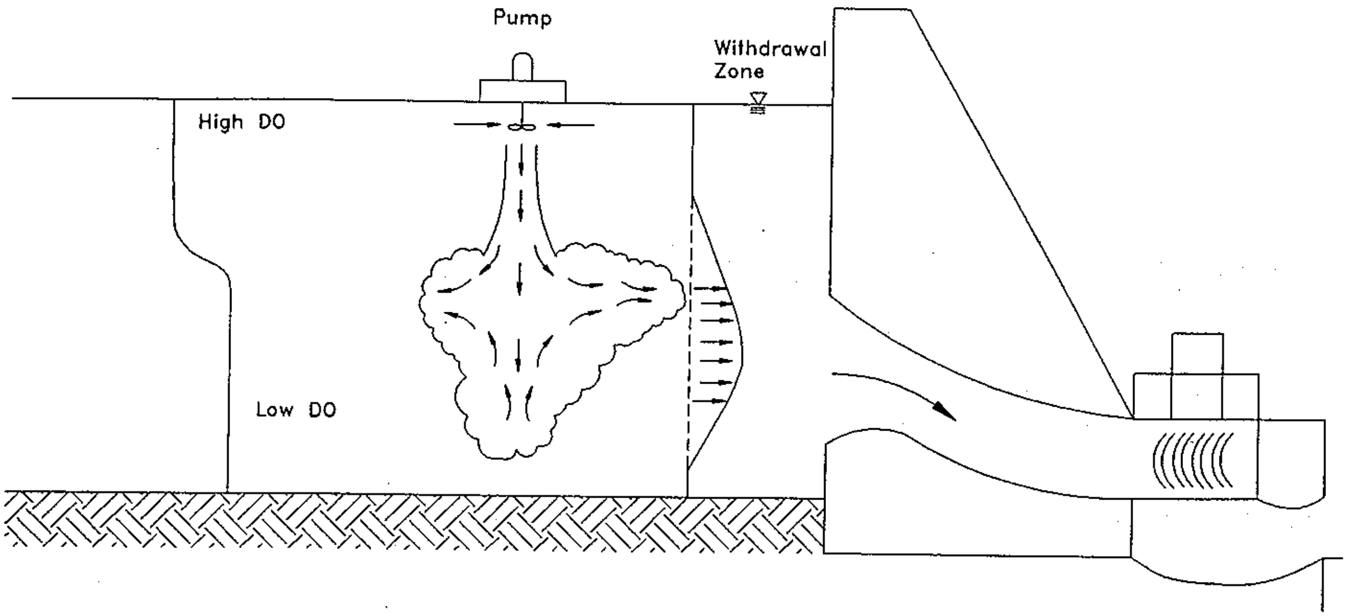

Figure 1. Schematic of localized mixing system with a surface pump

Additionally, a sufficient quantity of epilimnetic water must be transported downward by the mixing system to effectively dilute the release. Transport of an excess of epilimnetic water is inefficient because of pumping and power usage requirements and could result in partial or total destratification of the reservoir.

As shown in Holland (1984), the design of localized mixing systems requires use of an iterative solution procedure. Hundreds of calculations could routinely be required to obtain a system design while considering site-specific factors such as changing stratification patterns, outlet hydraulics, reservoir geomorphology, and outflow durations and patterns. An automated design procedure provides increased efficiency.

Knowledge-based system

The knowledge-based computerized system for localized mixing design, named PUMP, was developed using Turbo PROLOG version 2.0. This language allows incorporation of heuristic rules with computational procedures and mechanical pump data to arrive at a system design. These "rules" represent a collection of design and operational knowledge obtained through experience for which no first-principles mechanical information is known. Examples of such information include the spacing of system pumps, the start of operation of the system, and modification of the operation due to the decline of stratification.

Required input data are presented in Table 1 and Figure 2. The program automatically performs error checking routines.

The program computes penetration depth for a series of commercially available direct-drive mechanical pumps ranging in size from 3 to 40 horsepower (hp). Penetration

Table 1. Input Data for PUMP Program

Required Parameters	Example Values
Epilimnetic temperature, degrees Celsius (°C)	28.2
Hypolimnetic temperature, °C	12.5
Release temperature, °C	17.4
Epilimnetic DO, milligrams per liter (mg/L)	8.0
Release DO without enhancement, mg/L	3.5
Desired release DO, mg/L	5.0
Water surface elevation, feet (ft)	490.0
Thermocline elevation, ft	460.0
Outlet port center-line elevation, ft	428.5
Release volume, cubic feet per second (cfs)	4,600.0

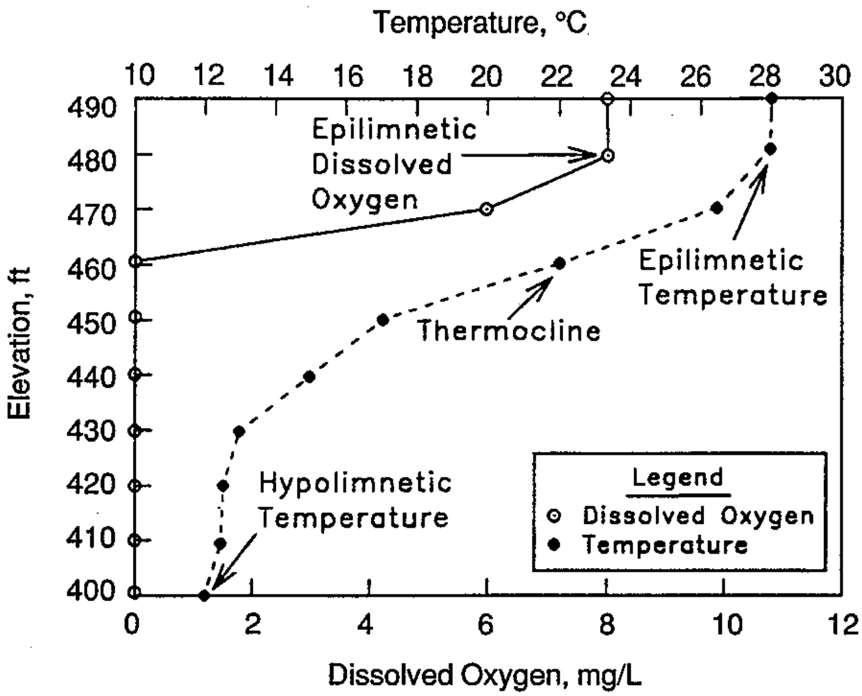

Figure 2. Temperature and DO profiles from which PUMP input data were taken

depth is compared to the structure outlets, and an initial system selection is made. The number of pumps required to achieve the desired release DO is computed based on the required epilimnetic dilution of the release and the maximum dilution available from a mixing system (Holland 1984).

Program application

To illustrate application, the PUMP program was used to design a localized mixing design for the data and outflow requirements listed in Table 1 (from J. Percy Priest Reservoir). PUMP recommended that six 40-hp pumps would be required to penetrate to the penstock center line. This requirement allowed dilution of the release with 1,533 cfs of epilimnetic water, achieving the release DO objective of 5.0 mg/L. PUMP also indicated the release temperature would increase from 17.4° to 21.0° C.

Before PUMP was developed a localized mixing system was designed and installed to improve hydropower releases from J. Percy Priest Reservoir near Nashville, Tennessee. The design of this system and development of operational guidance required several months of laboratory and field studies with repeated use of the procedures that have since been incorporated into PUMP. The recommended system consisted of six 40-hp pumps, with operation to begin in June and extending through October of each year (Price and Sneed 1989, Price 1988).

Because PUMP uses the same computational procedures initially used in the J. Percy Priest localized mixing design study, the agreement between the two pump system designs is not surprising. However, the time required to arrive at each design was significantly different, taking minutes rather than hours for consideration of each design or operational scenario through the use of PUMP.

Conclusions

PUMP allows engineers and scientists to quickly evaluate localized mixing alternatives for release water quality improvement. Assumptions inherent with localized mixing systems are included in PUMP along with simple error-checking routines. Because of the logical nature of the PROLOG language, additional pump design data and heuristic knowledge may be easily added when available.

References

Holland, J. P. 1984. "Parametric Investigation of Localized Mixing in Reservoirs," Technical Report E-84-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

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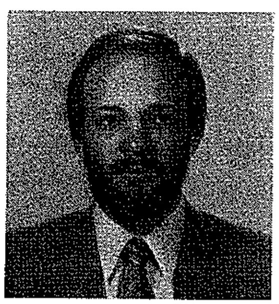

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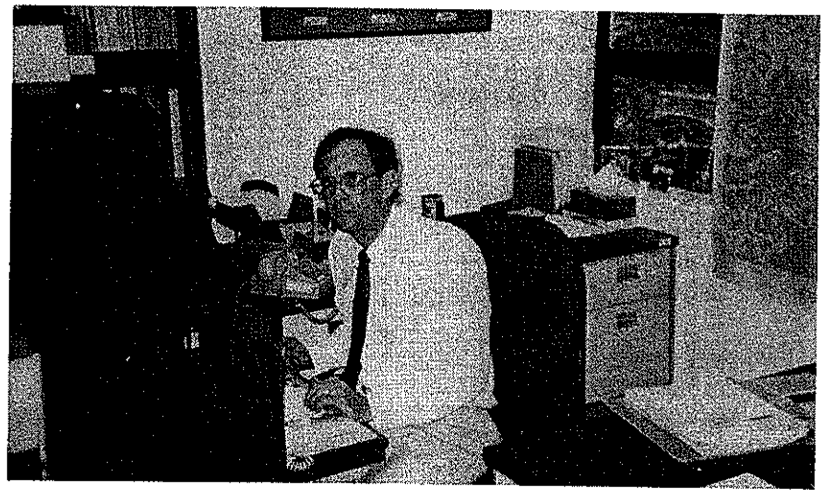
User survey and future of ENDOW

by
Jerry L. Miller



ENDOW is used to train personnel and assist experienced users in selecting environmental features

N. M. Aziz conducted a survey in summer 1990 to evaluate the use of the knowledge-based microcomputer system, Environmental Design of Waterways (ENDOW). The purpose of the survey was to help determine whether ENDOW is a helpful and useful tool in the project evaluation and review of environmental design for operations projects.

ENDOW was developed to provide guidance for preliminary and project evaluation for environmental design of stream channel modifications. The software was intended to encourage preliminary design of more environmentally responsive projects while discouraging use of design features in situations where they are likely to fail or impair other project components. The ENDOW knowledge base contains three modules, each of which corresponds to a type of channel alteration project:

- Streambank protection.
- Flood-control channels.
- Streamside levees.

Each module queries the user for information regarding a specific project setting and then recommends environmental features for detailed evaluation.

A questionnaire was mailed to 447 individuals on the ENDOW distribution list. Of these individuals, 238 were Corps and 209 were non-Corps employees; overall, 195 responses (43.6 percent) were received. Of the respondents, 136 were Corps and 59 were non-Corps employees, which represent 57.1 percent of the Corps employees surveyed and 28.2 percent of non-Corps. The survey was used to:

- Determine the use of ENDOW.
- Provide information to those charged with the maintenance and development of the ENDOW rule-based model.
- Provide data to users and others on the extent and ways in which ENDOW is being used.
- Provide information of specific uses, user groups, and future needs.

Data analysis

The study was designed to determine:

- ENDOW's frequency of use.
- User occupations and work experience.
- ENDOW's project use.
- Purpose of ENDOW use.
- Problems encountered in using the computer model.
- How ENDOW can be made more useful.

Each question is addressed individually.

Frequency of ENDOW use

Of the 195 total responses, 50.8 percent have used ENDOW. This represents 42.6 percent of Corps and 69.5 percent of non-Corps respondents. The lower percentage of Corps users can be explained by the fact that a large number of employees received ENDOW while attending short courses at the U.S. Army Engineer Waterways Experiment Station (WES) with no intention of using the software.

User occupation and work experience

Of the 136 Corps responses, 84 individuals (61.8 percent) worked in engineering, 30 (22.1 percent) in planning, and 22 (16.2 percent) in operations and construction. Of the 59 non-Corps responses, 25 individuals (42.4 percent) worked for other federal agencies, Nineteen individuals (32.2 percent) were consultants, and 15 (25.4 percent) worked in planning, construction, and education. Work experience of Corps and total respondents were approximately equal. Employees with more than 6 years' experience represented about 52 percent, those with 3 to 6 years' experience represented about 31 percent, and those with less than 3 years' experience represented about 16 percent of the respondents.

The remainder of the data analysis addresses only those respondents who have used ENDOW. The breakdown between Corps and non-Corps users was approximately equal; therefore, no distinction will be made between the two.

ENDOW and project use

About 54 percent of ENDOW use was spent on proposed projects, 14 percent on operational projects, and about 32 percent divided among regulatory projects, training, or testing the software (Figure 1). About 34 percent of the time, the purpose of ENDOW use was for project evaluation or review, 24 percent of the time was spent on training purposes,19 percent on project design, 16 percent on project formulation, and 7 percent on other purposes (Figure 2).

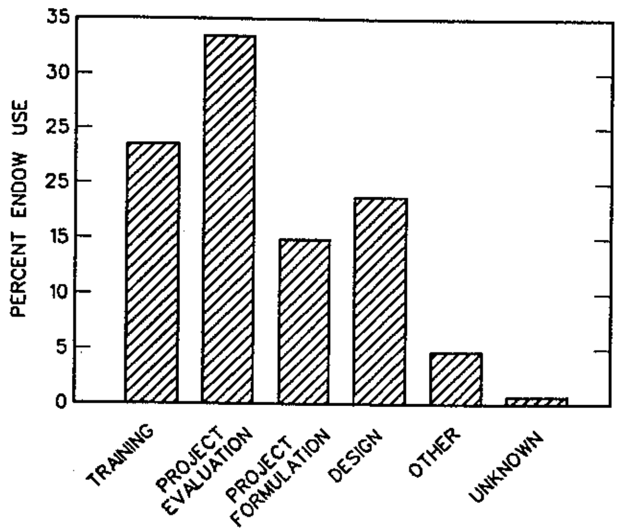


Figure 2. Purpose of ENDOW use

Problems Encountered

Seventy-three percent of the users indicated that they have not experienced any problem with the software, while 17 percent had specific problems, such as not being familiar enough with environmental design to give appropriate responses to the questions. Therefore, ENDOW would recommend they start over and revise their data. In some cases the user did not have enough project data to answer all the questions. About 9 percent had problems because of software "bugs" or hardware incompatibilities.

Improvement of ENDOW

About 56 percent of the survey respondents agreed that more environmental design features should be added to ENDOW, while the remaining users were neutral or did not respond. Additional suggested features include graphics, hydraulic design, wetlands, and water quality components. The survey results further emphasized the need for continued development of ENDOW for planning, training, and preliminary environmental design.

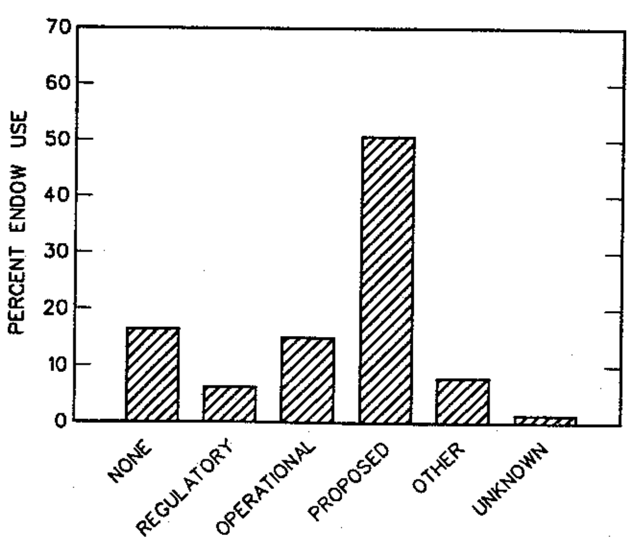


Figure 1. Percent ENDOW use on specified projects

Considerations of the data analysis

The first consideration was the method by which ENDOW is distributed. Many individuals obtained a copy of the software while they attended short courses at WES. These individuals may not have a direct need for ENDOW, which may explain the fact that the number of respondents was about evenly divided as users and nonusers. The second consideration, reflected in the users' responses, was that the streamside levees module is a recent addition to ENDOW. Therefore, its use has occurred over a shorter period of time than the other two modules.

Analysis of data in the first section of this article revealed that ENDOW was used mostly for project evaluation and review. The majority of these projects were consid-

Low-flow channel, Scottsdale, Arizona; green grass covers floodway which doubles as a park; low-flow channel was constructed to improve aesthetics and water quality

ered as proposed projects, emphasizing the original intent of ENDOW as a tool for planning and preliminary design. Analysis of the responses also showed that ENDOW was used as a training tool for entry level employees, while more senior employees applied ENDOW to actual projects. Senior employees generally agreed with the environmental recommendations of the software.

Progress and future of ENDOW since the survey

The first ENDOW User's Guide was published in December 1990 by Shields and Schaefer (1990). The guide provides general instructions for installing and using the ENDOW system. Menu options are discussed and detailed information and examples for the streambank protection, flood control channel, and streamside levee modules are given. A list of the engineers and scientists who contributed to the development of ENDOW is also presented in the appendix of the guide.

Once an environmental feature is selected, additional analyses and design are required to establish feasibility. A new release of ENDOW (ENDOW 3.0), which became available October 1991 supports preliminary hydraulic design for 8 of the 20 recommended environmental features for the streambank protection module and 9 of the 18 recommended environmental features for flood-control channels module via a user-friendly interface (P-SAM) to a set of computational routines (SAM) developed by Thomas (1990). The design routines perform hydraulic calculations at a given cross section for steady, uniform flow. Cross sections may be simple or geometrically complex with compound roughness configurations. The design routines module also computes riprap size, stable width, normal flow depth, and sediment concentration. ENDOW, P-SAM, and SAM will be contained in an ENDOW shell. In addition, the shell will contain slots for the user to load COED and HEC-2 if desired.

Obtaining ENDOW

ENDOW may be obtained free of charge by sending formatted disk(s) with at least 2 megabytes total capacity to:

US Army Engineer
Waterways Experiment Station
Engineering Computer Programs Library
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

References

Shields, F. D., Jr., and Schaefer, T. E. 1990. "ENDOW User's Guide," Instruction Report W-90-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

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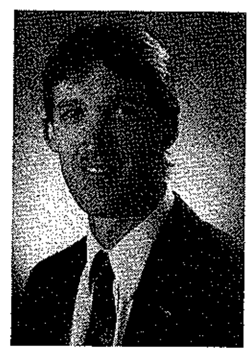

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Contents

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