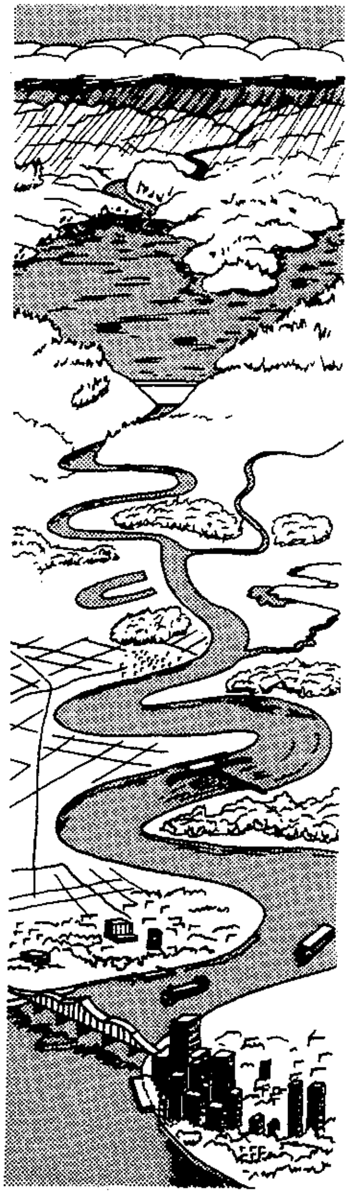
US Army Corps of Engineers
Waterways Experiment Station



WOTS/ Water Operations Technical Support

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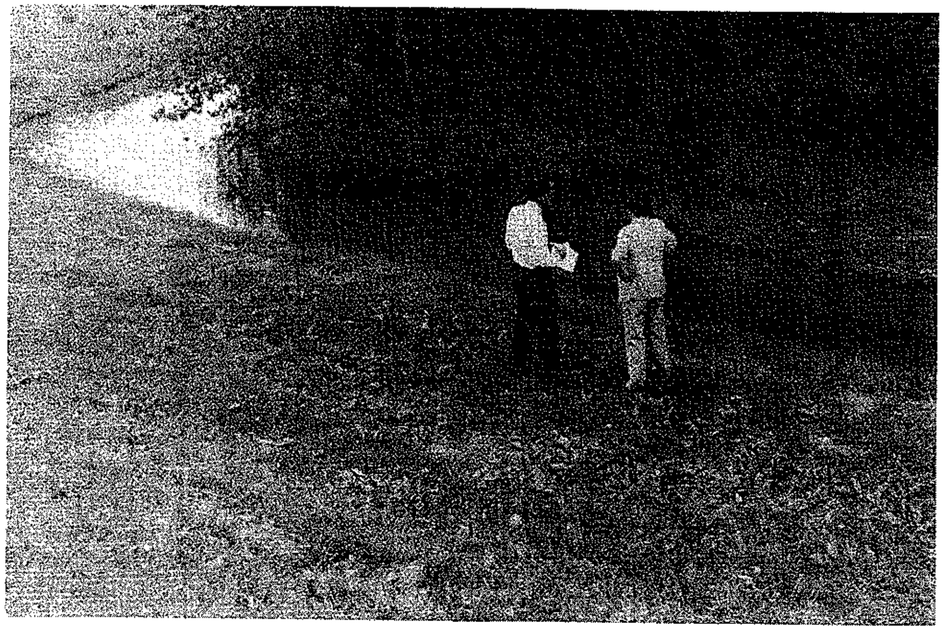

Interview with an expert

ENDOW: An Application of an Expert System in Technology Transfer

by
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An expert system is a computer system that emulates some of the problem-solving ability of a human expert in a given field. Development of expert systems is increasing, and scientists and engineers will eventually write and use these systems as routinely as they presently write and use computer programs for numerical calculations. Expert systems differ from procedural languages like FORTRAN in that they use logic and rules of thumb to assess data and solve problems. Expert systems are part of the larger field of artificial intelligence, and widespread application of both artificial intelligence and expert systems has not yet been attained.

Expert Systems and Technology Transfer

The US Army Corps of Engineers research and development community continually wrestles with the problem of effective and efficient transfer of research and development results to users. Expert systems can provide another "pathway" that complements but does not replace more orthodox pathways such as training courses, technical reports, Water Operational Technical Support (WOTS) assistance, workshops, and engineer manuals. Since the problem-solving ability of human experts is not always technology per se, expert systems have broader application than just technology transfer. However, these systems do offer a powerful new technology transfer tool that is just beginning to be developed.

In the future, Corps personnel may review technical literature using "hypermedia" instead of reading printed technical reports and journal articles (Texas Instruments, Inc. 1988). Hypermedia systems are envisioned as electronic data bases that will contain text, graphics, photographs, and maybe even sound and animation. Users will be able to pose questions, request more information about specific topics, or rapidly browse for overviews. Hypermedia or "dynamic books" will fuse the boundaries among computer-aided instruction, expert systems, and libraries.

ENDOW

A simple expert system, ENDOW (for Environmental Design of Waterways), has been developed under the WOTS program to facilitate technology transfer to Corps field offices. Early work on ENDOW was described in this bulletin (Nunnally and Shields 1986) and by Shields and Nunnally (1987). ENDOW is useful for rapidly identifying environmental alternatives for inclusion in project plans, designs, or procedures for operation and maintenance. The current release of ENDOW contains modules for streambank protection and flood-control channel projects, and a draft version containing an additional module for levee projects is in review. When running ENDOW, a user answers queries from the program regarding the project setting and environmental objectives. ENDOW then responds with a list of project features for further study and possible inclusion. Help screens that provide detailed descriptions of features and information about cost and performance can be requested for any feature selected.

ENDOW Development

The ENDOW program is a logical outgrowth of the WOTS program. At the conclusion of the Environmental and Water Quality Operational Studies (EWQOS), the WOTS program was initiated to maintain and transfer EWQOS-related technology. The knowledge base that was built for EWQOS Project VI was distinctly different from the rest of the EWQOS technology. While much of the EWQOS resulted in development of mathematical water quality models, Project VI was a series of information reviews for different types of waterway projects. At first, a set of algorithms or matrices was envisioned as a way to synthesize the Project VI results. Because of the difficulty of formulating, using, and updating such a system, the knowledge base was transferred to a computer program written in the PROLOG language.

A rough prototype system was then subjected to technical review and trial use. Several enhancements resulted that strengthened the technical basis of the system and facilitated use. The program was recoded so that users are asked only those questions needed to solve their specific problem. The questions that are asked in a given session are, therefore, selected based on the responses previously given. Technical reviewers in the US Army Engineer Waterways Experiment Station's Hydraulics Laboratory (HL) played a key role in system refinement to ensure that the criteria used for selecting environmental features and the wording of the various screens did not conflict with hydraulic design criteria. One of the major refinements to the streambank protection module, suggested by Dr. Steve Maynord, HL, was to ask the user to identify the major causes of erosion acting in the reach in question. Environmental features not compatible with the specified mechanism are screened out.

Present and Future Status of ENDOW

Endow Release 1.0 is presently available free of charge to users, and work on future releases continues. System review and revision is a cyclical process. The use of expert systems for technology transfer is complicated by technology refinement and creation. An expert system used to troubleshoot a particular machine is complete as long as the machine is not modified. However, a system like ENDOW must be continuously refined to incorporate new technology. To this end, ENDOW Draft Version 3.0 is currently under technical review by a landscape architect and several biologists in the WES's Environmental Laboratory. The levees module will also be reviewed by a geotechnical specialist.

Technical review of an expert system is really just another step in the most difficult part of expert system development—knowledge acquisition. While most of the effort involved in traditional software development is primarily a process of encoding algorithms and then debugging the code, the biggest hurdle in expert system development is obtaining knowledge from the human experts. Knowledge acquisition is difficult because experts may be protective of their expertise, they may have little interest in the expert system, or may be too busy to collaborate with expert system developers. Also, experts often have difficulty in articulating their problem-solving thought processes. Aside from motivating the experts, development of an interdisciplinary system like ENDOW requires professional judgments by several experts regarding exactly what is known and what is unknown. Although this is a tedious exercise, it leads directly to the most valuable result of expert system development—codification of knowledge into a set of rules and facts called a knowledge base.

When the current review process is completed, the knowledge base in ENDOW Draft Version 3.0 will be transferred to new software using an expert system development tool ("a shell"). ENDOW Release 1.0 was written in the PROLOG language because the shells examined prior to software development were either too costly or too inflexible or both. Figure 1 shows a sample session using ENDOW. Rapid improvement in expert system development packages during the last three years has resulted in cheaper, more powerful shells. A shell-based ENDOW will have more capabilities such as allowing users to ask why a given environmental feature has been recommended (Table 1). The primary reason for transferring ENDOW to a shell-based program, though, will be to facilitate expansion of the knowledge base.

Obtaining ENDOW

ENDOW runs on any personal computer with MS/DOS 2.0 or higher and at least 256 kilobytes of memory. ENDOW may be obtained by sending a request along with a blank, formatted double-sided, double-density 5-1/4-inch floppy diskette to the US Army Engineer Waterways Experiment Station, ATTN: CEWES-IM-SC, PO Box 631, Vicksburg, MS 39181-0631.

Table 1. ENDOW Capabilities

Release 1.0	*Draft Version 3.0*	*Future Releases*
Streambank protection module	—	—
Flood-control channel module	—	—
	Levees module	—
		Modules for additional project types
		Modules for design of specific features
On-line help screens	—	—
Glossary on diskette with program	—	On-line glossary
Results saved in a print file for future reference	—	—
	Print file may be labeled with up to a page of comments	—
Questions are not asked unless the answer is needed to reach a decision	—	—
		Users will be able to ask why and how a solution was reached

ENDOW

Select a goal(s), or if Correct, select CORRECT AS IS.

CORRECT AS IS

Environmental goal is preservation and development of aesthetics	**TRUE**
Environmental goal is preservation and development of aquatic habitat	**FALSE**
Environmental goal is preservation and development of wetland habitat	**FALSE**
Environmental goal is provision of recreational opportunity	**TRUE**
Environmental goal is riparian habitat preservation and maintenance	**FALSE**

Enter the median bed particle size in millimeters. (NO commas)	2
Enter the bankfull (2 year) discharge of existing stream in cfs (NO commas)	2000
Flood channel slope is less than 0.00007?	---F

WARNING, Flood channel may have a tendency to braid.
ENDOW suggests that a sediment transport study be done for the proposed flood channel.

Aquatic habitat is good in existing stream	---F
Available right of way is sufficient to allow for excavation of wide flood channel	---T
Existing channel contains visible evidence of recent sediment accumulation	---F
Available right of way is sufficient to allow for excavation of wide flood channel	---T
Existing channel contains visible evidence of recent sediment accumulation	---F
Existing channel has sinuosity greater than 1.5	---F
Existing stream is severely polluted or water quality is degraded	---T
Flood channel alignment will bypass meanders (bendways)	---F
Flood channel design discharge will be less than 10,000 cfs (283 cubic meters/sec)	---F
Riparian corridor has trees on one or both sides	---F
Flood channel will have concrete lining	---T
Flood channel slope will be less than .04	---T
Flood channel will have continuous flow or will be continually inundated	---F
Existing stream is severely polluted or water quality is degraded	---T
Flood channel alignment will bypass meanders (bendways)	---F
Flood channel design discharge will be less than 10,000 cfs (283 cubic meters/sec)	---F
Riparian corridor has trees on one or both sides	---F
Flood channel will have concrete lining	---T
Flood channel slope will be less than .04	---T
Flood channel will have continuous flow or will be continually inundated	---T
Project is located in flat terrain	---T
High areas that provide wildlife refuge from flooding are scarce	---T
Wetlands will be impacted by the project	---F

ENDOW suggests that you consider these designs or features to achieve the environmental goals established for this project. Further study of these alternatives is required to assess technical, economic, and institutional feasibility.

NO HELP DESIRED

Meandering alignment
Water level control structures
Special treatments for concrete
Use excavated material to create topographic diversity

Figure 1. A sample session with ENDOW Release 1.0 (Continued)

ENDOW HELP

Special treatments for concrete

A. Concept

Negative aesthetic impacts for concrete channels can be reduced by special treatments such as texturing or coloring. Brushing wet concrete to provide a textured finish is the most commonly used aesthetic treatment. Special form liners can also be used to produce textural effects, or color can be added to enhance the appearance of concrete.

B. Environmental Benefits and Considerations

Special treatments for concrete are used to produce positive visual impacts in areas of high visibility.

C. Experience with Special Treatments of Concrete

1. Location

Special treatments for concrete have been used primarily in urban settings. Notable examples include Tamalpais Creek (Corte Madera Creek Flood Control Project, San Francisco District) and Indian Bend Wash in Scottsdale, Arizona (Los Angeles District).

2. Performance

Aesthetic treatments for concrete hold up well unless water quality is corrosive or sediment loads are highly abrasive.

3. Cost

Costs vary with the type of treatment. Special form liners may add several thousand dollars to the cost.

D. References

Guidance for aesthetic treatments for concrete is contained in EM 1110-2-39. WES TR E-85-3 includes several examples of aesthetic treatments of concrete channels and floodwalls that have been used on CE flood control projects, including specially designed form liners, texturing, and coloring (pp 171-172 and 184).

Figure 1. A sample session with ENDOW Release 1.0 (Concluded)

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Applications of Mechanical Pumps and Mixers to Improve Water Quality

by
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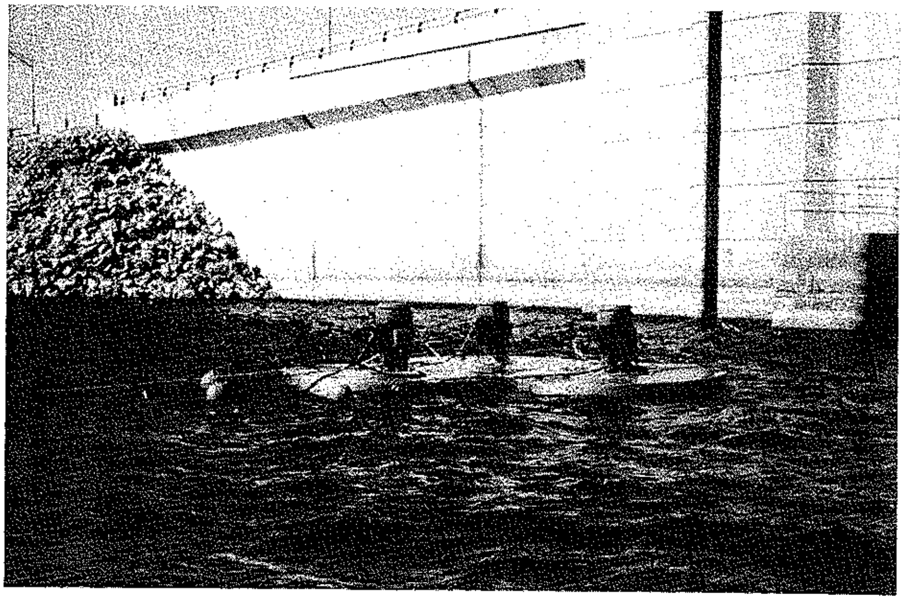

Localized mixing pilot study at J. Percy Priest Reservoir in the Nashville District

The thermal stratification that occurs in most US Army Corps of Engineers (CE) reservoirs may create water quality problems for reservoir managers. This thermal stratification, which begins to develop in the spring, effectively creates an upper well-oxygenated zone termed the epilimnion, an intermediate zone characterized by a rapid temperature change with depth termed the metalimnion, and a relatively uniform bottom zone termed the hypolimnion. These three zones are maintained to a certain degree by the corresponding densities, effectively preventing mixing of the epilimnion with the hypolimnion. The bottom zone is thereby isolated from the surface, such that the biochemical oxygen demand within this zone may exceed the rate of oxygen diffusion from the upper zones. Thus, it may become anoxic.

Anoxia in the hypolimnion may decrease the biological productivity by releasing iron, manganese, and hydrogen sulfide. In addition, if a low-level release structure is operated, such as for hydropower, significant levels of iron, manganese, and hydrogen sulfide may be released downstream.

Several techniques may be used to some degree to alleviate these conditions. Total lake destratification or hypolimnetic aeration/oxygenation may be used to increase the dissolved oxygen (DO) in the hypolimnion. Modification of the release structure, localized mixing, or reaeration techniques may also be used to enhance downstream water quality. Of these techniques, destratification, localized mixing, and downstream reaeration may be accomplished with hydraulic mixing pumps or devices that are readily available from commercial vendors. Localized mixing systems that use mechanical surface pumps are often inexpensive to design, install, and operate. Procedures for design of a localized mixing system using hydraulic pumps were published by Holland (1984), and Holland and Dortch (1984) give design guidance on destratification systems using hydraulic pumps. Although a variety of mechanical pumps are commercially available, example installations of three basic mechanical designs of surface pumps and mixers that have been used in localized mixing, destratification, and reaeration systems are discussed below.

Axial Flow Pump

An axial flow pump is a mechanical surface pump that consists of a large-diameter propeller (usually 6 to 15 feet) driven by a relatively small horsepower (gasoline or electric) motor (Figure 1) through a gear reducer. The propeller is positioned several feet below the water surface and rotates at a relatively low speed, generating up to several hundred cubic feet per second of flow at a relatively low velocity (2 to 5 feet per second (fps)). One type of axial flow pump, often referred to as a Garton pump, has been tested in a number of applications, both for localized mixing (Dortch and Wilhelms 1978, Garton and Peralta 1978) and lake destratification (Punnett 1988). Design guidance developed by Holland (1984) for localized mixing may be used to evaluate localized mixing applications of axial flow pumps.

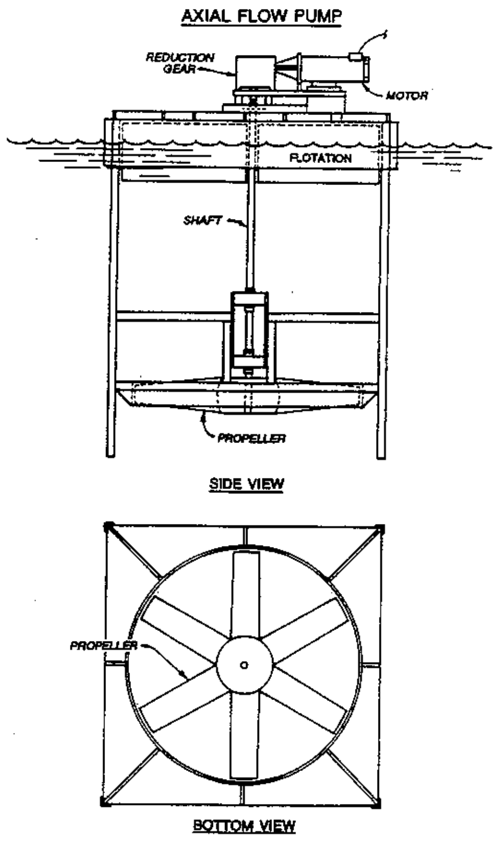

Figure 1. Schematic drawing of axial flow pump

A recent application of an axial flow pump has been made by Punnett (1988) on Beech Fork Lake, WV. This project was suffering from poor productivity and an anoxic hypolimnion. Total lake destratification was chosen as the method to improve the water quality. Using four axial flow pumps, each with a 3-horsepower (hp) electric motor generating approximately 75 cubic feet per second (cfs) per pump at an initial velocity of 2.7 fps, the 720-acre impoundment was successfully destratified. Actual operation of the system indicated that only 1.1 hp was used by each pump. Additional studies on the impacts to the benthic and pelagic community are continuing, but initial results indicate considerable improvement in biological productivity of the lake. A second application of axial flow pumps is underway at Douglas Reservoir, TN. This application, conducted by the Tennessee Valley Authority, involves the use of three axial flow pumps equipped with 30-hp electric motors, each generating approximately 500 cfs of flow (Mobley and Harshbarger 1987). Results indicate approximately 2.0 milligrams per litre DO was added to the release with all three pumps operating. A numerical model of this type of application has been formulated, but additional refinements are planned (Brown, Mobley, and Nubbe 1988).

Direct-Drive Mixer

A direct-drive mixer is a mechanical surface pump typically used in large mixing basins and sewage lagoons. This type of mixer is composed of a relatively small propeller (1- to 2-foot-diameter) that is connected directly to the drive shaft of an electric motor (3 to 75 hp). The motor is mounted on a circular float with the motor shaft issuing through the center and the propeller positioned approximately 2 feet below the water surface (Figure 2). This propeller rotates at a relatively high speed (several hundred revolutions per minute or rpm's) generating up to 45 cfs of flow at a relatively high initial velocity (up to 22 fps). This high velocity creates a jet that entrains a considerable volume of water as it issues downward. Most designs direct the water jet vertically downward, but elbow attachments are available for directing the jet at various angles from the surface (30, 45, or 60 degrees), but these elbows decrease the efficiency of the pump. Currently, design guidance (Holland 1984) is available for computing the depth of penetration of the jet and entrainment of epilimnetic water under strong stratification patterns.

These types of pumps have been used at two CE

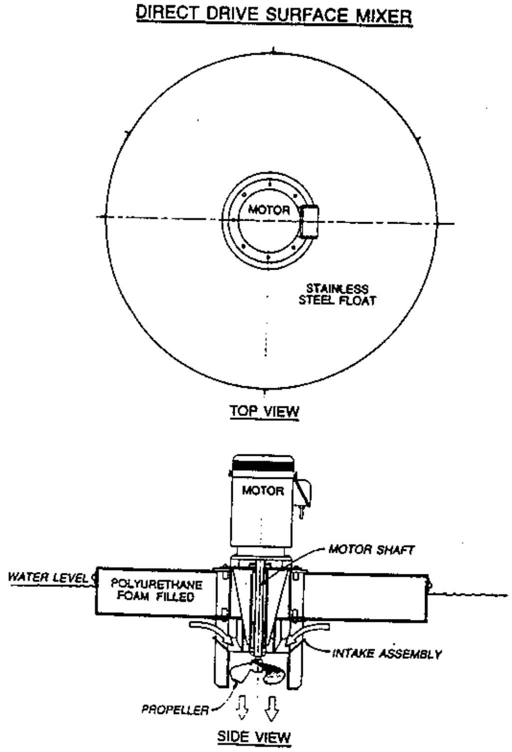

Figure 2. Schematic drawing of direct-drive mixer (reproduced with permission of Aeration Industries International, Inc.)

projects. At J. Percy Priest Reservoir in the Nashville District, three 40-hp pumps were leased and tested in a localized mixing application to improve the quality of hydropower releases. Conclusions from these tests indicated that the pumps would be successful in meeting release DO objectives, and a full-scale system implementation is currently under design. Design computations for the volume of epilimnetic water pumped across the thermocline and the depth of penetration of the jet compared very well with observed data for stronger stratifications tested at the project (Price 1988). A second application was made at Mark Twain Lake in the St. Louis District. The Clarence Cannon Dam, which has a peaking hydropower project, was constructed with a submerged skimming weir to control hypolimnetic withdrawal during hydropower releases. When the thermocline is above the crest of the weir, the area between the weir and the dam (the so-called mini-lake region) stratifies due to hypolimnetic flow over the weir. Upon startup of hydropower generation, a slug of low-DO cool water is released downstream, creating stress for the downstream fishery. A localized mixing system that would destratify the mini-lake was proposed as the solution. Pilot tests conducted using two 40-hp pumps indicated the jet penetrated 84 feet to the bottom of the mini-lake. Analysis of the test data indicated the area (approximately 380 acre-feet) could be destratified in approximately 11 hours.*

Aspirating Mixer

An aspirating mixer is a hybrid design combining aeration characteristics with a mixer. This type of pump is designed with a relatively small propeller (approximately 3 inches) mounted near the end of a hollow shaft connected to an electric motor (3 to 75 hp). The upper portion of the shaft near the connection to the motor has a port for air to enter into the shaft (Figure 3). The propeller, which is mounted several inches from the end of the shaft, rotates at 1,500 to 4,000 rpm's, creating a low-pressure zone that allows air to be pulled in through the port, down the shaft, and entrained into the flow. In addition, the direction of the jet

* *R. E. Price. 1987 (27 October). "Evaluation of Surface Mixers for Mark Twain Lake Destratification," Memorandum for Record, US Army Engineer Waterways Experiment Station, Vicksburg, MS.*

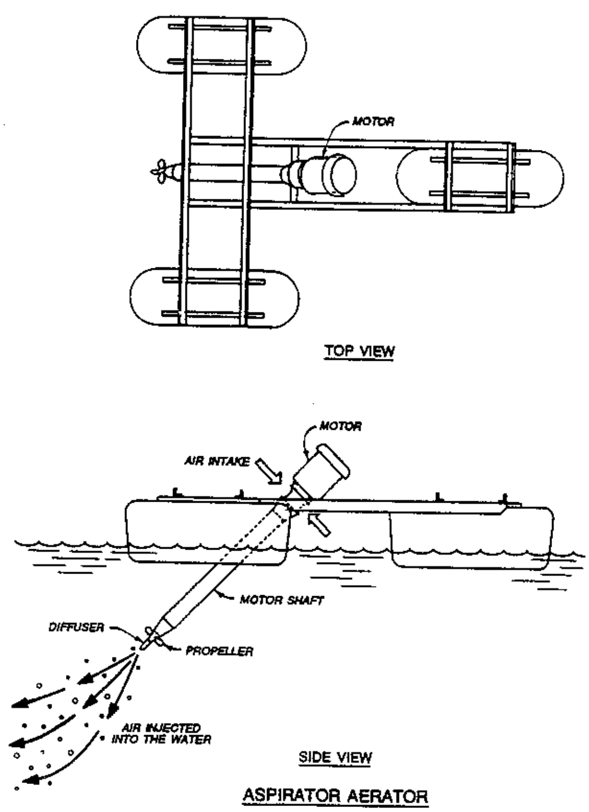

Figure 3. Schematic drawing of aspirator aerator (reproduced with permission of Aeration Industries International, Inc.)

may be varied from vertical to almost horizontal and the air port may be closed to prevent aspiration.

Although few applications of these types of pumps to CE reservoir projects have been made, they are particularly suited to relatively small, shallow areas requiring reaeration. For example, the stilling basin for a hydropower project that exhibits low-DO problems during nongeneration periods, or recreation areas that develop low DO during peak use periods, could be improved through application of these pumps. One application of this type of mixer has been made by the CE. The Seattle District conducted a pilot study to investigate the reaeration capacity of this type of mixer for the East Bay Marina in Olympia Bay, WA.* In this estuarine environment, both 3- and 5-hp units were tested for various injection angles (from the surface plane) and mixing rates. Unlike applications discussed above, thermal stratification was not a consideration, but the mixing rate, which was defined as the volume of water circulated per unit of time, was the key design parameter. The results of field tests indicated the 3-hp unit circulated 80 cfs and the 5-hp unit circulated 97 cfs. Based on these tests, a system consisting of 21 3-hp mixers was recommended and installed.

Summary

Thermal stratification occurring at CE projects may create water quality problems in the hypolimnion. Of the techniques currently available to alleviate these problems, those using mechanical pumps appear particularly promising in light of their immediate availability and simplicity of design and operation. The low-energy axial flow design has been proven effective in lake destratification applications and, along with direct-drive mixers, applicable to localized mixing applications. The aspirating mixer is particularly suited to shallow small areas requiring aeration such as stilling basins and harbors.

* *N. Skjelbreia and P. C. Storm. 1981 (Dec). "Evaluation and Design of East Bay Marina," Memorandum for Record, US Army Engineer District, Seattle, Seattle, WA.*

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The first article in this issue discusses the development of the expert system ENDOW (Environmental Design of Waterways) and its use in effective technology transfer. Applications of mechanical pumps and mixers to improve water quality are discussed in the second article. Mechanical pumps appear promising in alleviating water quality problems in the hypoliminion. The aspirating mixer is particularly suited to areas such as stilling basins and harbors that require aeration.

WATER QUALITY RESEARCH PROGRAM

This bulletin is published in accordance with AR 310-2. It has been prepared and distributed as one of the information dissemination functions of the Waterways Experiment Station. It is principally intended to be a forum whereby information pertaining to and resulting from WQRP can be rapidly and widely disseminated to Corps District and Division offices as well as other Federal agencies, state agencies, universities, research institutes, corporations, and individuals. Contributions of any type are solicited from all sources and will be considered for publication as long as they are relevant to the objectives of WQRP, i.e., to provide new or improved technology to solve selected environmental quality problems associated with Civil Works activities of the Corps of Engineers in a manner compatible with authorized project purposes. This bulletin will be issued on an irregular basis as dictated by the quantity and importance of information to be disseminated. Communications are welcomed and should be addressed to the Environmental Laboratory, ATTN: J.L. Decell, U.S. Army Engineer Waterways Experiment Station, P.O. Box 631, Vicksburg, Mississippi 39181-0631, or call AC 601/634-3494.

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