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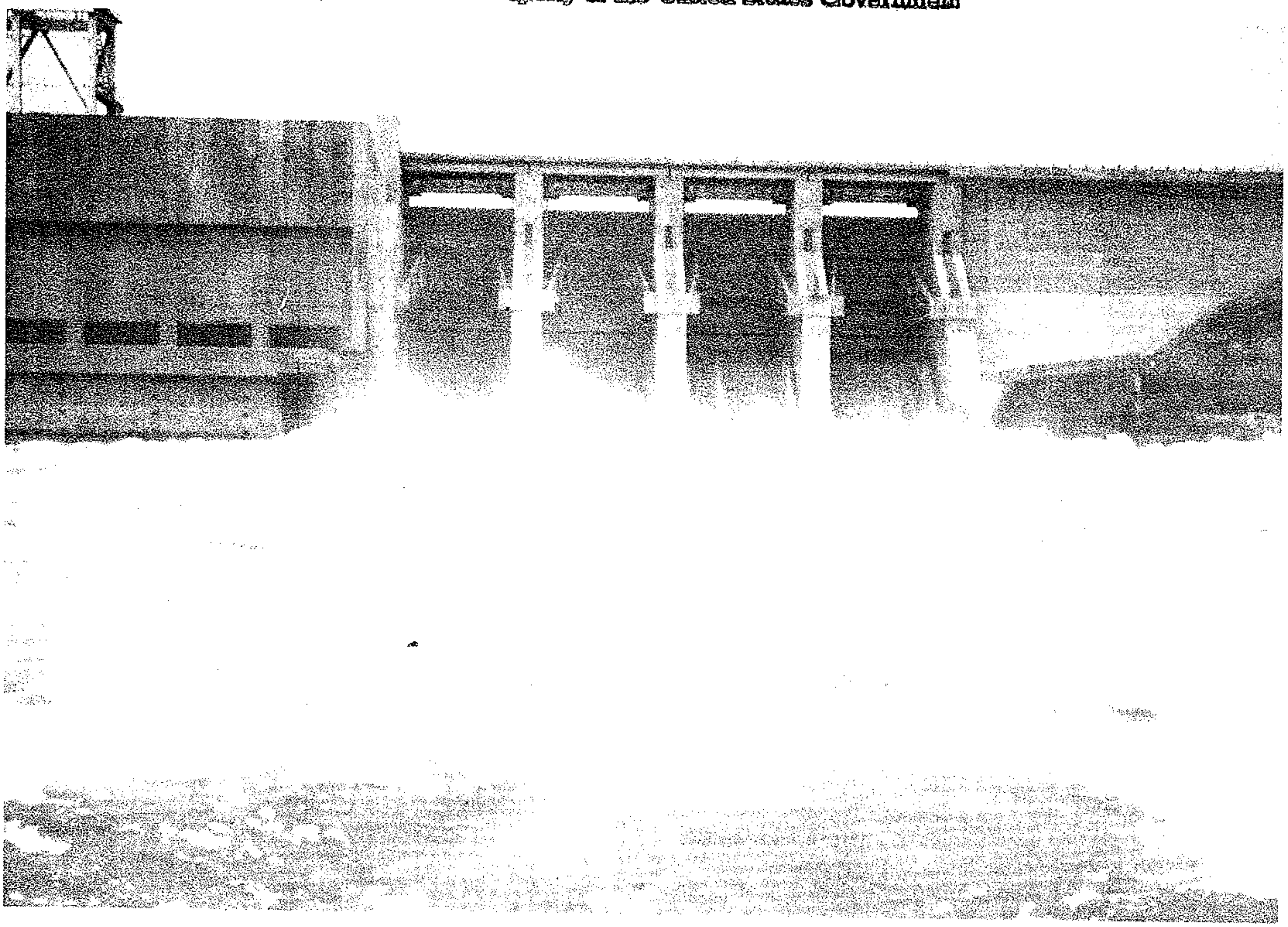

Operation of the Corps' reservoirs requires decisions that involve meeting project purposes while maintaining water quality in the reservoir. To assist the decisionmakers, the Environmental and Water Quality Operational Studies (EWQOS) Program has made significant advances in development of predictive techniques using models to describe reservoir hydrodynamics. The following article reports on verification techniques of two one-dimensional reservoir models, CE-QUAL-R1 and CE—THERM-R1.

EVALUATION OF ONE-DIMENSIONAL RESERVOIR MODELS

*Linda S. Johnson and Joseph H. Wlosinski**

CE-QUAL-R1 and CE-THERM-R1, one-dimensional (1-D) reservoir models, are being developed within EWQOS to assist engineers, planners, and managers in making decisions concerning reservoir water quality.

The CE-QUAL-R1 model has the capability to predict temperature; concentrations of oxygen, algae, various nutrients, and dissolved and particulate solids; and other water quality parameters in reservoirs and release waters. CE-THERM-R1 contains only those routines necessary for accurate simulation of temperature dynamics in a reservoir and, because of its smaller size, is less costly to operate and does not require the chemical and biological expertise needed to use CE-QUAL-R1.

Both models are being developed to evaluate the effects of project design or operation on water quality for both existing and proposed reservoirs. Detailed information concerning CE-QUAL-R1 and CE-THERM-R1 is available in the WES Instruction Report E-82-1 (Environmental Laboratory 1982), which is in loose-leaf format to permit updating as development of the models progresses. A limited number of copies were printed and distributed to Corps of Engineers (CE) field offices for use and comment at the user level.

The mathematical reservoir models consist of a number of linked equations describing the dynamics of reservoirs. The basic theory incorporated into these 1-D reservoir models has been developed in other EWQOS work units. For example, the equations describing inflow mixing, internal mixing, and biological processes were developed in Tasks IA.1, IA.2, and IB.1, respectively. Because the models are simplifications of the actual dynamics occurring in reservoirs, they must be rigorously tested to ensure accurate reproduction of observed water quality in existing reservoirs.

MODEL EVALUATION

The evaluation of the reservoir models is being conducted by means of a series of tests designed to ensure that the models are performing satisfactorily. These tests include checking the equations for correct dimensionality, ensuring that predictions are stable, testing the conservation of mass in the numerical codes, comparing the model predictions to the field-measured values, and determining the uncertainty of model coefficients.

The comparison of model predictions and actual measured values of water quality parameters is both qualitative and quantitative. Qualitatively, model predictions and field-measured values can be plotted, via an extensive graphics routine, and then examined visually. Figure 1 is an example of the type of graph available. Quantitative methods are also available to compare predicted versus measured values. At present, three different indices are available for comparison: a reliability index, a paired t-test for means, and a normalized mean error. The statistics are being used to compare results between simulations using various algorithms for the same process and between simulations using different coefficient values. The statistics are available for a profile of a particular variable for one point in time or for all points in time for a simulation.

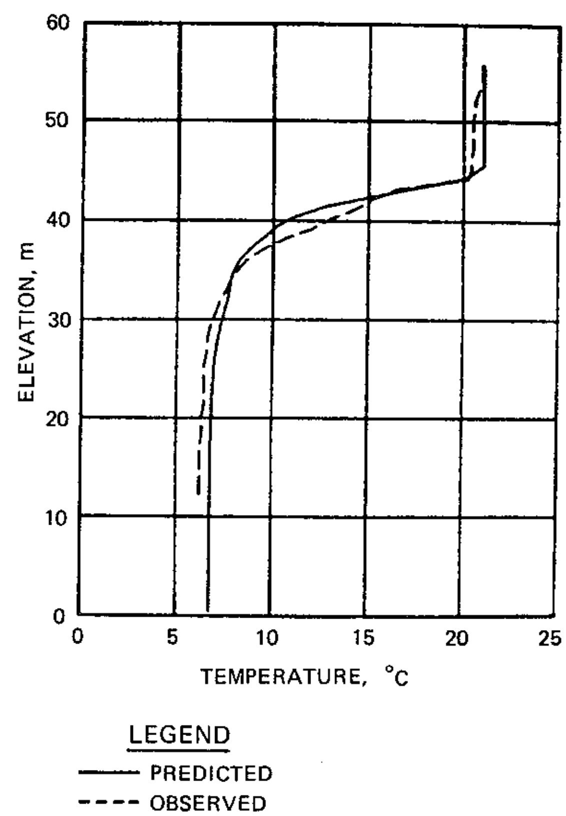

Figure 1. Example of graphics package output showing simulated and actual temperature profiles for DeGray Lake, 10 October 1979

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Statistical methods are also being developed to determine the uncertainty of model coefficients (e.g., biological and chemical rate coefficients and mixing coefficients). One method, being developed under contract, relies on maximum likelihood theory. This method will allow users to determine quantitatively how well model coefficients were estimated. The method will also allow the degree of uncertainty in model predictions of water quality variables to be estimated in each model application.

AN EXAMPLE

A report of a recent test of the model's predictive ability was presented at the American Society of Civil Engineers 1981 Fall Convention and Exposition in St. Louis, Mo. (Johnson and Ford 1981). The objective of the Johnson and Ford study was to test CE-THERM-R1 by calibrating the model coefficients with a data set from one reservoir for one year (including meteorological data and inflow and outflow quantities) and then verifying the model using four independent data sets characterized by different hydrometeorology and reservoir operating conditions.

Predictions were evaluated with emphasis placed on the model's ability for realistic reproduction of observed phenomena (such as onset of stratification, mixed layer depths, and density gradient in the metalimnion) rather than matching individual data points. The five data sets would show whether or not the model was capable of simulating three conditions: the same lake but a year characterized by different hydrometeorological conditions, such as wet versus dry year; the same lake but with a different operation scheme, for instance bottom versus surface withdrawal; and a different lake that is similar in location and morphology.

The model was calibrated using data collected at DeGray Lake during 1976. DeGray is a CE project located in southwestern Arkansas. It has a maximum depth of 57 m and an effective length of 32 km. 1976 was selected because it was the first year a complete set of temperature data was collected at DeGray and because meteorological conditions approximated the long-term average. Verification of the model included data collected at DeGray during 1975 and 1979. These data were compared to model simulations of DeGray for those years. The hydrometeorological conditions at DeGray during 1975 revealed warmer temperatures, greater runoff, and less wind when compared to 1976. In 1979 the release level at DeGray was lowered 12 m; temperatures were cooler; runoff increased; and wind speeds were slower than for 1975 or 1976.

The model was also verified using data collected at Lake Greeson during 1973 and 1975. Simulations of Lake Greeson were made without changing the mixing coefficients or meteorological forcing functions from those used for DeGray. Lake Greeson is also a CE project located in southwestern Arkansas. Its maximum depth is 51 m, and it has an effective reservoir length of 16 km. The only difference between the Lake Greeson data sets and those for DeGray was the input data concerning site-specific characteristics such as area-capacity curves, outlet structure details, inflows and outflows, and light extinction coefficients. The Greeson data sets were selected to evaluate the model's ability to simulate, without recalibration, a different lake that is similar in location and morphometry.

The results of the simulations showed that for all cases, the model accurately predicted the onset of stratification, overturn, mixed layer depths, surface temperatures, metalimnetic density gradients, and hypolimnetic temperatures. Figure 2 on page 4 shows the results of the DeGray 1979 simulation.

STATUS AND FUTURE WORK

Currently, the algorithms and coefficients used in CE-QUAL-R1 are being verified using data collected at DeGray Lake during 1979 and 1980 and at Eau Galle Lake, Wisconsin, during 1981. Data collection will continue at Eau Galle through 1982 to provide an additional data set for verification. Once the verification process is complete, the User's Manual and computer code will be updated to include the verified algorithms for existing processes in the model and for the processes added since Instruction Report E-82-1 was published (e.g., anaerobic chemistry and macrophyte compartment). The update will also incorporate comments and suggestions received from CE offices using CE-QUAL-R1 and CE-THERM-R1 and from other users, including the U. S. Environmental Protection Agency (EPA), whose Center for Water Quality Modeling, Athens, Ga., has recommended CE-QUAL-R1 for use in EPA's assessments of reservoir water quality.

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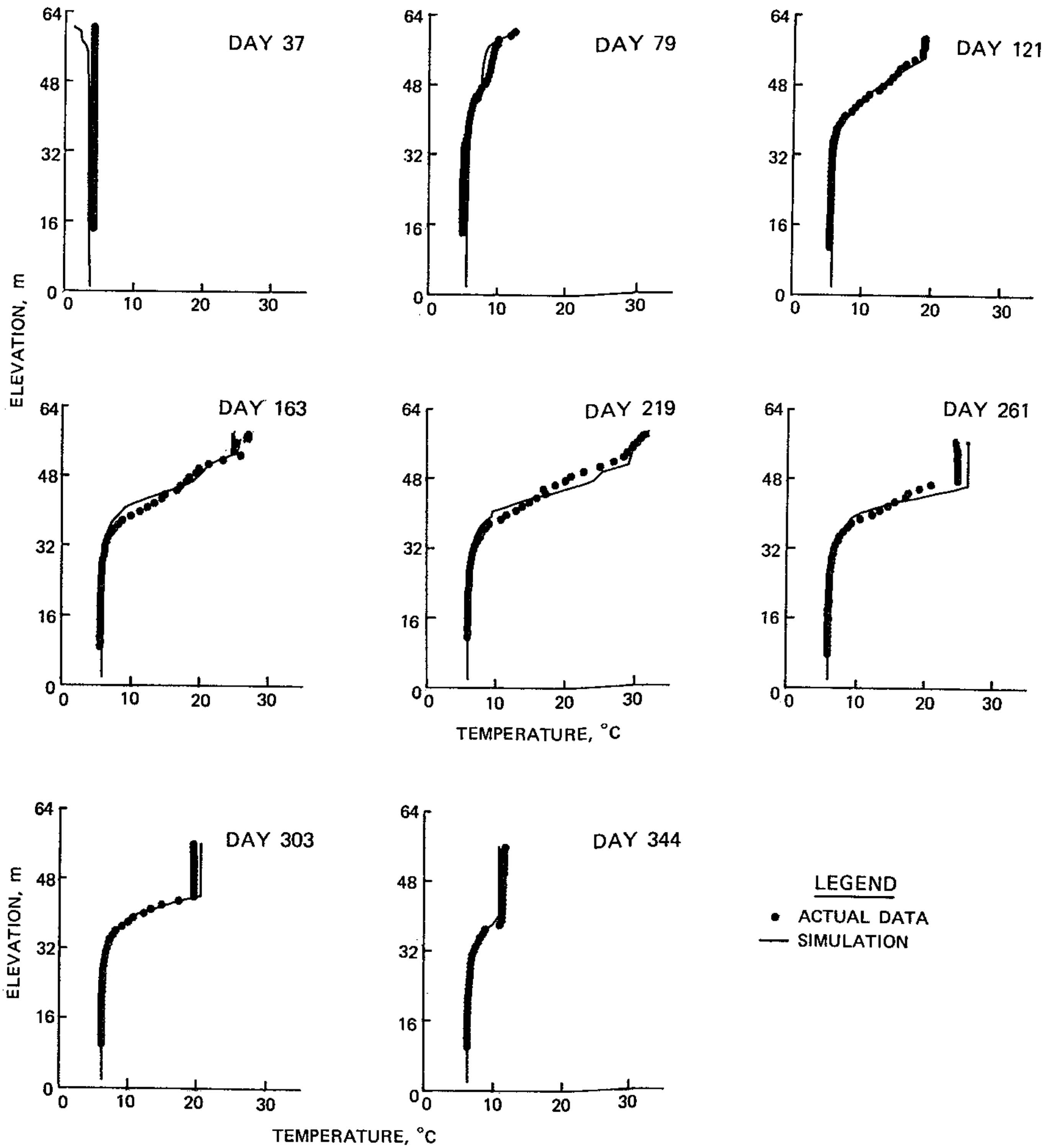

Figure 2. Comparison of simulated and actual temperature profiles for DeGray Lake, 1979

RESERVOIR SITE PREPARATION—AN UPDATE

*Douglas Gunnison**

After initial filling, a new reservoir undergoes several years of dynamic biological and chemical transformations associated with the decomposition of flooded organic matter. When inundated, brush, debris, and standing timber are desirable, to some extent, because of the refuge and food these materials provide for fish. Decay of these substances lowers dissolved oxygen, increases concentrations of objectionable materials, and makes achievement of water quality objectives more difficult. Degradation of organic matter in the litter layer and upper layers of topsoil is an important sink for dissolved oxygen and a source of nutrients and inorganic constituents such as iron, manganese, and sulfide.

In the past, guidance was not available to permit field offices to make cost-effective decisions concerning the amount and type of reservoir site preparation and the scheduling of initial filling needed to meet environmental quality objectives. One objective of EWQOS Work Unit IIF is to provide the guidance necessary for such decisionmaking.

APPROACH AND ACCOMPLISHMENTS

Assessment of environmentally compatible strategies for reservoir site preparation, clearing, and initial filling requires two major approaches: literature surveys and laboratory studies

Literature Surveys. To implement the first approach, extensive literature surveys have been conducted both in-house and through agreements with other federal agencies and universities to provide specific reports, each addressing a particular area of concern for reservoir site preparation. One report, "Factors Affecting Fish Production and Fishing Quality in New Reservoirs with Guidance on Timber Clearing, Basin Preparation, and Filling" (Ploskey, 1981), has been published and a second report, "Microbiological Water Quality of Reservoirs" (Burton, 1982), is being prepared for publication.

A draft Engineer Technical Letter (ETL) entitled "Interim Guidance-Environmental and Water Quality Considerations Relative to Reservoir Site Preparation and Filling" was submitted to OCE in June 1982. This ETL covers the existing regulations and specifications on reservoir site preparation and the biological and geochemical activities involved in the release of nutrients and contaminants from soils and vegetation. Environmentally-related concerns described in detail include depletion of dissolved oxygen, nutrient release and eutrophication, release of color-producing substances, public health considerations, and reservoir fisheries.

Lab Studies. The second approach involves the use of laboratory soil-water reaction columns** in a series of preimpoundment water quality studies to determine project-specific effects of soil flooding and its relationship to reservoir water quality. In this case, studies are funded either by this EWQOS work unit or in conjunction with project studies being conducted for CE Districts. Wherever possible, close coordination is maintained between groups collecting water quality data for reservoirs during initial filling to allow comparisons between the real system and results obtained in the laboratory.

To date, laboratory studies have demonstrated that processes occurring in newly flooded soils, particularly those having high contents of organic matter, and the decomposition of herbaceous vegetation and leaves on trees and shrubs strongly influence water quality. The intensity of these activities is a function of the properties of the soil or vegetation and this, in turn, is site specific.

Laboratory investigations have also indicated that the use of simplified testing procedures supplies the information required to determine the need for clearing and the advisability of various filling practices. Continued experience with this approach will provide data that, in conjunction with laboratory tests and mathematical models, can be used to predict the water quality of proposed impoundments.

SUMMARY

Work Unit IIF links considerations in the literature with the relationships between vegetative decomposition, soil flooding, and other environmental quality concerns into practical cost-effective techniques for application to reservoir site preparation and filling. The work unit provides applicable

(Continued on page 8)

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** See EWQOS Newsletter Vol. E-80-4, Aug 1980, article on Task IB.2 for a detailed description of these chambers.

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Reservoir Site (Continued from pg 5)

methodologies for assessing the impacts of soil flooding and vegetative decomposition on reservoir water quality, as well as guidance on the use of the information obtained from each method.

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