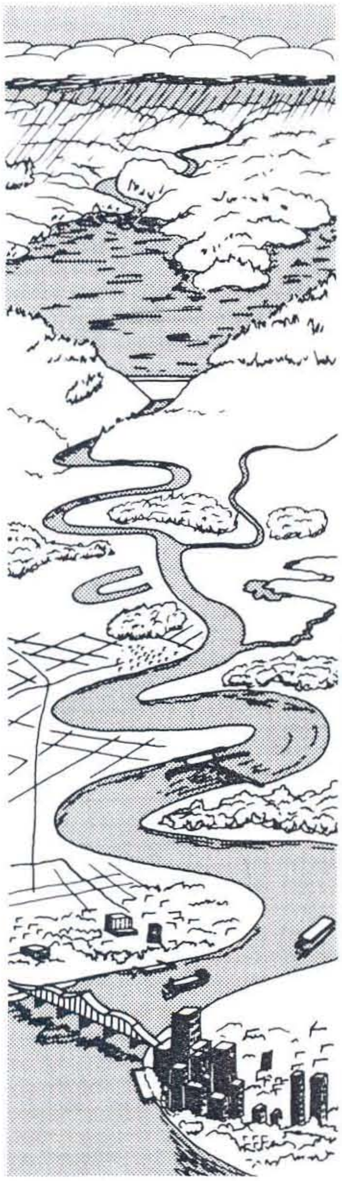
EWQOS

Environmental & Water Quality Operational Studies

VOL E-85-1 INFORMATION EXCHANGE BULLETIN MAR 1985



SIMPLIFIED TECHNIQUES FOR ASSESSING EUTROPHICATION-RELATED PROBLEMS IN RESERVOIRS

William W. Walker
Environmental Engineer
Concord, Massachusetts

Robert H. Kennedy
Environmental Laboratory, WES

Excessive inputs of nutrients, sediment, and organic materials to lakes and reservoirs leads to a deterioration in water quality. The process by which this occurs is referred to as eutrophication. Symptomatic of the occurrence of eutrophication are increased nutrient levels and algal production, reduced water clarity, and depleted oxygen in bottom waters. Since these conditions adversely impact the economic, aesthetic, and recreational value of important water resources, reservoir managers should have a means for evaluating present conditions and predicting future conditions.

Important in this regard is the development of simplified modeling techniques. Compared to the more complex water quality models, these simplified or empirical models are mathematically and conceptually less complex. While limited to predicting average steady-state conditions, the models offer the advantages of low data requirements, ease of use, and shorter application times.

Task IE of the Environmental and Water Quality Operational Studies (EWQOS) Program involved the development of such techniques. Since previous models were developed for natural lakes exhibiting characteristics different from reservoirs, initial efforts in Task IE centered on evaluating the suitability of these earlier models for reservoir problem-solving applications (Walker 1981, 1982). Subsequent efforts led to modifying these models and developing several new models specifically applicable to reservoirs (Walker 1985). Recent efforts have resulted in an assessment method for use in eutrophication-related water quality investigations.

This method involves four steps: problem identification, data compilation, data reduction, and model implementation. In typical applications, most of the effort and cost is associated with data compilation and data reduction. However, the assessment method involves three computer programs designed to assist users at various stages in the assessment process. These programs, FLUX, PROFILE, and BATHTUB, perform the following functions:

FLUX — estimation of tributary mass discharges (loadings) from grab-sample concentration data and continuous flow records.

PROFILE — reduction and graphical display of in-reservoir water quality data.

BATHTUB — implementation of nutrient balance and eutrophication response models in a spatially segmented hydraulic network.

PROBLEM IDENTIFICATION

The problem identification stage defines the scope of the assessment and modeling effort. The following factors are specified at this stage:

- The reservoir and watershed of interest and any applicable water quality standards or criteria.
- Whether the reservoir is existing or planned.
- Specific management strategies or impacts to be evaluated.
- Whether evaluative or predictive evaluations are to be performed.
- Whether nutrient balance or eutrophication response models are to be used.

Specifying of these items lays the groundwork for the assessment procedure. The first three items are self-explanatory. If the analysis is not directed toward evaluating specific management strategies or impacts, the general objective may be to develop perspectives on reservoir water quality conditions and controlling factors as part of an evaluative study. This could lead, in turn, to future evaluations of specific management strategies designed for water quality control.

The fourth item defines the general types of evaluations to be performed. In an evaluative mode, the models are used as a framework for interpreting monitoring data from the reservoir and/or its tributaries. For instance, an evaluation study can provide insights into factors controlling algal productivity. In other applications, the trophic state indicators of a particular reservoir could be ranked with respect to established water quality criteria or with respect to other reservoirs. In a predictive mode, the models would be applied to predict future conditions in a planned reservoir or in an existing reservoir undergoing a change in nutrient loading regime.

Model classes (the fifth item) are determined by the types of analyses to be performed. Both nutrient balance and algal response models would be required for a predictive analysis. An evaluation study could be based exclusively upon algal response models and pool water quality data. In the latter case, existing conditions and controlling factors within the reservoir could be defined, but watershed/reservoir or load/response relationships could not be evaluated. As a rule, monitoring requirements are generally much more stringent for implementing nutrient balance models than for implementing algal response models.

Internal models and pool monitoring data may be used in preliminary evaluation studies and, depending upon results, be followed by more elaborate nutrient balance monitoring and the modeling of priority projects. Priorities would be established based upon the severities of existing eutrophication-related problems (if any), intensities and types of water use, and potential for future improvement or degradation owing to changes in loading regime.

DATA COMPILATION

The assessment procedure is initiated by compiling necessary reservoir and watershed data. The reservoir data required for implementation of eutrophication response models include morphometric characteristics, outflow hydrology, and pool water quality obtained over at least one complete growing season. The watershed data required for implementation of nutrient balance models include basic watershed characteristics (subwatershed delineation, topography, geology, land uses, and point-source inventories) and tributary flow and nutrient concentration data taken at reservoir entry points over at least one full year.

DATA REDUCTION

Pool and tributary water quality information is reduced or summarized in a form that can serve as model input. Since the models generally deal with conditions averaged over a growing season within defined reservoir areas (segments), data reduction involves averaging or integrating individual measurements.

The FLUX program assists in reducing tributary and reservoir discharge monitoring data. Using a variety of calculation techniques, FLUX estimates the average mass discharge or loading passing a given tributary monitoring station. These estimates are based upon grab-sample concentration data and a continuous flow record. Potential errors in the estimates are also quantified and can be used to select the best loading estimate, assess data adequacy, and improve future tributary monitoring efficiency via optional allocation of sampling effort among seasons and/or flow regimes. Graphic displays of concentration, flow, and loading data are provided for diagnostic purposes.

The PROFILE program assists in the analysis and reduction of pool water quality data. A variety of display formats are provided to develop perspectives on spatial and temporal water quality variations within a given reservoir. Algorithms are included for calculating hypolimnetic oxygen depletion rates and for estimating area-weighted surface-layer mean concentrations of nutrients and other response measurements used in subsequent modeling steps.

MODEL IMPLEMENTATION

BATHTUB facilitates applying empirical eutrophication models to morphometrically complex reservoirs. The program performs water and nutrient balance calculations in a steady-state spatially-segmented hydraulic network that accounts for advective and diffusive transport and nutrient sedimentation. Eutrophication-related water quality conditions (expressed in terms of total phosphorus, total nitrogen, chlorophyll-a, transparency, organic nitrogen, particulate phosphorus, and hypolimnetic oxygen depletion rate) are predicted using empirical relationships previously developed and tested for reservoir applications (Walker 1985).

Outputs are expressed in terms of a mean value and coefficient of variation for each response variable. Coefficients of variation are based upon a first-order error analysis that accounts for input variable uncertainty and inherent model error. Applications of BATHTUB would normally follow use of the FLUX program for reducing tributary monitoring data and use of the PROFILE program for reducing pool monitoring data, although use of the data-reduction programs is optional if independent estimates of tributary loadings and/or average pool water quality conditions are used.

SUMMARY

Empirical modeling techniques provide a simple means for describing and/or predicting eutrophication-related water quality problems in lakes and reservoirs. Using such techniques within the framework of the assessment procedure facilitates the orderly and comprehensive evaluation of water quality conditions in existing or proposed reservoirs under a variety of circumstances. This represents a valuable tool for district personnel in developing sound management strategies for reservoirs.

A detailed description of the assessment procedure and documentation for the computer programs will be available by the middle of FY 85 in the form of a user's manual. A workshop, held in January 1985, featured lectures and working sessions during which participants gained hands-on experience.

REFERENCES

Walker, W. W., Jr. 1981. "Empirical Methods for Predicting Eutrophication in Impoundments; Report 1, Phase I: Data Base Development," Technical Report E-81-9, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Walker, W. W., Jr. 1982. "Empirical Methods for Predicting Eutrophication in Impoundments; Report 2, Phase II: Model Testing," Technical Report E-81-9, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Walker, W. W., Jr. 1985. "Empirical Methods for Predicting Eutrophication in Impoundments; Report 3, Phase III: Model Refinements," Technical Report E-81-9, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

SEDIMENT CHARACTERISTICS IN THREE CE RESERVOIRS

Robert C. Gunkel, Jr., Robert F. Gaugush, and Robert H. Kennedy
Ecosystem Research and Simulation Division, EL

SYNOPSIS—Studies of sediment distribution and deposition were designed to better define relationships that contribute to sediment accumulation and quality. Sediment moisture content was found to be a reliable indicator of sedimentation patterns in reservoirs. Differences in sediment moisture content were related to differences in sediment composition and quality. These data will contribute to the planning of reservoir management strategies.

Sediment accumulation in lakes and reservoirs leads to the progressive deterioration of valuable environmental and recreational resources. In addition to the reduction in lake depth and volume, an obvious consequence of sediment accumulation, sediments may also cause significant changes in water quality (Thornton et al. 1981). Suspended sediments, transported from watershed to lake by tributary streams and rivers, are often enriched with plant-stimulating nutrients, metals, and other contaminants that cause water quality problems when released to lake waters. Because of these potentially important impacts on water quality, reservoir managers should more fully understand