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Project Summary

Application of Water Quality Models to a Small Forested Watershed: I. The Nondesignated 208 Area Screening Model

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The report presents an evaluation of the application of the Water Quality Assessment Methodology *(Water Quality Assessment: A Screening Method for Nondesignated 208 Areas,* EPA-600/9-77-023) to a forested watershed on portions of the U.S. Military Academy Reservation and the Harriman Section of The Palisades Interstate Park in Orange County, N.Y. As part of the calibration and verification process, field data for water quality, hydrologic, and meteorological parameters were collected. The report details the selection of sampling sites, instruments, techniques, and analytical methods used in the data collection. Parameter selection for model use is explained.

This Project Summary was developed by EPA's Environmental Research Laboratory, Athens, GA, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Basin planning requires a set of analysis procedures that can provide an assessment of the current state of the environment and a means of predicting the effectiveness of alternative pollution control strategies. In 1977, the Environmental Research Laboratory published *Water Quality Assessment: A Screening Method for Nondesignated 208 Areas* (EPA-600/9-77-023), which contains a set of consistent analysis methods that accomplish these tasks. The assessment procedure, called the Water Quality Assessment Methodology (WQAM), is directed toward local and state government planners who must interpret technical information from many sources and recommend the most prudent course of action that will maximize the environmental benefits to the community and minimize the cost of implementation. An integral part of the WQAM development process is the calibration and verification of the model on actual watersheds. This report evaluates its use in characterizing wasteloads and water quality in small forested watersheds in New York.

The West Point Study Area comprises 3247 acres of watershed draining to the dam on Popolopen Lake (Figure 1). Elevations range from 678 ft at Popolopen Lake to 1401 ft along the northwest margin of the basin. Soils on the hills are shallow with zero to 18-24 inches overlying bedrock. Lowland soils are deeper, up to 6 feet.

Summer temperatures at West Point average 74 degrees Fahrenheit, but short hot spells in the nineties are

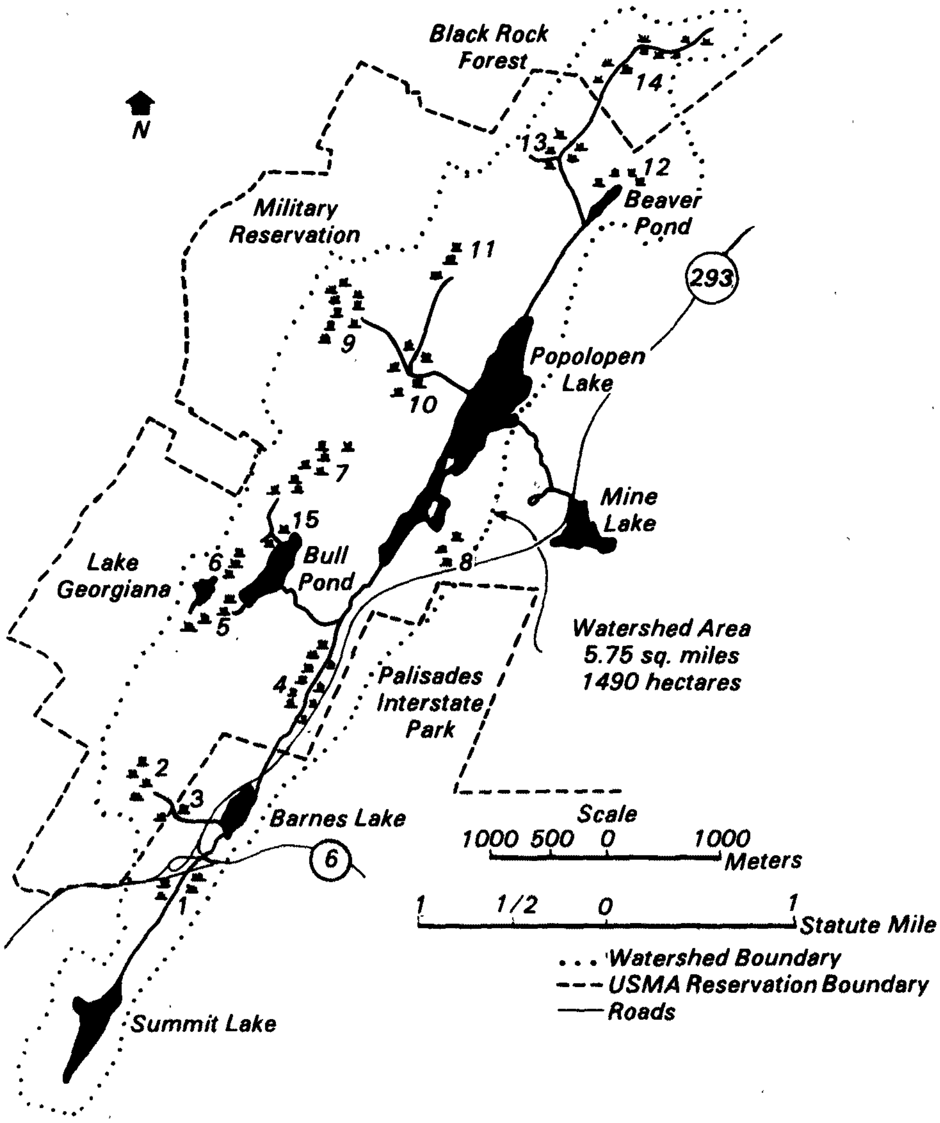

Figure 1. The West Point study area showing the watershed boundary and wetland locations.

common. Winters are moderately cold, with temperatures averaging just below the freezing point. It is not unusual to have rain throughout the winter. Snowpack typically comes and goes throughout the winter. The mean annual precipitation at West Point is 47 inches, distributed evenly through the year.

Drainage on the watershed is a modified trellis pattern influenced by the lineation in the underlying rocks and faults. Six lakes (ponds) and 21 wetland complexes affect the flow of water on the watershed. Five of the six lakes are manmade; Bull Pond, the deepest lake, is natural. Three of the five manmade lakes (Summit, Popolopen, Beaver) have depths greater than the dam height and thus must have existed as small ponds or wetlands prior to impoundment.

The streams in the area have cut to bedrock in most cases. Channels are strewn with boulders and stones. Streams flash to high flow after storms because of the impervious bedrock material close to the surface. There is little overland flow under the forest canopy. A great deal of interflow takes place at the soil-bedrock interface.

The entire watershed tributary to Popolopen Lake was modeled for the study. Individual sub-areas are shown in Figure 2. The ground surfaces of all areas were modeled individually for nonpoint wasteloads of sediment, nitrogen, phosphorus, and organic matter. In addition, composite loads from areas 1 through 4 and for th entire study area were predicted. Th estimated wasteloads of surroundin and tributary areas were used as input to model three lakes for sedimentation eutrophication, and thermal stratification

The data collection network on th West Point Study Area was designed t gather data for the EPA-supporte model testing program and to serve a the basis for a future program dealin with the hydrology and nutrient budget of wetlands. The study was designed t obtain:

1) input to a simulation model.
2) data against which the model prediction will be compared during the calibration of the model to the West Point Study Area.
3) data against which the prediction from the calibrated model will be compared to verify that the model is providing valid predictions.
4) data to support the wetland studies.

Data needs are in the following areas.

1) Hydrology - stream flow, evaporation, precipitation, etc.
2) Meteorology - temperature, dew point, radiation, wind speed, etc.
3) Physical characteristics of the watershed - area, slope, soil depth, soil types and extent, cover, aspect, etc.
4) Water Quality - both chemical and biological.
5) Rate constants for reactions.

The report elaborates on the instrument and site selection criteria used. Parameter selection and sources used to select parameters for modeling are presented in the report.

Two basic problems may have restricted the application of the WQAM to the West Point Study Area: 1) the study area is almost totally forested with no agricultural land; 2) the assumption that the majority of the nutrient and organic loads are tied to sediment may not hold for watersheds having relatively low sediment yields. Little work has been done on applying the Universal Soil Loss Equation to forested lands and thus input parameters are less clearly defined.

Based on the loading functions provided in the WQAM documentation, loading functions estimates were made of the average annual loads of sediment, nitrogen, phosphorus and organic matter contributed from each of eight sub-areas of the West Point Study Area. These estimated loads for the entire study area (sub-areas 1 through 8) and for the four southern sub-areas as a whole (sub-areas 1 through 4) are presented in Table 1.

In order to make the WQAM work on the West Point Study Area, we have in several instances, turned to the Water Resources Evaluation of Non-Point Silvicultural Sources (WRENSS) model (EPA-600/8-80-012) and borrowed pieces to patch up difficulties in the WQAM. Which is the better model, the patched-up WQAM or the WRENSS model? The WRENSS model was developed for forested areas and probably should be used for large forested watersheds in preference to the WQAM. WQAM was meant to identify problem areas in large regions, portions of which may contain forests. It should contain procedures to allow modeling of forested areas or incorporate the WRENSS model procedures for this purpose. A comparison of the ease of use of the two procedures and comparison with field data are needed to decide whether the WRENSS model or the patched-up WQAM is the better alternative.

The impoundment models were applied without modification. The thermal profile predictions for lakes of various depths and residence times can be said to be validated for The West Point Study Area, Figure 3, although we could have used better guidance in the procedures on how to decide whether our lakes were well mixed. These procedures could easily be applied with confidence to other lakes in the Hudson Highlands. For existing impoundments, however, the data requirements for their use are such that we think many modelers would be prevented from using the prediction, finding it easier and cheaper to measure a thermal profile than to obtain data necessary to compute lake volume and residence time. For planned impoundments, the designers would know volumes and easily predict residence time.

The sedimentation rate prediction is easily applied but is only as good as the nonpoint source sediment yield predictions. When the best predictive method for forested areas is determined, then a closer look at the sediment accumulation prediction can be made.

The impoundment eutrophication predictions in the WQAM will indicate a eutrophication problem only in phosphorus-limited situations. The procedures should be expanded to allow prediction in nitrogen limiting situations as well as those in which neither phosphorus or nitrogen controls. The stream models in the WQAM docu-

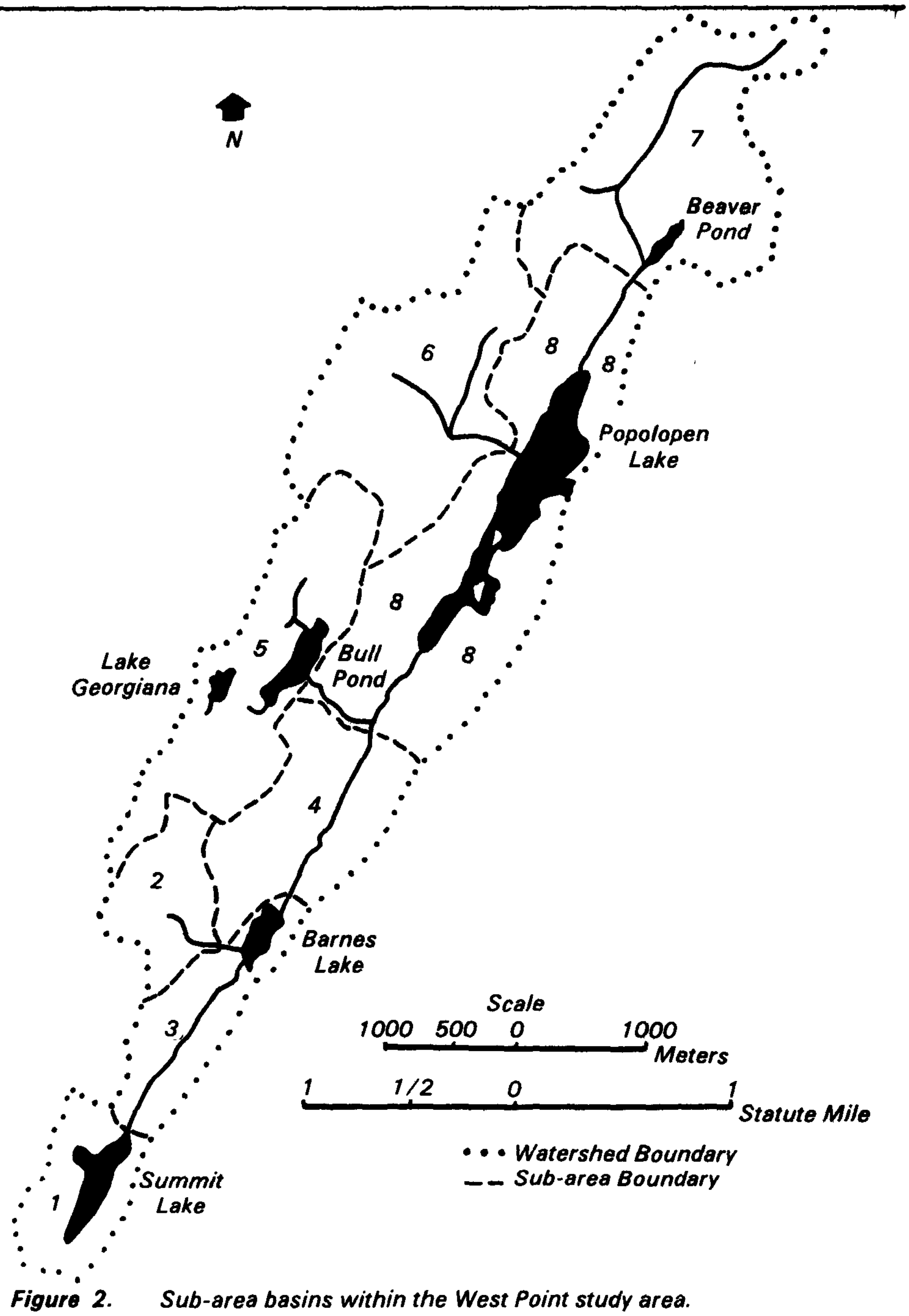

Figure 2. Sub-area basins within the West Point study area.

Table 1. *Summary of Predicted Nonpoint Loads from the West Point Study Area Using the Water Quality Assessment Methodology*

	Southern Area (sub-areas 1-4)	Entire Study Area (sub-areas 1-8)
Sediment, tons/year	621	2,115
Sediment, tons/acre-year	0.66	0.65
Nitrogen, lb/year	5,818	19,839
Nitrogen, lb/acre-year	6.1	6.1
Phosphorus, lb/year	1,305	4,442
Phosphorus, lb/acre-year	1.38	1.37
Organic Matter, lb/year	93,150	317,250
Organic Matter, lb/acre-year	98.5	97.7

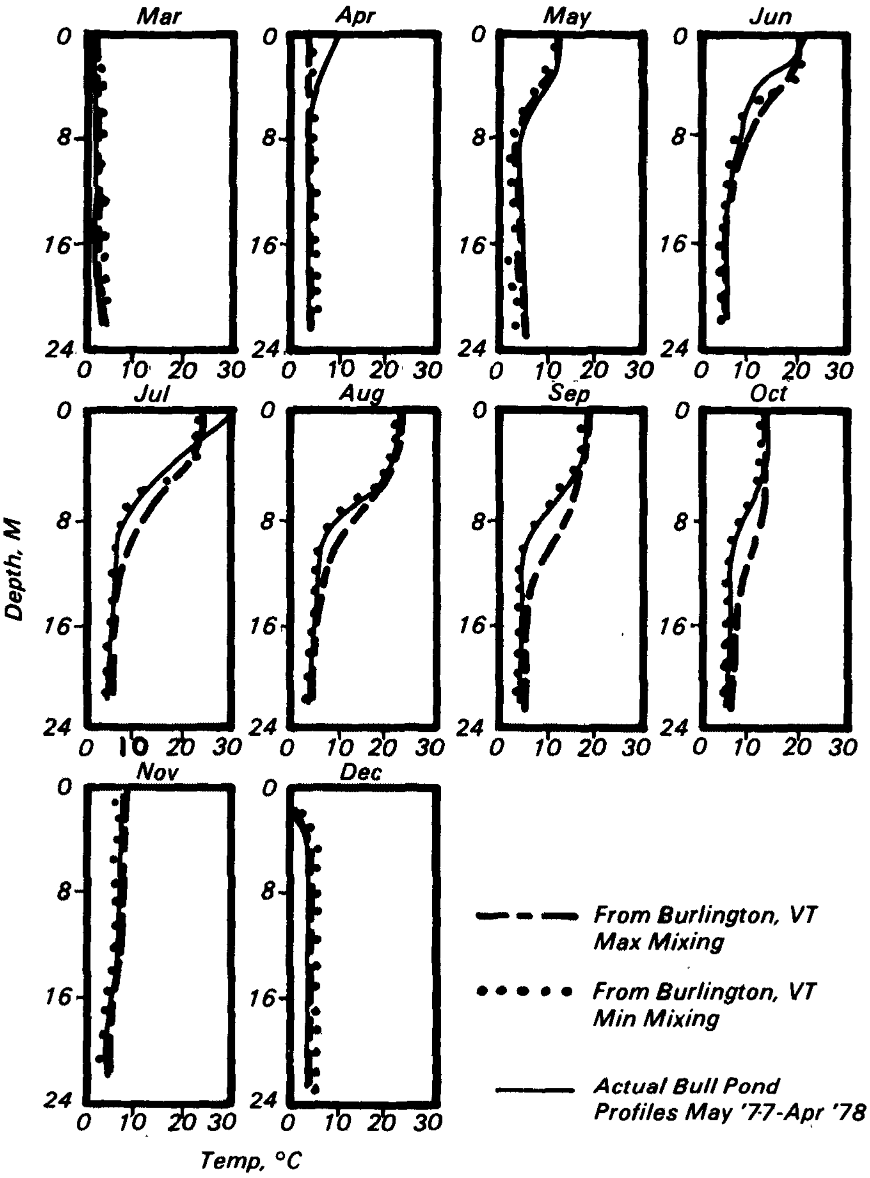

Figure 3. *Comparison of Bull Pond thermal profiles with model estimates assuming varying degrees of mixing.*

mentation have provision for this and perhaps could be expanded to lakes.

The dissolved oxygen model gives a reasonable approximation for DO levels during the mid-summer maximum stress period. Assuming $K_s = 0$ yields a DO prediction higher than observed and can lead one to conclude, as we did, that the benthic DO demand prior to stratification is zero. This is not reasonable for every lake, and our test at Bull Pond yielded a difference between actual and predicted DO levels of almost 1.0 mg/l. In lakes with higher levels of decaying organic matter the difference would be greater. Table V-10 in the WQAM documentation should be used in preference to Equation 17-13 for assigning an L_{ss} value. The assumption, based on observations at Bull Pond, that $k_s = 0$ appears justified in other parts of the model. Again this works well for Bull Pond, but in other lakes with a higher settleable BOD rate, it will lead to a prediction error.

Conclusions

1. Wasteloading from nonpoint sources on the West Point Study Area or any other steeply sloped area cannot be modeled by the WQAM without extension or modification of the algorithm for assigning a value to the topographic factor, LS.
2. Procedures for use of the erosion control practice factor, P, for forested areas need to be clarified in the WQAM.
3. The formulation for deriving the sediment delivery ratio, S_d in the WQAM, yields sediment loading values higher than we are comfortable with. The sediment delivery index in the WRENSS model derived from eight forest parameters seems better suited to forested areas.
4. Lake eutrophication predictions in the WQAM only work for phosphorus-limited conditions. The model needs to be extended to other situations.
5. The lake thermal profiles model in the WQAM, when applied to the West Point Study Area, gives a reasonable prediction of actual field conditions.
6. The lake dissolved oxygen prediction in the WQAM has been verified for one lake in the West Point Study Area.
7. Application of the WQAM to forested watersheds should be done with caution until the methodology is thoroughly tested and verified.

Recommendations

1. That further data collection be conducted on the West Point Study Area to enable verification of the wasteloading prediction from nonpoint sources based on the WQAM.
2. That WQAM model procedures be revised to give guidance to the user with forested terrain to model on how to set the erosion control practice factor, P, in the universal soil loss equation.
3. That the procedures from the WRENSS model for calculation of the topographic factor, LS, and sediment delivery index, SDI, be added to the WQAM as replacements for LS and S_d for steeply sloped forested areas only.
4. That the WRENSS model be applied to the West Point Study Area and verified and that the revised WQAM (see 3 above) be verified on the same watershed to determine which model gives the better prediction of water quality from a forested watershed.
5. That for the average annual rainfall factor, R, maps presented in the USDA Agriculture Handbook 537 be substituted for the generalized version presented in the WQAM documentation.

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The complete report, entitled "Application of Water Quality Models to a Small Forested Watershed: I. The Nondesignated 208 Area Screening Model," (Order No. PB 82-242 520; Cost: $12.00, subject to change) will be available only from:

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