State of New Jersey
Department of Environmental Protection

Calibration Enhancement of the System-Wide Eutrophication Model (SWEM) in the New Jersey Tributaries

Final Technical Report
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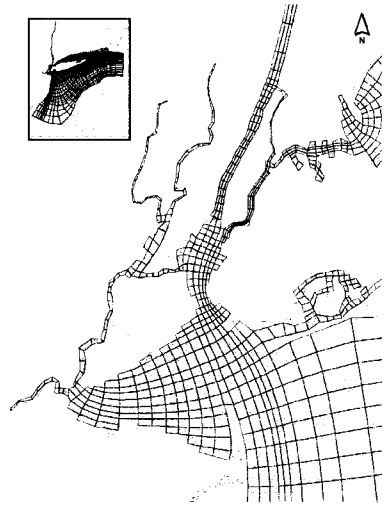

HydroQual, Inc.
under agreement with the
Passaic Valley Sewerage Commissioners

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EXECUTIVE SUMMARY

Background

SWEM was developed by HydroQual, Inc., for the City of New York Department of Environmental Protection (NYCDEP) for NYCDEP planning purposes. The NY/NJ Harbor Estuary Program (HEP) maintained a strong interest in and oversight over the development of SWEM. SWEM underwent extensive technical review by representatives of the States of NY, NJ, and CT, and by panels of experts convened by both HEP and the Long Island Sound Study (LISS). The technical review process, with the concurrence of HydroQual, identified that if SWEM is to be used by HEP, LISS, and the States for regional nutrient management, enhancements to the calibration of SWEM in New Jersey waters are warranted. Through its representation on HEP's System-wide Nutrient Workgroup (SWNWG), the State of New Jersey Department of Environmental Protection (NJDEP) agreed to sponsor the necessary enhancements to the calibration of SWEM in New Jersey waters. The necessary enhancements are being performed on behalf of the NJDEP by HydroQual under an agreement with the Passaic Valley Sewerage Commissioners (PVSC).

Summary of Calibration Enhancements - Hydrodynamics

The areas of improvement identified for the enhancement of the SWEM hydrodynamic sub-model include refinements in model geometry (i.e., longitudinal resolution of the model grid segmentation and bathymetry) and adjustments in bottom friction. The Raritan River was re-segmented longitudinally and bathymetry adjustments were made in all three tributaries. Adjustments in bottom friction were made in the Hackensack River. These adjustments improved the calibration of the hydrodynamic sub-model to salinity and temperature as well as the calibration of the water quality sub-model to all of the state variables. A weakness of the calibration which remains is that the SWEM computational grid is restricted to only one lateral element wide in each of the three New Jersey tributaries. Lack of lateral resolution hampers the ability of a model to capture secondary currents and small-scale bathymetric features. Adjustments to bottom friction in SWEM serve as a compensating mechanism for limited lateral resolution.

Summary of Calibration Enhancements - Water Quality

The areas of improvement identified for the enhancement of the SWEM water quality sub-model include loadings, vertical mixing coefficients, benthic filtration rates, nitrification rates, vertical light extinction coefficients, and temperature effects on algal growth. The enhancements both improved the overall level of calibration and/or made SWEM more defensible. In the absence of data, tributary headwater loading concentrations as well as ambient light extinction coefficients

were assigned using a more stringent protocol than was followed during the original calibration/validation. Adjustments to benthic filtration rates in the New Jersey tributaries were made in SWEM to make use of data that were not considered in the original SWEM calibration/validation. Adjustments to vertical mixing coefficients, temperature effects on algal growth, and nitrification rates improved the ability of SWEM to better represent measured ambient water quality data. The calibration enhancement effort has led to several conclusions and recommendations regarding the future application of SWEM.

Conclusions and recommendations regarding the future application of SWEM are presented in this report in Sections 1 and 5 and reflect both the professional judgment of HydroQual and feedback and guidance provided by NJDEP during its review of an earlier draft of this report. Section 1 highlights overall conclusions and recommendations. Section 5 presents detailed recommendations for future monitoring. The report appendix provides documentation of the NJDEP review.

SECTION 1

CONCLUSIONS AND RECOMMENDATIONS

- SWEM is a suitable planning tool for addressing nutrient management and regulatory issues in the NY/NJ Harbor Estuary. Further, SWEM is technically defensible and is generally appropriate for TMDL/WLA/LA development in most of the estuary. Collection of additional data in the New Jersey tributaries and, potentially, further SWEM enhancement or additional model development is recommended for TMDL/WLA/LA development within these waters. It is judged, however, that the model is satisfactory at present for preliminary management planning in the New Jersey tributaries.

- As with any model, the application of SWEM for management decisions will require an understanding of model limitations and a judicious interpretation of results.

- Although SWEM is ready to be applied to answer nitrogen and carbon management questions, there still remains room for improvement. In particular, landside loadings (i.e., CSO and stormwater runoff) in SWEM are assigned based on the outputs of a hybrid of Storm Water Management Models (SWMM) and the Rainfall Runoff Modeling Program (RRMP). RRMP was developed and calibrated in the 1970's by HydroQual and has not been updated since. SWMM outputs represent the current best estimates of landside loadings. Unfortunately, SWMM outputs are available to HydroQual only for a limited portion of the SWEM drainage area, basically New York City. To the extent that SWMM outputs are available for New Jersey and other jurisdictions, these should be incorporated in SWEM. To put proper perspective on the significance of this weakness, it is important to remember that for nutrients, CSOs and storm water runoff are only a small percentage (i.e., less than 3% of the total nitrogen loading system wide excluding open ocean inputs) of the total loading. The urgency for inclusion in the model of all available SWMM outputs would apply more in the context of pathogens management rather than nutrient management.

- The synoptic field program conducted in 1994-95 in support of SWEM as well as supplemental monitoring funded by the New Jersey Harbor Dischargers Group (NJHDG) provides a spatially and temporally comprehensive database to fully support calibration and skill assessment of SWEM. The monitoring addressed all SWEM elements: hydrodynamics, loadings, detailed water column biology and chemistry, and sediment fluxes. While the calibration database is unprecedented in terms of its extent, several shortcomings are noted:

- Measurements of light extinction are missing in the New Jersey tributaries. This is due in part to the fact that monitoring was conducted around the clock and sampling events conducted at night do not include light extinction measurements. During other sampling events, there were photometer problems and valid readings were not obtained. Light extinction measurements can be made at a low cost using secchi disks. It is recommended that secchi disk depth be routinely monitored in the New Jersey tributaries as is done in other portions of the Harbor for which extant secchi disk depth measurements from 1994-95 were used to supplement the calibration database. In the New Jersey tributaries in general, there are more nutrients available than the phytoplankton can use and light plays a critical role in controlling or limiting algal growth. It is primarily through algal growth that nutrients are linked to the dissolved oxygen balance. For these reasons, it is important that light penetration be properly accounted for in SWEM.

- The laboratory which conducted the monitoring program in support of SWEM chose to group tributary headwaters with the loading sampling rather than with ambient water sampling. As a result, no direct measurements were made of algal biomass at tributary headwaters and dissolved oxygen was not measured either. As a result, the tributary headwater concentrations for algal carbon and dissolved oxygen assigned in SWEM are estimated as opposed to based on direct measurements.

- The monitoring program in support of SWEM was designed to include twelve ambient sampling events and sampling of loads over twelve months. Due to budgetary problems with the laboratory, the scope of the monitoring program was reduced to nine ambient sampling events and sampling of loads over eight months. The scope reduction of the sampling of loads is the reason why tributary headwater input concentrations are not available for the months October and July through September.

- The water year 1988-89 was selected as the SWEM validation year because there is a significant database available (although not as comprehensive as the 1994-95 database) from the Long Island Sound Study for the calibration of the LIS3.0 model, and it is the year upon which the Long Island Sound nitrogen TMDL is based. 1988-89 was also selected because it represents a markedly different condition than 1994-95, providing an opportunity to demonstrate SWEM robustness. Unfortunately, the 1988-89 database is lacking in the New Jersey tributaries. For this reason, it is appropriate to say that SWEM has been validated in Harbor and Sound waters, but not in the New Jersey tributaries. No other year or hybrid of years was identified as having enough data to serve as a validation condition for the New Jersey tributaries. Where possible, 1988-89 SWEM results in the New Jersey tributaries and

adjacent waters are compared to data from years between 1988 and 1995, providing a very cursory, gross scale skill assessment.

- The project to enhance the calibration of SWEM in the New Jersey tributaries was a fruitful effort which both improved the level of calibration of SWEM in the three tributary rivers and strengthened the technical basis of assumptions/judgments made in assigning SWEM input values in the absence of data.

- Calibration of SWEM in the Hackensack River was more difficult than originally anticipated at the outset of the project and is limited by a lack of lateral segmentation in the SWEM computational grid and a lack of detailed kinetics for marsh related phenomena.

- In most marine environments, and in the NY/NJ Harbor Estuary complex, nitrogen is the nutrient which is typically managed or controlled. In addition to nitrogen, phosphorus and silica are also important to algal growth and thus the dissolved oxygen balance and have been included in SWEM. In all waters, the SWEM silica calibration is deficient in comparison to nitrogen. This deficiency is being addressed by a study now commencing under funding from the New York City Department of Environmental Protection and could eventually lead to a correction throughout the SWEM domain. As silica may periodically be limiting to algal growth instead of nitrogen in certain Harbor locations, it is advantageous to perfect the silica calibration.

- Modeling now being conducted in the NY/NJ Harbor Estuary under the CARP program will necessitate that SWEM be run for four additional water years, covering 1998 through 2002. The SWEM effort under CARP is a significant opportunity in that it provides the opportunity to have available the necessary SWEM hydrodynamic and carbon inputs to test nutrient management actions in SWEM under a total of six different hydrodynamic, hydrological, and meteorological conditions. Further if nutrient data are available for the four additional years for which SWEM will be run under CARP, it would be possible to perform further skill assessment of SWEM. It is noted that it is unlikely that enough data exist from 1998 through 2002 to support a full SWEM validation in the New Jersey tributaries. At the very least, organic carbon measurements made for CARP can be used for a further skill assessment of SWEM.

SECTION 2

INTRODUCTION

This report presents the technical details of calibration/validation enhancements to the System-wide Eutrophication Model (SWEM) in the Hackensack, Passaic, and Raritan Rivers. The calibration/validation of SWEM for the full model domain, as shown in Figure 2-1, and the initial calibration/validation efforts in the Hackensack, Passaic, and Raritan Rivers have been previously presented by HydroQual in a series of technical reports and have been approved through a peer review process by representatives of the States of NY, NJ, and CT, and by panels of experts convened by both the Harbor Estuary Program (HEP) and the Long Island Sound Study (LISS). This report will not present a review of the initial calibration/validation, but will present enhancements to the calibration/validation of SWEM in New Jersey waters. It is assumed that this report will be used by individuals already familiar with SWEM and the physical features of the estuarine portions of the Hackensack, Passaic, and Raritan Rivers.

Model calibration involves the adjustment of model forcings, constants, coefficients, parameters, and formulations so that the model is able to reproduce the major trends in observed data and explain causality. Model validation involves applying the calibrated model under a different set of environmental conditions. In the validation procedure, the calibrated model is not changed. Enhancements to SWEM conducted under this project were applied to both the calibration and validation. The only allowable differences between calibration and validation are model inputs associated with the specification of the measured or observed conditions specific to calibration or validation conditions (i.e., temperature, precipitation, light extinction, etc., for a given year).

This report is broken down into two major sections or tasks which address the sub-models that comprise SWEM: hydrodynamics and water quality. Within each sub-model section, emphasis is placed on the calibration year 1994-95 since for this period a comprehensive database is available for calibration. An additional year, 1988-89, is also considered as it is the validation year for SWEM. The 1988-89 database is not as extensive as the 1994-95 database and is particularly lacking in the New Jersey tributaries. Although the 1988-89 database was sufficient for validation purposes in the Harbor and in Long Island Sound, it does not provide for a robust model skill assessment in the Hackensack, Passaic, and Raritan Rivers. Where possible, data from other years are included in comparisons to 1988-89 model results to supplement the 1988-89 database. Overall, there is not a sufficient database available to validate the calibration of SWEM in the Hackensack, Passaic, and Raritan Rivers.