DRAFT FINAL REPORT

Three-Dimensional Hydrodynamic and Water Quality Model of Peconic Estuary

for:

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13 - SUMMARY AND CONCLUSIONS

13.1 Summary of EFDC Water Quality Model Framework

A suite of 22 state variables was required to model the eutrophication processes in the water column (see Table 4-1). Three variables (salinity, water temperature, and total suspended sediment) that are necessary for certain computations involving the 22-state variables, were provided by the EFDC hydrodynamic model. The interactions among the state variables were shown in Figure 4-1.

Kinetic interactions affecting the state variables were described in over 80 partial differential equations that required evaluation of more than 130 parameters. The kinetics described carbon, phosphorus, nitrogen, and silica cycles as well as the dissolved oxygen balance. Algal production is the primary source of carbon although carbon also enters the Peconic system through external loads. Predation on algae releases particulate and organic carbon to the water column, a portion of which undergoes first-order dissolution to dissolved organic carbon and the remainder settles to the bottom sediments.

External loads provide the ultimate source of phosphorus to the system. Dissolved phosphate is consumed by algae during growth and is released through respiration and predation as phosphate and organic phosphorus. A portion of the particulate organic phosphorus hydrolyzes to dissolved organic phosphorus and the remaining balance settles to the bottom. Dissolved organic phosphorus in the water column is mineralized to phosphate, a portion of which sorbs to inorganic solids and settles to the bottom. Within the sediment layer, particulate phosphorus is mineralized and recycled back into the water column as dissolved phosphate.

External loads provide the primary source of nitrogen to the Peconic system. Inorganic nitrogen is consumed by algae and released as ammonia and organic nitrogen through respiration and predation. A portion of the particulate organic nitrogen hydrolyzes to dissolved organic nitrogen and the remaining balance settles to the bottom sediments. Dissolved organic nitrogen in the water column is mineralized to ammonia. Depending on the concentration of oxygen in the water column, a fraction of the ammonia is either oxidized to nitrate through the nitrification process, or nitrate is lost to nitrogen gas through denitrification. Particulate nitrogen settles to the bottom where it is mineralized and recycled to the water column as ammonia. Nitrate moves in both directions across the sediment-water interface depending on the relative concentrations in the water column and sediment pore water.

In the silica cycle, diatoms consume the available silica and recycle both available and particulate biogenic silica through the actions of metabolism and predation. Particulate silica dissolves in the water column or settles to the bottom. A portion of the settled particulate biogenic silica dissolves within the sediments and returns to the water column as available silica. The sources and sinks of dissolved oxygen in the water column are algal photosynthesis, algal respiration, atmospheric reaeration, nitrification, and chemical oxygen demand.

13.2 Summary of Results

Comparison of the EFDC Peconic Estuary hydrodynamic and water quality model predictions with observations indicated the following characteristics:

- Initially, the eight-year verification period (October 1988 to October 1996) was simulated using the coarse-grid version of the model. Particular attention was given to reproduction of the seasonal cycles of temperature, salinity, algae, and nutrients in the estuary. Comparisons of predicted and observed data for all parameters were considered to be reasonable with the coarse-grid model. Development of the coarse-grid model to calibrate the kinetic parameters proved to be a wise decision. It has saved immeasurable resources on the project because the coarse-grid executes over 10 times faster than the fine grid allowing modelers to turn around several eight-year runs per day rather than a single run every 3.5 days.
- Following calibration of the coarse grid, the identical kinetic parameters and other conditions were input into the fine-grid model of Peconic Estuary and the model was verified for the eight-year verification period (October 1988 to October 1996). For all water quality parameters, the fine-grid version of the model provided better model-data comparisons than the coarse-grid.
- Although the coarse-grid served a valuable purpose in the calibration process, it is apparent that the fine-grid version of the model is needed to examine management scenarios in the western bay where the longitudinal water quality gradients are steep. However, the coarse-grid model can be used to determine gross bay-wide responses to management actions.
- The recurrence and magnitude of the winter and summer algal blooms were replicated in all six main bays of the Peconic system.
- The seasonal and long-term trends of total phosphorus, total nitrogen, total organic carbon, and silica constituents were replicated reasonably well throughout the system. The fact that the nutrient predictions continue to match the observations in the eighth simulation year is testament to the correctness and robustness of the model formulation and the selected process coefficients.

- Dissolved oxygen agreed well with the observations in all seasons of the year. This indicates that the predictive sediment flux model is in proper calibration and the correct amount of organic matter is feeding into the bottom sediments.
- The correspondence between the predicted and observed sediment oxygen demand as well as the benthic flux rates of ammonia, nitrate, phosphate, and silica was remarkable. The fact that these flux rates match the observed data in both the 1989 period and the later 1994-95 period again gives credence to the calibration of the sediment process model.
- The long-term sediment recovery scenario has provided perhaps the most significant finding of the entire modeling study. The calibrated and verified model indicates that approximately eight years is required for the benthic sediments in Peconic Estuary to respond changes in external loadings. This test was performed using extreme "Pastoral conditions", so it would be useful to run additional experiments using less extreme loading changes to determine if this time scale is shorter.

13.3 Conclusions

The dynamic simulation of eutrophication in an estuarine system is a very complicated and computationally intensive endeavor because a large number of chemical, biological, and biochemical processes interact, and the reaction rates and external inputs vary with time. In addition, the flow rates and associated circulation are also time-varying, having time scales ranging from minutes to months or even years in the case of sediment flux recovery. Furthermore, flow and pollutant transport in an estuary usually interact with density stratification that can be described as the classic two-layer system in the western portion of Peconic Estuary.

The present EFDC hydrodynamic and water quality model of Peconic Estuary represents the current state of the art in eutrophication modeling. The model provides several advances over the previous WASP model of Peconic Estuary developed under BTCAMP. First, the coupling of the model to a three-dimensional, time-varying hydrodynamic model provides more realistic circulation physics of the estuary. Second, the water quality model itself includes an expanded suite of 22 state variables (the WASP model included only 13 state variables). Third, the coupling to a fully-predictive sediment process model allows the simulation of sediment oxygen demand and nutrient fluxes. Fourth, the model provides for a continuous, multi-year application on an intratidal time scale.

The EFDC hydrodynamic and water quality model of Peconic Estuary meets or exceeds the goals specified at the initiation of the project. The model exhibits a high degree of correspondence to observations monitored in the estuary and properly simulates the seasonal eutrophication processes that occur in Peconic Estuary. The model is fully acceptable as a tool for management of eutrophication issues in Peconic Estuary.