Nitrogen Workgroup Modeling Recommendations

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Nitrogen loading from human activities is causing significant impairments to Long Island's coastal ecosystems. The Peconic Estuary on the eastern end of Long Island is one such estuary that is showing symptoms of nitrogen pollution that require action. Increased nitrogen loads have resulted in eutrophication, low dissolved oxygen, degraded aquatic habitat that supports seagrass and wetlands, as well as increased harmful and toxic algal blooms. As a result, the Peconic Estuary Program (PEP) is focusing their management efforts to reduce nitrogen loading to the estuary, particularly from groundwater. This objective was stated during the Strategic Planning session that took place in January 2013, which specifically identified accelerating the implementation of the PEP Total Maximum Daily Load (TMDL) and increasing strategic focus on nitrogen reductions as critical to restoring the Estuary. This approach has more recently been formalized through the PEP's 2015-2018 Action Plan that lists a series of management actions to address this priority.

The Strategic Planning session had identified a general lack of information on the proportion in which various sources contribute nitrogen to groundwater as a barrier to effective communication about - and therefore action on - reducing nitrogen loading. The group also identified a lack of knowledge concerning the role of non-point groundwater flow and nitrogen loads to the estuary and how to recommend suitable management actions. The group recognized the need for expertise in these areas to provide guidance in evaluating different approaches that quantify and model nitrogen loading and groundwater transport that will yield appropriate management actions for the east end of Long Island.

Nitrogen Workgroup: Scope and Goals

To move forward on resolving these issues, the Management Committee requested that the Technical Advisory Committee (TAC) provide technical guidance by forming a specialized workgroup consisting of members with expertise in nitrogen and groundwater source modeling and recruiting new members as needed. The Management Committee envisioned the final project would accelerate nitrogen TMDL implementation and strategically address groundwater nitrogen loading in order to develop a tool for communication between the PEP, policy makers and the public that would inform:

1. The most important load reductions that must be achieved from identified groundwater nitrogen sources in order to reach sustainable levels,
2. Recommended methods for achieving these reductions based on sources and conditions in the estuary (including technical support and cost/benefit assessment of various management options), and
3. Strategies for building public support for load reduction initiatives and for financing the implementation.

The findings from the Nitrogen Workgroup are intended to result in an updated implementation plan for the Peconic Estuary nitrogen TMDL that may include establishing updated load reduction goals for non-point source loads.

Progress and Conclusions

The workgroup is an independent, non-advocacy based group, comprised of estuarine managers and professionals in the fields of hydrography, wastewater management, groundwater modeling (see list of participants at end of document). The workgroup focused their efforts on a technical review of existing nitrogen loading data and groundwater modeling, and evaluation of the need for existing model refinement or new modeling approaches for the Peconic Estuary. Specifically, the workgroup:

1. Reviewed and evaluated models that are currently used in other estuary programs throughout the country that address nitrogen loading and groundwater conveyance,
2. Determined the suitability of an existing model for the Peconic Estuary Program's needs, and
3. Identified assumptions and data gaps for application of existing models to the east end of Long Island.

In addition to reviewing the existing information on estuarine nitrogen loading and groundwater transport, the workgroup had three different guests present their nitrogen modeling efforts in other estuaries. This allowed the workgroup to learn from their expertise and evaluate the suitability of the approaches for Long Island. Presentations were given by Dr. Joe Costa (Director of Buzzards Bay National Estuary Program), Stephen Lloyd (The Nature Conservancy Long Island), and Donald Walter (United States Geological Survey (USGS)).

A review of existing models identified a variety of different numerical methods, but the workgroup concluded that the following two approaches used together had the most potential to achieve the management goals of the Peconic Estuary Program and should be explored:

1. Nitrogen Load Model, NLM (Valiela et al. 1997)
2. Solute/Mass Transport Groundwater model.

The workgroup focused on these two models, determining their suitability to the east end of Long Island and identifying their strengths, limitations, and assumptions that may require validation, as well as the data necessary to run the models. A combination of these approaches has been utilized by the Suffolk County for the Forge River watershed as part of the Suffolk County Comprehensive Water Resources Management Plan and the ongoing Forge River TMDL. Although the NLM was not used, a similar spreadsheet model was used to develop inputs to the mass transport groundwater model. A summary of the workgroup's review of both models is outlined below.

I. Nitrogen Load Model	
General Description	Uses existing land use data and septic loading data to quantify nitrogen sources to groundwater. Simple approach based on attenuation coefficients for nitrogen inputs into groundwater that categorizes current total nitrogen loads.
Strengths	Simple spreadsheet model summarizing nitrogen loads to the estuary based on current land use and land cover. Useful, 'visual' way to portray results and instantaneous loading to the aquifer. Can be used to predict loads from various nitrogen management scenarios. Designed as a comparative tool (e.g. between subwatersheds) - good for determining relative magnitude of sources. Published and peer reviewed, has been applied widely in the northeast. Because it does not account for groundwater travel times, is should only be used as a predictive tool within limited groundwater travel times (e.g. < 2 years). Outputs are made in pounds of nitrogen, not concentration, which is appropriate to feed into a solute transport model. Nitrogen loads can be entered into a calibrated water quality/hydrodynamic model to get estuarine concentrations.
Limitations	Only a "snapshot" of loadings at one time. Does not calculate instantaneous loading to the estuary because it does not incorporate a time variable, but can estimate loadings to the aquifer at one moment in time. Not a dynamic model. Many assumptions in attenuation coefficients that require validation. Cannot be used predictively as it does not account for complex groundwater movement (dispersion) or long-travel times. Model is sensitive to particular attenuation coefficients. Cannot be used to directly predict concentration in receiving waters, only load. Difficult to verify with field measurements because it cannot predict instantaneous concentrations.

Costs	The Nature Conservancy has already developed and run the NLM for the east end of Long Island. Additional costs incurred to the program would be to improve model assumptions or to collect field data and verifications as needed.
Other Considerations	

II. Solute Transport Model	
General Description	Solute transport models are used to trace mass spatially through time and 3-dimensional space, based on hydrodynamics and geological characteristics. These numerical models provide estimates for loads into a receiving waterbody of nitrogen. The models are dynamic (i.e. not static) enabling initial conditions to vary and provide simulations for different management options (i.e. predictive models). The ability to provide accurate simulations is, however, directly related to how well the model can be calibrated to current and historical conditions.
Strengths	They are existing well developed and peer reviewed models that are widely accepted among the scientific community - open source codes are available (e.g. flow model-USGS MOD FLOW) and readily available to use and develop. Suffolk County has an existing regional groundwater flow model of the entire County that can readily be refined to use for the nitrogen transport and loading estimates to the Peconic Estuary. Likewise, the USGS is developing a new Long Island regional groundwater flow model, with refined representation of surface waters and aquifer properties, for use in improved source-area (groundwatershed) delineation and other applications. They are dynamic models and effective for tracing solutes in groundwater

	transport. Dynamic model simulations are very useful to predict anticipated outcomes from changes in land use or nitrogen inputs and therefore, helpful for planning and management. Tracks "concentrations" of mass and can be readily integrated with a hydrodynamic model of the estuary for predicting changes to water quality. Can be calibrated and/or verified with field measurements. These models are the most appropriate method to evaluate nitrogen loading to an estuary. The NLM can be used to provide loading inputs for historical land use types. Those loads are run in the transport model and can be compared to concentrations measured from water supply and monitoring wells. Solute transport model inputs are in mass per unit time (lbs./day) and the output is in concentration.
Limitations	Require high quality historical land use data (particularly if historically the land use was not open space and was used for agricultural purposes). These models require training to run and process the results and can have a steep learning curve.
Costs	Resource intensive in terms of computing power and technical expertise, requires more types of input data than spreadsheet models. These models currently exist as they were previously developed for the Suffolk County Department of Health Services (SCDHS) and Suffolk County Water Authority (SCWA), and by the USGS largely with Federal funding, so much of the baseline work is finished. Some refinements should be made, but the cost of doing so is relatively small compared to starting "from scratch".
Other Considerations	Sources and magnitudes of uncertainty in model input and output, datasets may be evaluated through a variety of well-established techniques.

Recommendations from the Nitrogen Workgroup:

- A solute transport model should be used in conjunction with the results of the Nitrogen Load Model to draw on the strengths and weaknesses of both.
- For evaluating different nitrogen management actions, a solute transport model is the preferred model for the Peconic Estuary because this model:
  - ❑ Is a spatially explicit, three-dimensional, time varying groundwater model that can accurately predict inputs to surface waters by tracking the time varying movement and transformations of solutes within the aquifer,
  - ❑ Is needed to predict long-term trends from greater travel distances, which the Peconic Estuary is known to display (e.g. Peconic River recharge area),
  - ❑ Can be used to assess historical, current and (or) projected, future loads to surface waters, and
  - ❑ Is able to predict long-term trends from greater travel distances such as in the Peconic River corridor.

In addition:

- It would be beneficial to link the solute transport model with a coupled hydrodynamic-water quality model of sufficient spatial resolution to set appropriate nitrogen load targets by subwatershed, based on the ecological endpoints. Current nitrogen TMDL end-points are based on dissolved oxygen (DO), which is important, but there needs to be consideration of additional endpoints such as water clarity, healthy seagrass, healthy wetlands, elimination of harmful algal blooms and productive fisheries.

- NLM can provide a "snapshot" of the estuary loadings based on groundwater travel time. This information can be used as a valuable communication tool for outreach purposes to illustrate relative contributions of nitrogen from each source. The NLM can determine what sources are contributing the greatest amounts of nitrogen to the aquifer at a single point in time. However, to understand the loading to receiving surface water, the load, receiving water hydrodynamics and nitrogen processing, determine the surface water ambient nitrogen concentration.

    - NLM should be viewed as a qualitative tool for management scenario evaluations within the shortest (e.g. 2 year) groundwater travel times, It is not designed for groundwater simulation; particularly with long travel times, but may prove useful for short travel times as a loading tool if underlying assumptions are met and land use data are accurate. Improved definitions of groundwater discharge to surface waters will improve NLM results in regards to management scenarios.
    - NLM can identify priority areas for early "no-regrets" action and to test load reduction scenarios in the 2-year zone.

- The PEP must establish good baseline information from which to better understand the sources of nitrogen, the relative magnitudes of the existing loads, and to quantify the reductions needed. To provide optimal output for management and planning, these models must be based on accurate, up-to-date input data and be validated with field collected (real-world) data measurements.

- The Peconic Estuary Program and its partners need to keep in mind that it may take decades to see the results of nitrogen management efforts in the ecosystem. Similarly, for some locations where groundwater of particularly long travel time discharges, nitrogen loads may still be increasing due to the legacy of the past land uses and practices. Management decisions need to be made considering these facts.

Intermediate Steps

- Update the watershed boundary beyond the shallow-water contributing area in the Peconic River according to the work being completed by the NY State Department of Environmental Conservation (NYSDEC) and USGS Groundwatersheds Project that will be done in 6 to 18 months. This may change the loadings considerably in the western Peconic River recharge area where significant water quality impairments are known to exist. This is essential to complete before the CCMP is updated or extensive nitrogen load modeling is conducted.
- Establish monitoring schedule to collect field data to improve NLM, and validate assumptions and predictive output from the models:
    - Sample solute (nitrogen) concentrations at points along groundwater flow paths from entry at the water table to exit at streams and other discharge locations,
    - Determine extents of denitrification in groundwater by examining nitrogen exchange and transformations in the hyporheic zone,
    - Collect field data on dissolved organic carbon (DOC) and DO in aquifers to validate attenuation coefficients (particularly in agricultural areas), Collect field data, especially in areas with high nitrogen input, to better understand concentrations of nitrate, nitrite, nitrous oxide and ammonium concentrations and what controls concentrations; and
- Collect data regarding other sources of freshwater entering the estuary. Calculate septic load per tax parcel for septic loading data input to NLM and solute transport model.
- Investigate loadings from groundwater affected by legacy land use and practices. Examine private well data to determine inputs from 10, 20, and 50 years ago that are still present in the system and assess if we are on an increasing or decreasing trend in nitrogen load locally and system-wide. GIS files for existing base flow contributing areas were already developed for Suffolk County as a part of the Comprehensive Water Resources Management Plan and can be acquired.
- Re-examine atmospheric deposition in the western portion of the Peconic Bay and consider what U.S. Environmental Protection Agency (USEPA) expects for reductions based on atmospheric regulations. Look at NLM output data in relation to atmospheric

deposition and review cost-benefits of different land-based reductions and how much nitrogen we can expect to remove from the system.

- Determine most appropriate and consistent way to handle atmospheric deposition to the water's surface, especially in the eastern estuary which is not enclosed and where boundaries are arbitrarily defined.
- Consider using modeling load outputs to develop recommendations for nitrogen concentrations which can be used as a measurement for BMP/technology implementation. Both nitrogen load in mass (lb or Kg) and nitrogen concentration (based on receiving waterbody hydrodynamics) are essential to analyze nitrogen management approaches.
- Create a results delivery method to share model results with the public and stakeholders.

Nitrogen Workgroup Participants

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