

Technical Memorandum 3

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TO: Ron Mitchum (BCDCOG)
Environmental Technical Advisory Committee

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SUBJECT: Charleston Harbor System
Establishing Marsh Loadings

In order to quantify the exchange of nutrients between marshes and open water of the Charleston Harbor System previous studies were reviewed and current data will be used to confirm marsh-open water exchanges for use in 3-D water quality modeling. Current data collection has been coordinated with Dr. Dan Tufford of the University of South Carolina, who is currently working on a rice succession model of nutrients and sediment fluxes from freshwater marshes to the Cooper River. Confirming literature review loading estimates with data collected by Dr. Tufford's research team will provide a defensible basis for marsh loading estimates used in the Charleston Harbor System, 3-D water quality model.

The following previous studies were reviewed to quantify the exchange of nutrients between marsh and open water connections:

1. Maybank Project: A Study of the Intertidal Marshes and Streams. US EPA Environmental Services Division, Athens, Georgia. May 1984
2. Nutrient Dynamics and Water Quality Interactions in the Goose Creek Sub-Basin of the Charleston Harbor Estuary. Department of Environmental Health Science University of South Carolina, Columbia, S.C. October 1996
3. Burke III, Roy 1984. Proposed Protocol for: Incorporating the Effects of a Spartine Salt Marsh into a Simplified Water Quality Model of Adjacent Tidal Waters in Georgia. US EPA, Region 4.
4. Nixon, Scott W and Virginia Lee. Wetlands and Water Quality. Technical Report Y-86-2, October 1986.
5. ATM Savannah River marsh report and data collection

Data collected during the Maybank study (1) found that the marshes are normal processors of nutrients and make net contribution of nutrients and protein-enriched detritus to the estuary. A primary source of detritus for export to the estuary would be the marsh macrophytes growing in the studied area. These conclusions were developed from water samples analyzed for ammonia (NH₃), nitrite-nitrate (NO₂-NO₃), total Kjeldahl nitrogen (TKN), total phosphorus (TP), and total organic carbon (TOC) and continuous records of dissolved oxygen and temperature.

Intensive tidal transport studies of water and nutrient exchange between tidal wetlands and estuarine waters were conducted at Browns Marsh on the Goose Creek, a tributary to the Cooper River (2). The data collected found consistent trends of nitrogen uptake by the tidal marshes, which removed 20-34% of the nitrate flowing across the marsh during each tidal cycle. Nitrate uptake by the wetlands exhibited distinct seasonal patterns of daily removal, yielding annual uptake of 8.4 g N/m^2 . Ammonium exchanges also suggested a tendency for net annual export of $5.7 \text{ g N/(m}^2 \text{ year)}$. Organic matter exchanges in the wetlands were also variable but displayed a strong tendency toward net export ($57.3 \text{ g C/(m}^2 \text{ year)}$). Algal biomass (chlorophyll-a) was exported from the marsh during the winter ($0.1\text{-}0.8 \text{ mg/(m}^2 \text{ day)}$) and imported during the late summer and fall ($1.4\text{-}1.9 \text{ mg/(m}^2 \text{ day)}$) yielding an approximate annual balance. The net removal of dissolved inorganic nitrogen by the tidal marshes (21.1 tonne/year) was a significant fraction of the overall nitrogen budget for the estuary and provided a buffer to potential impacts of point-source wastewater discharges as well as nonpoint urban runoff.

Research was performed on eleven freshwater wetlands and intertidal salt marshes in the Southeast (4). All of the studies showed that the wetlands acted as sinks for total nitrogen (TN) and phosphorus (TP). Nitrogen fixation ranged from virtually zero up to $40 \text{ g N/m}^2\text{/yr}$, with highest rates generally in salt marshes where it appears that this process may play an important role in the nitrogen budget. Rates of reported measurements of denitrification varied from 2 to $110 \text{ g N/m}^2\text{/yr}$ lost to the atmosphere and confirm the general impression that the removal process is of considerable importance in the nitrogen budget of wetland systems. Some data also suggested that swamps may preferentially remove inorganic, oxidized forms of nitrogen and phosphorus or convert them to reduced, inorganic forms. The other major mechanism by which wetlands serve to remove nutrients is through burial in peat and sediments.

Results of all LTBOD sampling at Marsh Exchange Transect sites in the lower Savannah River (5) demonstrate that all BOD samples collected during mid-ebbing tides exceed the values of BOD collected during corresponding mid-flooding tides. This indicates the fact that marshes import organic matter to adjacent waters. On basis of data available in (6) figures, which demonstrate the field research results, the clear conclusion about nitrogen BOD (NBOD) importing properties of the salt marsh can be made only for three of the available five Marsh Exchange Sites.

The following assumptions were made from this literature review:

- The major mechanism for exporting particulate matter from the marsh to adjacent waters is turbulent scouring.
- Organic dissolved matter is exported from the marsh during storms and ebb tides.
- Dissolved oxygen transported into the marsh by each flood tide is consumed by sediment SOD and never sees the estuary again.
- Particulate and dissolved matter is transported into the estuary mainly by terrestrial and urban runoff. In non-freshwater fed estuaries this transport is minimal except during storm periods.
- The forces of deposition on, and retention by, the marsh remain essentially constant. During and after storm periods export by turbulent scour far exceeds mass import back to the marsh by settling and filtering. As the time between storms increases, the effects of

turbulent scour diminish and deposition/retention increase, until the marsh and adjacent waters reestablish equilibrium.

- Long-term and short-term considerations must be made when developing loadings for the water quality model. In the long term, over a month or a year, nutrient import can dominate export. In the short term, following storms, export dominates. This is especially important when interpreting loading rates from a literature review, where data can range from hourly to annual rates. Caution must be used when extrapolating rates that were measured in the field over a day to equivalent annual rates.

From these assumptions two approaches were used to estimate “marsh loadings”:

- First, the over-simplified approach that fortuitously produces reasonable numbers for modeling estimates;
 - (Coastal Ecological Systems of the U.S.) The net productivity of Spartina is 1600 g C/m²/yr. Benthic algae is 390, for a total of 2000 g C/m²/yr. If 45% is exported (Teal, 1962) then 8450 lb CBOD/mi²/day is dumped into the estuary (assuming CBODu/TOC=0.6).
If 21% exported (de la Cruz, 1965) then 3943 lb/mi²/day exported.
The estimate of “terrestrial runoff to estuaries converted to 2816 lb CBODu/mi²/day.
The Savannah Estuary Modeling Study (5) (COE) used 9594 lb CBODu/mi²/day based on medium Spartina densities found in North Carolina, an export rate of 40%, Reimold’s detritus production rate of 12 mg/g live Spartina, and CBODu/TOC=1.
- Second, the rational approach evaluating components of the marsh estuary real connections.
 - This assumes three primary producers: Spartina, phytoplankton, and benthic algae. CBODu and DO deficit come from fixing inorganic carbon into complex organic forms, and breaking complex organic materials down to a lower energy state by the food web. Further assumptions must be made about the relative amounts of particulate and dissolved organic carbon (POC, DOC) and the relative amounts of refractory CBOD and labile CBOD. Additional estimates are required to separate what happens in the marsh water column and in marsh soils (SOD), and what happens during “wet” and “dry” weather conditions.
Marsh SOD. (“Flux of Organic Matter through a Salt Marsh”). It was found a mean release rate of 6.4 mg C/m²/hr on creek banks, and 5.2 in the short Spartina areas of the marsh. Marsh SOD seemed relatively invariant from season to season.

The more appropriate assumptions will be confirmed with data collected in the CHS by Dr. Dan Tufford’s research team.

In 2004 as part of water quality monitoring for 3-D modeling, LTBOB will be monitored at both salt and freshwater marshes along the Cooper River to confirm loads input to the model. In coordination with this monitoring, Dr. Dan Tufford of the University of South Carolina – Columbia, will be collecting samples from historic rice fields along the Cooper River to establish the magnitude of sediment, oxygen and nutrient fluxes between the marshes and Cooper River. This research stems from work previously done by Dr. Hank Mckeller in Brown’s Marsh (2).

Dr. Tufford and his research team are collecting *insitu* and nutrient samples at two freshwater marshes, Dean's Hall and Mulberry Plantation, on the Cooper River. The study will include four parts as outlined in a work plan by Dr. Tufford:

(1) Water Quality (BOD/DO) Functions- We plan to quantify tidal, daily, and seasonal patterns of DO and BOD exchange between these wetlands and the main river channel. We will deploy *in situ* oxygen monitors (YSI) and automated sequential samplers (ISCO) to quantify changes of these parameters over consecutive tidal cycles within each wetland type.

We will perform BOD sampling once per season in fields dominated by subtidal and intertidal communities. Laboratory analysis will be for BOD5 and BOD20. Data from detailed tidal cycle studies will quantify high tide/low tide differences, day-night differences, and seasonal patterns of DO and BOD exchange. Mass balance computations will be based on integrations of water flow (from detailed bathymetry and stage-volume relationships for of each study site) and concentration changes for DO and oxygen demand.

YSI multi-parameter sondes will be deployed during water sampling to record water temperature, DO concentration, pH, and conductivity during sampling to estimate oxygen solubility and to allow calculations of oxygen diffusion.

(2) Sedimentation - We will also assess sediment dynamics in relation to river loading by taking a portion of the samples collected in the BOD determinations described above and measuring total suspended sediment (TSS). This will be done gravimetrically by filtering known volumes of sample water. The TSS is derived as the volume normalized difference of the filter weights before and after filtration. Mass balance will be determined as described above.

(3) Model Development- We plan to validate the spatial simulation model, improve parameterization, add function, and test management scenarios during this project cycle. Validation, discussed earlier, will ensure the underlying mathematical implementation of the forcing functions is reasonable. During year one this will be done with our existing estimates of community depth ranges, peak biomass, and inferred sediment accumulation rates. During year two the validation will be further tested using results of the field work described in this proposal. Improved parameterization will result from the field and lab work providing site-specific values for sediment accumulation and community growth. New function includes spatially variable sediment accumulation and DO/BOD dynamics. During the last 6 months of the project we will parameterize the model to test the effects of specific management scenarios on community succession and water quality response.

(4) Management Planning - We will work with stakeholder groups to obtain their perspective and suggestions on management scenarios. Likely examples are examination of water release scenarios and their effects on marsh dynamics, and investigation of site-specific water level control alternatives such as rediking and recontouring. Innovative designs that meet multiple interest group requirements may make this aspect of a management plan a palatable alternative in critical habitat situations. An important aspect

of this will be to bracket the scenario analyses to estimate the effect of extreme cases, for example, the “do nothing” alternative that allows natural succession to proceed until all the impoundments are filled.

The nutrient data described in Part 1 of the study will be analyzed by the research team using a Lachat autoanalyzer and insitu samples will be collected with a YSI. In conjunction with samples collected by Dr. Tufford, LT BOD samples will be collected through the CHS 3-D modeling project to associate BOD5 measurements with Ultimate BOD for input to the 3-D water quality model. Data collected by the research team is vital in understanding exchanges between freshwater marshes and the Cooper River. These data will confirm assumptions made to develop loadings for 3-D water quality modeling.