Applying the SWAT hydrologic model on a watershed containing forested karst

D.M. Amatya[1] and A.E. Edwards[2]
[1]Research Hydrologist and [2]Hydrologic Technician US Forest Service Southern Research Station, Center for Forested Wetlands Research, Cordesville, SC

The US Forest Service Center for Forested Wetlands Research is working on a South Carolina Department of Health and Environmental Control (SC DHEC)'s Section 319 Grant Program funded Total Maximum Daily Load (TMDL) project for the watershed of Chapel Branch Creek (CBC) draining to Lake Marion in Santee, South Carolina (Fig. 1). The Santee Limestone, a major aquifer for the region, where groundwater flows northeast to Lake Marion, underlies the watershed. Lake Marion is the dammed portion of the Santee River, which continues to flow past the Santee Dam and serves as the northern boundary for Francis Marion National Forest.

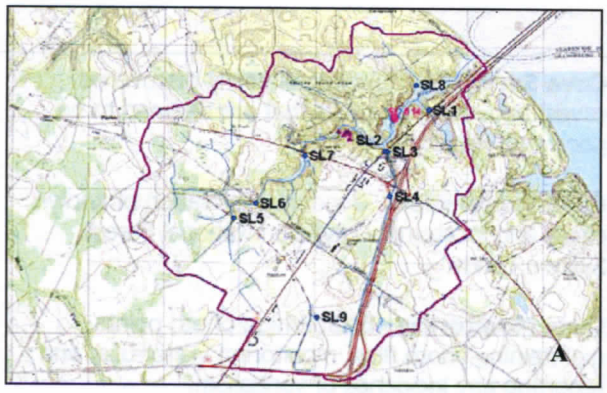
This 1,555 acre watershed is small but contains a combination of many land uses such as commercial, industrial, medium and low density residential, agricultural, and a forested state park. Several sinkholes and cave passages exist where the groundwater emerges and mixes with surface water entering the cave to form the CBC headwaters that flows toward the lake. This creek is on the SC DHEC's 2008 (303d) list of impaired water bodies for excessive TP and pH. The first goal of the project is the identification of areas generating the excess non-point source nutrients, Nitrogen and Phosphorous. The second goal is to implement Best Management Practices (BMPs) to decrease the nutrient loadings.

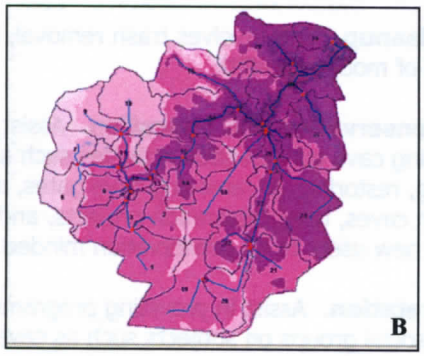
To evaluate the nutrient loadings for establishing the TMDLs after the implementation of the BMPs, this project is utilizing the GIS-based USDA Soil and Water Assessment Tool (SWAT). This model uses a digital elevation model (DEM) to delineate watershed boundary and sub-watersheds, with the option of user-defined flow paths to account for man-made structures such as ditches. A local meteorological station across the lake and three on-site rain gauges are sources of data for the weather inputs. Additional inputs are detailed NRCS SSURGO soil data and land use digitized from recent NAIP aerial photography. These inputs are combined to simulate daily, monthly, and annual hydrologic outputs within various locations on the watershed. The model's flow is calibrated and validated by actual flow data measured continuously at several sampling locations (SLs). Samples for nutrient analysis are collected on a flow-proportionate basis and are used for nutrient loading calculations at those locations in the flow paths of the watershed.

SWAT was mainly designed for predicting effects of upland agricultural land use on surface waters, so adjustments need to be made to address the karst terrain hydrology in a part of the watershed. The Forest Service delineated flow paths in this karst system by dye tracing (Fig. 3a), a previous cave survey, and expeditions into the cave. Complicating the model outputs is a surface stream entering the cave and joining the main groundwater stream before the spring outlet.

Dye trace conducted in September 2008 to determine flow paths and times to the cave spring at the CBC headwaters. Picture is at the cave spring. Image: A. Edwards

Therefore, in an effort to account for the potential effects of ground water flow from the karst system in both measured and simulated water balance, an additional logger to measure stage and calculate flow was installed at the cave spring outlet. Similarly, an ISCO sampler will be installed with the flow logger to sample storm events to quantify the nutrients at this location affected by karst groundwater. Data obtained from this karst





affected stream outflows

should be helpful for the successful modeling. The model predictions help determine the potential source areas, their loadings, and load allocations with proper BMPs, implementation of which help reduce nutrient loads and improve water quality in the Chapel Branch Creek Watershed.

However, stakeholders' "buy-in" to the load allocations will be a key to the success of the project. For that matter, early involvement of the key stakeholders like Town of Santee, Santee State Park, Santee Cooper, SC Department of Transportation, Santee National Golf, and Santee Cooper Country Club in study design and data collection has developed a strong cooperation towards the goal of achieving successful TMDL implementation using various BMPs. ■

Images from top:

a) Outline of watershed boundary on topographic map. Sample Locations (SL) in the watershed are sites chosen for sample collection and/or continuous flow measurement. The purple triangles are the sinkholes and cave entrances.

b) SWAT view of delineated watershed and subwatershed; red dots are outlet points for the sub-watersheds and the blue lines are the user-defined flow routes.

c, d) Dye trace conducted in September 2008 to determine flow paths and times to the cave spring at the CBC headwaters.

c) The cave spring outlet into CBC headwaters

d) Looking down into one of the karst windows during a dye trace.

Images: A. Edwards