Modeling the Temporal Dynamics of Dissolved Organic Carbon in a Headwater Stream, Southeastern Pennsylvania

Yi Mei[1,3], George M. Hornberger[1,3], Lou A. Kaplan[2], J. Denis Newbold[2], Anthony Aufdenkampe[2]

1.Department of Civil and Environmental Engineering, Vanderbilt University, Nashville, TN, 37235

2.Stroud Water Research Center, Avondale, PA, 19311

3.Vanderbilt Institute for Energy & Environment, Vanderbilt University, Nashville, TN, 37235

VANDERBILT

STROUD WATER RESEARCH CENTER

INTRODUCTION

The temporal variation of the delivery of dissolved organic carbon (DOC) from hillslopes to the adjacent streams is determined by hydrological and biogeochemical processes that have not been completely quantified. Physically based, distributed models can provide much more detailed information about the mechanisms surrounding the fate and transport of dissolved organic carbon (DOC) than can lumped models. We present such a model of soil and stream water DOC in this research.

The Penn State Integrated Hydrological Model (PIHM) was adopted as the framework and coupled with a convection-dispersion chemistry transport model to simulate the spatial and temporal dynamics of DOC in our research site. Our research site is White Clay Creek (WCC) watershed, WCC watershed is a 725 ha, 3rd-order watershed located in southeastern Pennsylvania.

OBJECTIVES

- **Objective I: Incorporate a depth decaying Soil Organic Carbon model into the semi-discrete finite volume scheme of PIHM .**

- **Objective II: Numerical simulation of the hydrology and DOC in the WCC watershed, and catch the major dynamic of DOC in the stream. Identify the major DOC contribution area of the watershed to the stream.**

MODEL STRUCTURE

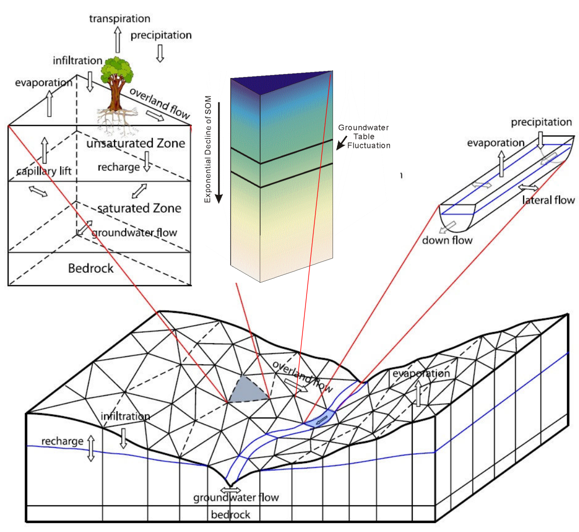

Fig 1. Vertical distribution of soil organic mater(som) and Groundwater table fluctuation in PIHM frame work.

Modified from: Qu, Y. and C. J. Duffy (2007), A semidiscrete finite volume formulation for multiprocess watershed simulation, *Water Resources Research, 43(8).*

DOC MODEL DESCRIPTION

- **Incorporated exponential decline source term in semi-discrete finite volume scheme of convection dispersion equation**

- Soil organic matter was added as a source for DOC transport, and was assumed to be exponentially declined from the ground surface. The following are the general equation for subsurface flow. It was implemented for unsaturated and saturated zone respectively.

$$\frac{\partial}{\partial t}\left(Yn\bar{C}\right)+B_d\frac{\partial}{\partial t}\left(\int_{z_a(t)}^{z_b(t)} S_0 e^{-\alpha(H-z)}dz\right)=\sum_{i=1}^{k}\left(qC_s+D_i\frac{dC}{d\varsigma_i}\right)$$

Where:

$$\frac{\int_{z_a}^{z_b}\theta C dz}{\int_{z_a}^{z_b}\theta dz}=\bar{C} \qquad Y=\int_{z_a}^{z_b}\frac{\theta}{\theta_s}dz=\frac{1}{n}\int_{z_a}^{z_b}\theta dz$$

- **The sorption process in both saturated and unsaturated zone were treated differently**

- Linear equilibrium sorption isotherm were used for the unsaturated zone.
- Rate limited kinetic sorption model were used for the saturated zone.

FIELD METHODS

Fig 2 Riparian zone

Fig 3 Middle hillslope

Stream storm DOC sampling:

- A transect was set up for storm DOC sampling in WCC watershed.

- Storm events sampling was conducted with ISCO (Teledyne Isco, Inc, Lincoln, Nebraska) by the side of transect. The storm events on July 10-13 was collected using this ISCO with2 hours sampling interval.

RESULTS

- **Flow simulation**

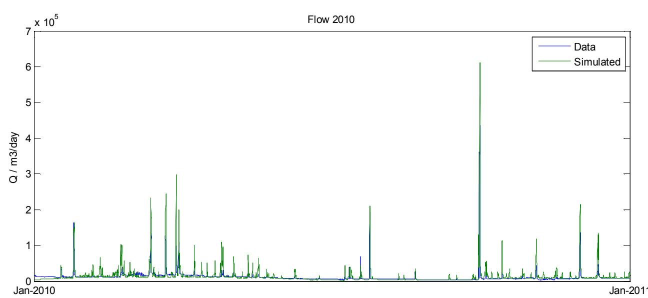

Fig 4: Simulated hydrograph at the outlet of WCC for 2010

- **DOC simulation**

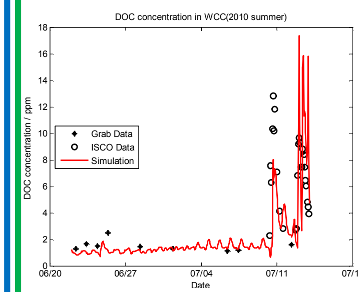

Fig 5a. Simulation of DOC in WCC in July

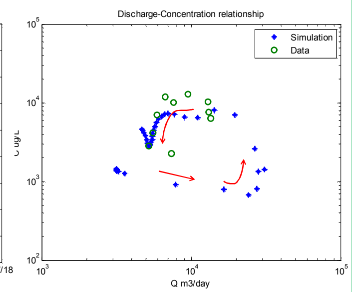

Fig 5b. Q-C relationship during a storm

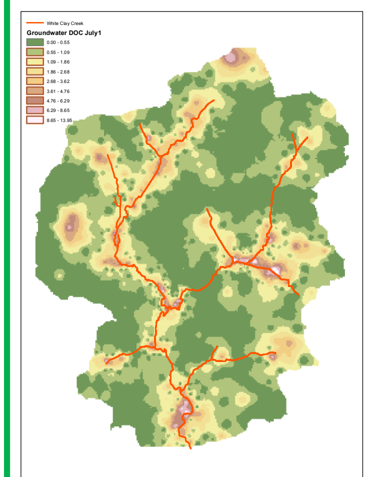

Fig 6. DOC in groundwater July 1,2010

- The simulated annual stream discharge preserved the same mass balance as the observed data (Fig 4).

- The model replicate the same temporal pattern as the sampling data (Fig 5 a).

- The discharge and concentration relationship for both model and data rain follow counterclockwise cycle (Fig 5b).

- Model simulated spatial distribution of groundwater DOC shows that DOC concentration is higher in the riparian zone groundwater than the rest areas (Fig 6).

DISCUSSION

- As DOC is "flushed" from its terrestrial sources to the stream. The groundwater level fluctuation in the riparian zone is a key factor causes the rapid DOC response of the storm in WCC.
- The modeling practice caught the basic dynamic of DOC in stream, and generated a reasonable groundwater water DOC distribution of summer 2010.
- This work indicates that the riparian zone is the major DOC source area for exported DOC from the watershed.

ACKNOWLEDGMENTS

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