Identification of contaminant source locations in Amite River watershed

Basic Information

Title:	Identification of contaminant source locations in Amite River watershed
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Descriptors:	
Principal Investigators:	Zhi-Qiang Deng

Publications

1. Tong, Y. and Deng, Z. (2013). “Moment-Based Method for Identification of Pollution Source in Rivers.” ASCE Journal of Environmental Engineering, DOI: 10.1061/(ASCE)EE.1943-7870.0000683 (in press).
2. Ghimire, B. and Deng, Z.-Q. (2013) “Hydrograph-based approach to modeling bacterial fate and transport in rivers.” Water Research, 47 (3), 1329 – 1343, DOI: 10.1016/j.watres.2012.11.051.

Problem and Research Objectives

The Federal Clean Water Act (CWA) has played a major role in resolving point source pollution problems through a system of laws, regulations and judicial enforcement. However, pollutants from watershed-wide nonpoint sources are difficult to monitor and nearly impossible to regulate through the conventional CWA-based approach alone, often producing unknown source pollution to water bodies. In fact, the Louisiana's 2010 Integrated Report for water quality assessment indicated that about 82% of lakes and 16.6% of rivers in Louisiana are impaired by unknown sources, making it challenging to restore the impaired water bodies. The unknown source pollution may also be caused by illegal dumping or discharges. Therefore, the identification of pollution source location is essential to the restoration of water quality and thereby to the compliance with the CWA.

The overall goal of this project is to develop new methods for identifying the location of pollution sources, including both point and nonpoint sources. The proposed strategy is to test and demonstrate the new methods by identifying the locations of unknown pollution sources of BOD (Biochemical Oxygen Demand) in the Lower Amite River watershed (Figure 1). The Amite River, particularly the lower reach of Amite River, is impaired by BOD. Primary objectives of the project are: (1) to provide a simple yet effective method for identification of point contaminant source discharging to a river and (2) to develop a new method for identification of critical source areas of nonpoint source pollution in the Amite River watershed.

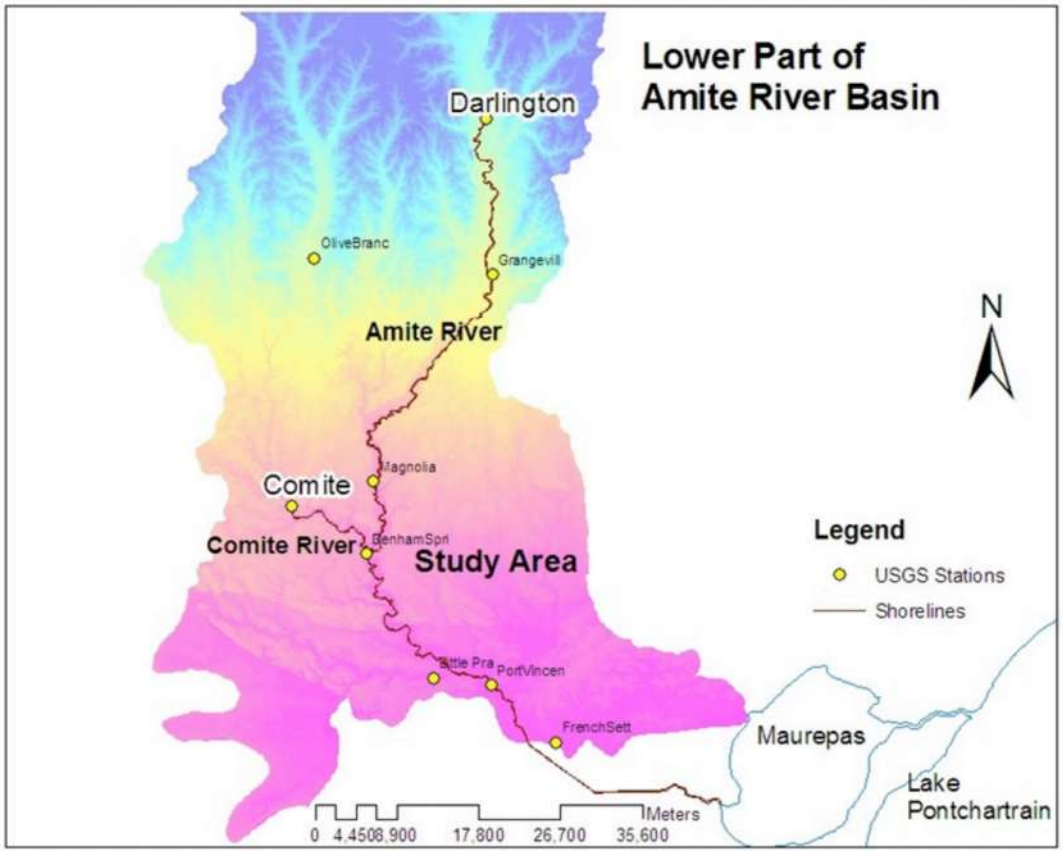

Figure 1. Map for the Amite River watershed.

Methodology

The objectives are accomplished by executing three tasks: (1) development of a moment-based method for identification of point pollution source by determining the location and total mass of discharge, (2) mapping watershed time of concentration by using US EPA program BASINS and watershed modeling tool HSPF; and (3) development of a watershed-based method for identification of nonpoint pollution source by locating unknown nonpoint source areas of BOD in the Amite River watershed. The proposed tasks are implemented by combining PI's proven variable residence time model for solute transport in rivers, watershed modeling systems BASINS/HSPF, and various data.

The project has broader implications for environmental restoration and sustainability in Louisiana and in the nation as well. This project provides an efficient and cost effective tool for environmental and water resources management agencies to locate unknown pollution sources from both point and distributed discharges and thus to reduce the uncertainty in TMDL development and implementation. While this study focused on the Amite River watershed, the approach developed in this study can be easily extended to other watersheds in Louisiana and in the nation. In addition, the project provided research and educational training opportunities for graduate and undergraduate students.

PRINCIPAL FINDINGS AND SIGNIFICANCE

1. Moment-Based Method for Identification of Pollution Source in Rivers (Paper 1)

(1) A moment-based method is developed for identification of source location and quantity of accidental pollution along a river. The first two moment equations are derived through the Laplace transform of the Variable Residence Time (VART) model. While the first moment in combination with observed data is used to determine the location of pollution source (x), the second moment in combination with observed data is employed to estimate the total mass (quantity) of released pollutant (M_{est}). The two moment equations are written as:

$$x = \frac{\sum_{t=0}^{\infty} Ct}{\sum_{t=0}^{\infty} C}\sqrt{U^2 + 4K_S\frac{4\pi D_S}{A}} - \frac{2K_S}{\sqrt{U^2 + 4K_S\frac{4\pi D_S}{A}}} \tag{1}$$

$$M_{est} = Q\sum C(t_i)\Delta t_i \times (1 - CF), \qquad i = 1,2,\ldots,n \tag{2}$$

where $CF(\%) = -0.4512 * \left[1 - \exp(-0.00939 \times \text{distance})\right]$ represents a distance correction factor (%) for the estimated total mass M_{est}; x stands for the distance from the unknown pollution source location to the sampling station where concentration C and time t are recorded; U = cross-sectionally averaged flow velocity; K_S = longitudinal Fickian

dispersion coefficient; A = cross-sectional flow area of main channel; D_S = effective diffusion coefficient [L^2/T] in the storage zone; and Q is the river discharge.

(2) The two moment equations are tested using 23 sets of conservative tracer injection data collected from 23 reaches in five rivers with the reach length ranging from about 3 km to 300 km. Results show that the first moment equation is able to predict the pollution source location with a percent error less than 18% in general (Figure 2). The percent error involved in the estimation of the corrected total mass is commonly less than 20% (Figure 3). While developed and tested using conservative tracer data, the moment-based method can also be applied to tracking the source location of reactive pollutants, providing a simple yet effective tool for pollution control and environmental management. The model predicted source location and mass (quantity) are compared with corresponding measured data in Figures 2 and 3, respectively.

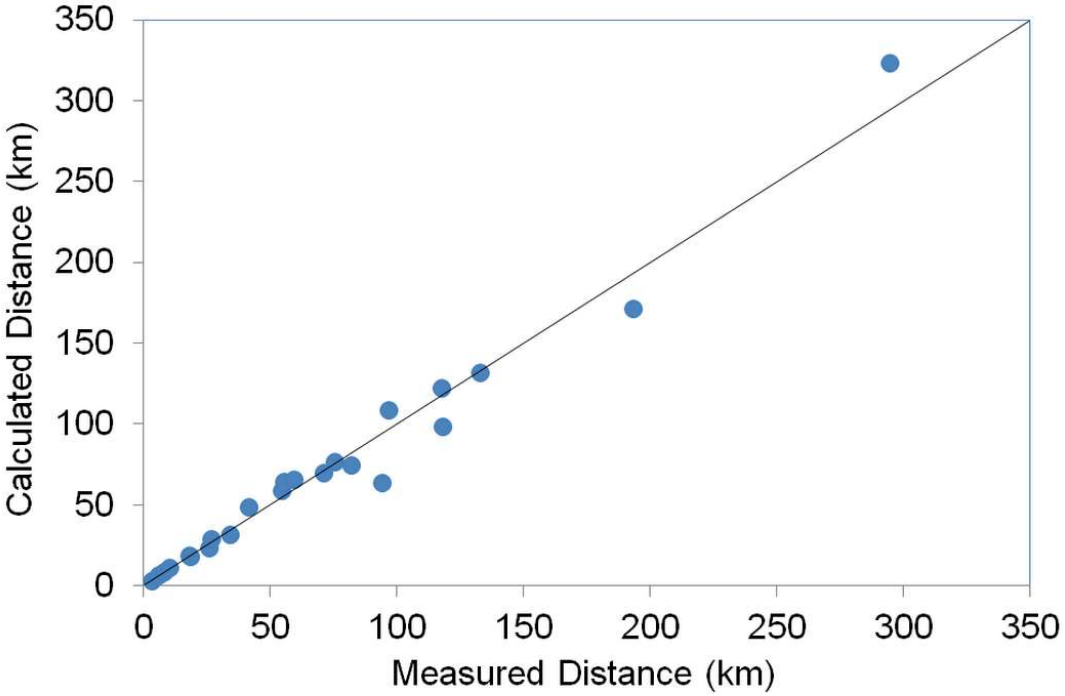

Figure 2. Comparison between calculated and measured distance.

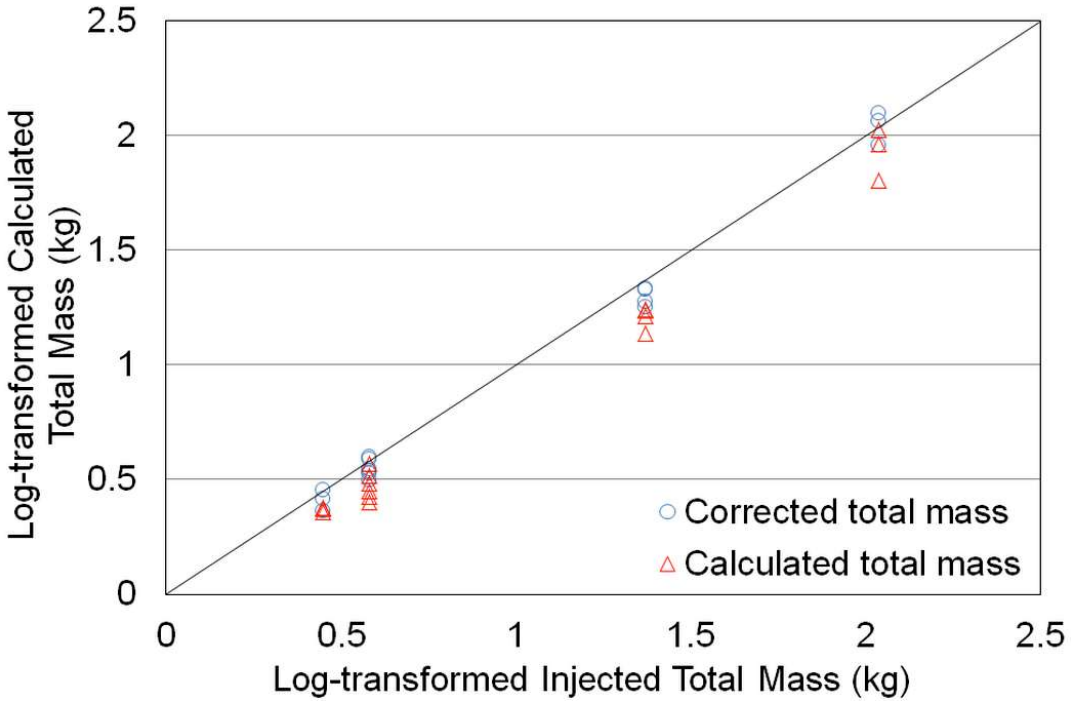

Figure 3. Comparison between calculated total masses with/without correction against injected total mass.

2. Identification of Critical Source Areas of Nonpoint Source Pollution (Paper 2)

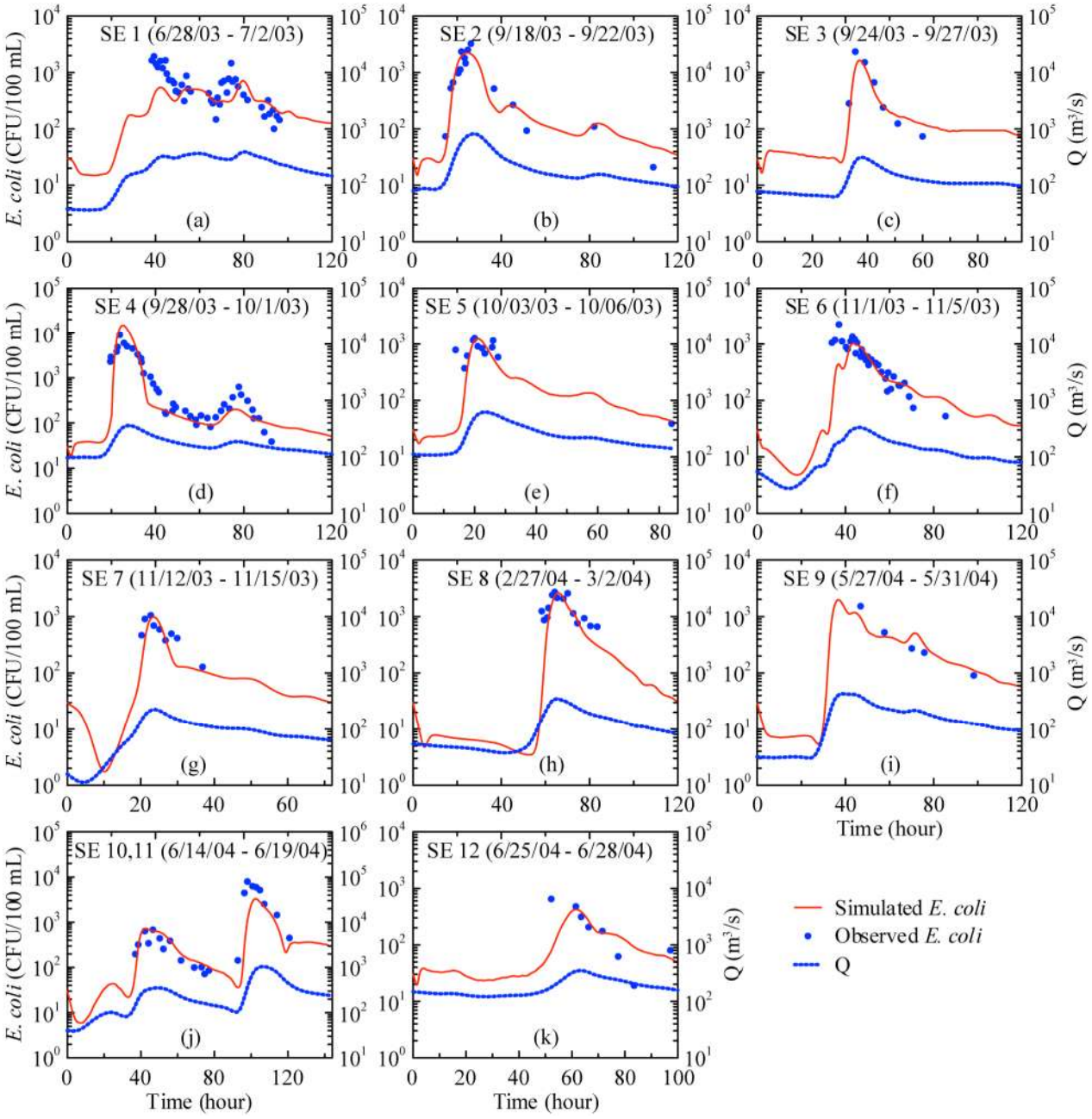

Figure 4. E. coli concentrations observed and simulated with the hydrograph-based approach.

(1) A new hydrograph-based approach is proposed for predicting bacterial source and concentrations in rivers. Sediment resuspension from streambed may be an important source for bacterial transport during high flows. Results from this study indicate that the most important source responsible for bacterial transport in streams is watershed loading during flood events and hyporheic exchange during low flow periods. Figure 4 shows a

comparison between the observed and model predicted E. coli concentrations using the new hydrograph-based approach.

(2) More details about the hydrograph-based approach to source area identification can be found in Paper 2.

3. Identification of Nonpoint Source Areas of BOD in Amite River Watershed

(1) The variation in dissolved oxygen (DO) along the Amite River due to BOD loading from the watershed is mapped using ArcGIS and Google Earth to better understand the longitudinal variation in DO. The Google Earth map indicates that the DO level drops significantly downstream of the Claycut Bayou confluence and particularly the Bayou Manchac confluence, as shown in Figure 5, implying that the Claycut Bayou watershed and the Bayou Manchac watershed (Figure 6) are potentially the major source areas of DO pollution to the Lower Amite River. The Claycut Bayou and the Bayou Manchac collect runoff from the Baton Rouge metropolitan area.

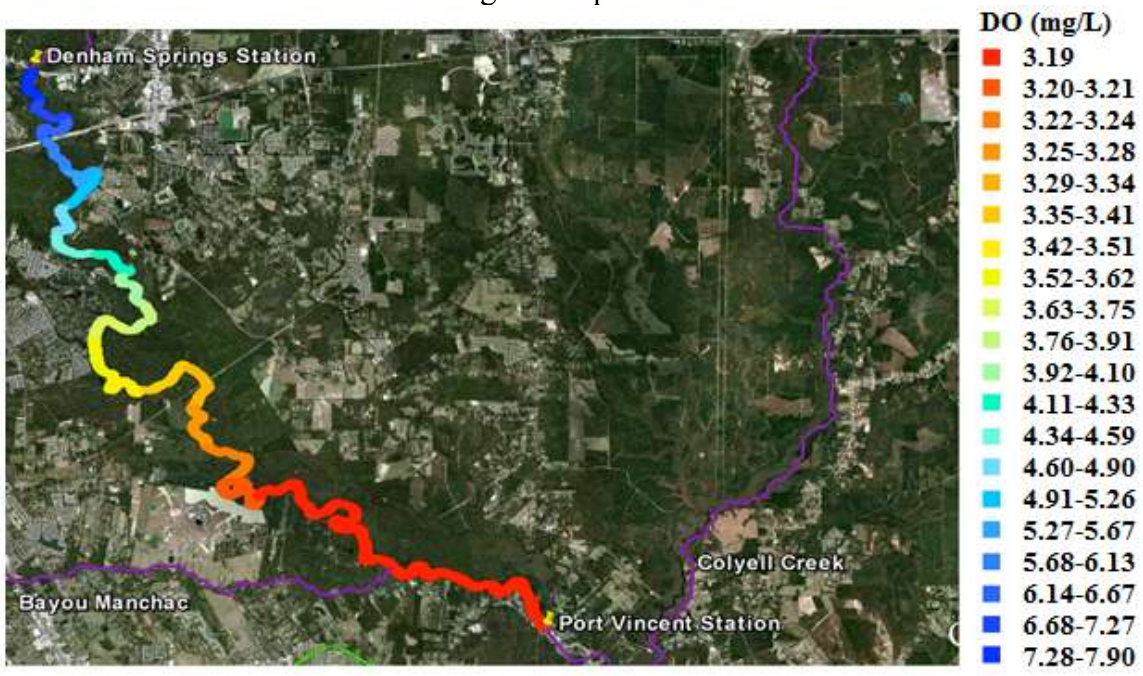

Figure 5. Reach-scale map showing DO variation along Amite River due to BOD loading from the watershed.

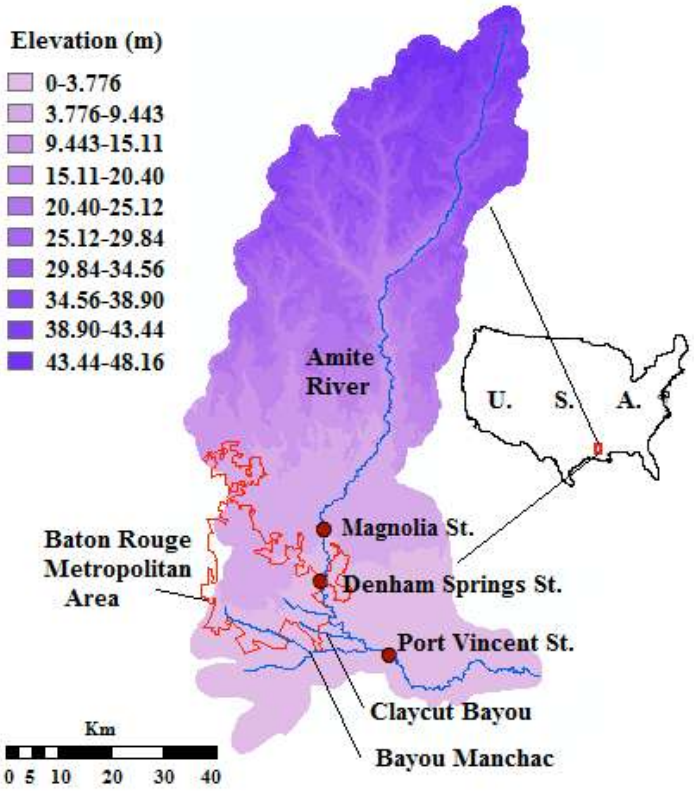

Figure 6. Map of Amite River watershed showing the critical source areas of BOD in the Claycut Bayou and the Bayou Manchac subwatersheds.

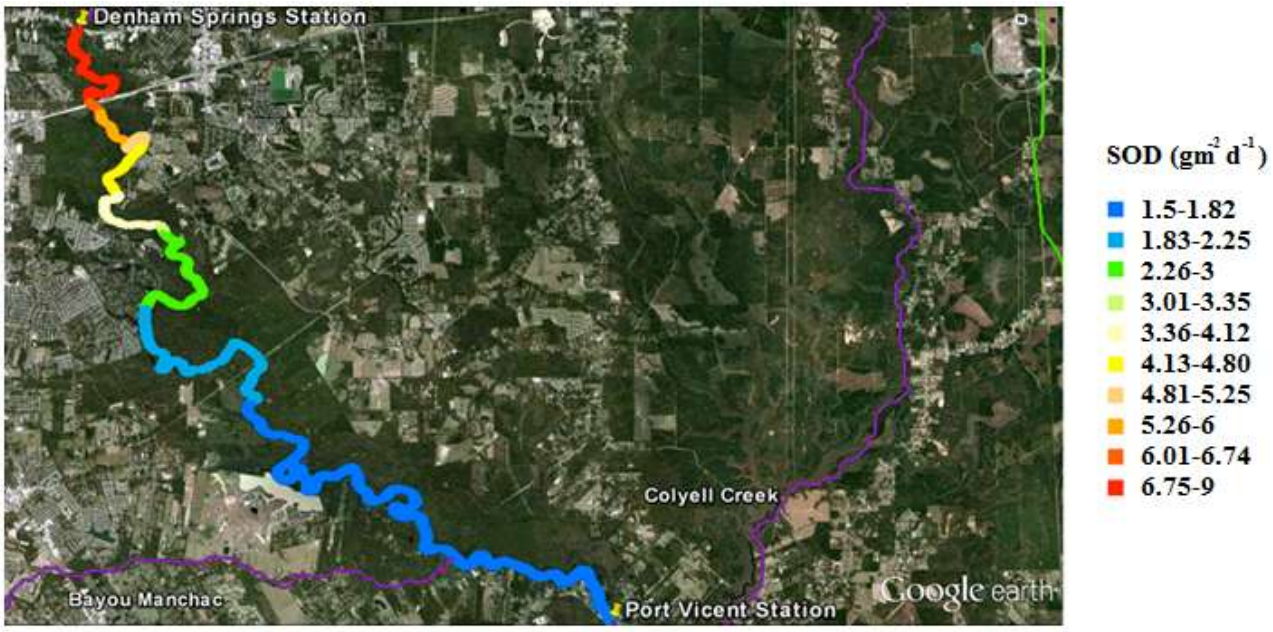

Figure 7. Spatial variation in SOD along Amite River between Denham Springs and Port Vincent Stations due to BOD loading from the watershed.

(2) Figure 7 shows longitudinal variation in SOD along the 40 km-long Lower Amite River. The SOD is dependent on availability of DO in water column. The low SOD in the lower portion of the river reach is attributed to the low DO fluxes into the sediment layers due to low DO gradient across the sediment water interface. The SOD map in Figure 7 is consistent with the DO map in Figure 5, indicating again that the Claycut Bayou watershed and the Bayou Manchac watershed are the major source areas of DO pollution to the Lower Amite River. TMDL implementation efforts for the Amite River should focus on the restoration of the Claycut Bayou watershed and the Bayou Manchac watershed by implementing low impact development practices.

INFORMATION TRANSFER

The findings and methods developed in this project for identification of contaminant source locations in the Amite River Watershed will be transferred to the Louisiana Department of Environmental Quality for pollutant TMDL development and implementation and thereby for the restoration of the Lower Amite River.

STUDENT SUPPORT

Name of supported graduate student: Yangbin Tong (Male)
Degree Program: M.S. in Water Resources
Thesis Title: Development of Watershed-Based Modeling Approach to Critical Source Area Identification
Graduation Date: August 2013

Name of supported graduate student: Bhuban Ghimire (Male)
Degree Program: Ph.D. in Water Resources
Dissertation Title: Development of Hydrograph-Based Approach to Modeling Fate and Transport of Sediment-Borne Bacteria in Lowland Rivers
Graduation Date: May 2012

Name of supported undergraduate student: Julian Moore (Male)
Degree Program: B.S. in Environmental Engineering
Research Topic: EVEG 3273 Independent Research
Graduation Date: December 2012

FOLLOW-ON FUNDING

Proposal Title: **Process-Based Modeling and Mitigation of Nitrogen and Phosphorus Inputs in Boeuf River Watershed (in review)**
PI: Zhiqiang Deng
Funding Agency: USDA (National Institute of Food and Agriculture)