Louisiana Water Resources Research Institute
Annual Technical Report
FY 2008

Introduction

This report presents a description of the activities of the Louisiana Water Resources Research Institute for the period of March 1, 2008 to February 28, 2009 under the direction of Dr. John Pardue. The Louisiana Water Resources Research Institute (LWRRI) is unique among academic research institutions in the state because it is federally mandated to perform a statewide function of promoting research, education and services in water resources. The federal mandate recognizes the ubiquitous involvement of water in environmental and societal issues, and the need for a focal point for coordination.

As a member of the National Institutes of Water Resources, LWRRI is one of a network of 54 institutes nationwide initially authorized by Congress in 1964 and has been re-authorized through the Water Resources Research Act of 1984, as amended in 1996 by P.L. 104-147. Under the Act, the institutes are to:

"1) plan, conduct, or otherwise arrange for competent research that fosters, (A) the entry of new research scientists into water resources fields, (B) the training and education of future water scientists, engineers, and technicians, (C) the preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena, and (D) the dissemination of research results to water managers and the public.

2) cooperate closely with other colleges and universities in the State that have demonstrated capabilities for research, information dissemination and graduate training in order to develop a statewide program designed to resolve State and regional water and related land problems. Each institute shall also cooperate closely with other institutes and organizations in the region to increase the effectiveness of the institutes and for the purpose of promoting regional coordination."

The National Water Resources Institutes program establishes a broad mandate to pursue a comprehensive approach to water resource issues that are related to state and regional needs. Louisiana is the water state; no other state has so much of its cultural and economic life involved with water resource issues. The oil and gas industry, the chemical industry, port activities, tourism and fisheries are all dependent upon the existence of a deltaic landscape containing major rivers, extensive wetlands, numerous large shallow water bays, and large thick sequences of river sediments all adjacent to the Gulf of Mexico.

History of the Institute

Louisiana has an abundance of water resources, and while reaping their benefits, also faces complex and crucial water problems. Louisiana’s present water resources must be effectively managed, and the quality of these resources must be responsibly protected. A fundamental necessity is to assure continued availability and usability of the state's water supply for future generations. Specifically, Louisiana faces five major issues that threaten the quality of the state’s water supply, which are also subsets of the southeastern/island region priorities:

Nonpoint sources of pollution are estimated to account for approximately one-half of Louisiana's pollution. Because of the potential impact of this pollution and the need to mitigate its effects while maintaining the state's extensive agricultural base and coastal zones, continued research is needed in the area of nonpoint issues. Louisiana’s regulatory agencies are addressing non-point source problems through the development of waste load allocation models or total maximum daily load (TMDL) calculations. There are serious technical issues that still require resolution to insure that progress is made in solving the non-point source problem.

Louisiana's vast wetlands make up approximately 40% of the nation's wetlands. These areas are composed of very sensitive and often delicately balanced ecosystems which make them particularly vulnerable to

contamination or destruction resulting both from human activities and from natural occurrences. Understanding these threats and finding management alternatives for the state's unique wetland resources are priority issues needing attention.

Water resources planning and management are ever-present dilemmas for Louisiana. Severe flooding of urban and residential areas periodically causes economic loss and human suffering, yet solutions to flooding problems can be problems in themselves. Water supply issues have also recently a focus of concern. Despite the abundance of resources, several aquifers have been in perennial overdraft, including the Chicot aquifer. Louisiana passed its first legislation that restricts groundwater use in the past year. Water resources and environmental issues are intricately interconnected; therefore, changes in one aspect produce a corresponding responsive change in another. Further study is needed to understand these relationships.

Water quality protection, particularly of ground water resources, is an area of concern in Louisiana. Researchers are beginning to see contamination in drinking water supplies that was not present in the past. Delineating aquifer recharge areas, understanding the impacts of industrial activities on water resources, evaluating nonpoint sources of pollution, and exploring protection alternatives are issues at the forefront.

Wastewater management has been a long-standing issue in Louisiana. The problem of wastewater management focuses primarily on rural and agricultural wastewater and the high costs for conventional types of wastewater treatment as found in the petrochemical industry.

The Institute is administratively housed in the College of Engineering and maintains working relationships with several research and teaching units at Louisiana State University. Recent cooperative research projects have been conducted with the University of New Orleans and the EPA’s Hazardous Substance Research Center- South & Southwest.

Research Program Introduction

The primary goal of the Institute is to help prepare water professionals and policy makers in the State of Louisiana to meet present and future needs for reliable information concerning national, regional, and state water resources issues. The specific objectives of the Institute are to fund the development of critical water resources technology, to foster the training of students to be water resources scientists and engineers capable of solving present and future water resources problems, to disseminate research results and findings to the general public, and to provide technical assistance to governmental and industrial personnel and the citizens of Louisiana.

The priority research areas for the Institute in FY 2008 focused on selected research themes developed in conjunction with the advisory board. These themes corresponded to the major water resource areas affecting Louisiana described in the Introduction above. Projects selected were from a range of faculty with different academic backgrounds including geological scientists, environmental engineers and water resource engineers and scientists. Supporting research in this priority area has increased the visibility of the Institute within the State.

The individual research projects designated as Projects 2005LA38G, 2007LA50B, 2007LA51B, and 2007LA52B, as listed below.

• Project 2005LA38G, Tsai & Singh - Saltwater Intrusion Management with Conjunctive Use of Surface Water and Ground Water

• Project 2008LA59B – Chou, “Field Monitoring of Environmental Contaminants of Toxic Metal in Lake Pontchartrain and Ground Water”

• Project 2008LA58B - Deng, “Uncertainty-based TMDL Calculations for Dissolved Oxygen in Amite River”

• Project 2008LA57B- Tsai, “Electrical Resistivity Tomography (ERT) Laboratory Experiments on Saltwater Encroachment Tracking and Modeling in Saturated Heterogeneous Sediment”

• Project 2008LA56B - Pardue and Korevec, “Information Transfer Symposia”

These projects include one project that focuses on water quality issues (Project 2008LA58B), two projects that focus on groundwater (Projects 2008LA57B and 2008LA59B) and one information transfer project (2008LA56B). The physical study will also support the Institute’s long-standing commitment to computer modeling of water resources processes.

Saltwater Intrusion Management with Conjunctive Use of Surface Water and Ground Water

Basic Information

Title:	Saltwater Intrusion Management with Conjunctive Use of Surface Water and Ground Water
Project Number:	2005LA38G
Start Date:	9/1/2005
End Date:	8/31/2009
Funding Source:	104G
Congressional District:	Louisiana
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Management and Planning, Solute Transport
Descriptors:	Management modeling, Saltwater Intrusion, Optimization, Conjunctive Use
Principal Investigators:	Frank Tsai, Vijay P. Singh

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SYNOPSIS

Title: Saltwater Intrusion Management with Conjunctive Use of Surface Water and Ground Water
Project Number: 2005LA38G
Start Date: 9/1/2005
End Date: 8/31/2009
Funding Source: 104G
Research Category: Ground-water Flow and Transport
Focus Categories: GW, M&P, MET, MOD, NPP, ST, WQL, WQN
Descriptors: Management modeling, Saltwater Intrusion, Optimization, Conjunctive Use
Primary PI: Frank T.-C. Tsai
Other PI: Vijay P. Singh

Problem and Research Objectives

Ground water is the primary source of drinking water for 61 percent of Louisiana's residents. Irrigation withdrawal is accounted for 37 percent of the total ground water withdrawal (Sargent 2007). Ground water has been an essential, reliable water supply source for economic development in the Baton Rouge area. Although the Baton Rouge area receives abundant surface water, ground water is the major water source to the public and industry due to its high water quality. However, population growth and economic development in southeastern Louisiana have led to increased ground water demand. Recent drought also has escalated ground water withdrawal (Bohr 2003). Heavy pumping for public-supply and industrial uses in the Baton Rouge area has induced the movement of saltwater across the Baton Rouge Fault; and saltwater has been detected north of the Fault in most of the freshwater aquifers. According to a joint study conducted by USGS and the Louisiana Department of Transportation and Development (LDOTD), ground water levels in the East Baton Rouge Parish have declined by as much as 300 feet since the 1940s (Tomaszewski 1996). Within the past 10 years, water levels in many wells have declined at a rate of 1 to 3 feet per year due to drought and large withdrawals. Pumping in the Baton Rouge area has also had regional impacts, lowering water levels in many adjacent parishes. If pumping continues at the current higher rate, saltwater could invade Baton Rouge's public production wells and industrial area in the near future.

To protect ground water from saltwater intrusion, the project aims to develop a multi-objective saltwater intrusion management model such that the ground water resource can be sustained in the Southeastern Louisiana aquifer system. We target "1,500-foot" sand aquifer for the pilot study. The objective of this study is to use Bayesian model averaging (BMA) to assess the optimized operations from a ground water management model under model structure uncertainty. The ground water management model consists of a joint operation of a hydraulic barrier system and an extraction system to reduce the chloride concentration and prevent further saltwater intrusion in the "1,500-foot" sand aquifer in the Baton Rouge area. The hydraulic barrier serves the interception and dilution of the chloride concentration. The extraction wells pump out brackish water in the area intruded by the saltwater. Uncoupled ground water flow and mass transport models are employed to simulate saltwater intrusion in the two-dimensional "1,500-foot" sand aquifer. A genetic algorithm (GA) is used to obtain the optimal operations. The uncertainty of boundary head values in the ground water model leads to the consideration of

multiple saltwater intrusion simulation models. In each simulation model, multiple semivariogram models along with the generalized parameterization (GP) method (Tsai 2006; Tsai and Li 2008a,b) are considered to estimate spatially correlated hydraulic conductivity. The BMA method, which integrates multiple simulation models and multiple semivariogram models, is employed to predict chloride concentration movement under optimal operations. Using the BMA, this study evaluates the uncertainty of the remediation results caused by the uncertainty from boundary head values and experimental semivariograms.

The study area shown in Figure 1 is the "1,500-foot" sand aquifer, where the extent of the saltwater intrusion was predicted at the beginning of year 2005. There are three major ground water production centers in this area, which have developed a large depression cone and caused saltwater intrusion across the Baton Rouge Fault. Recent study of ground water modeling in this area indicated that the ground water heads are continuously decreasing (Tsai and Li 2008a), which could result in undesired chloride concentration level at the production wells in the future.

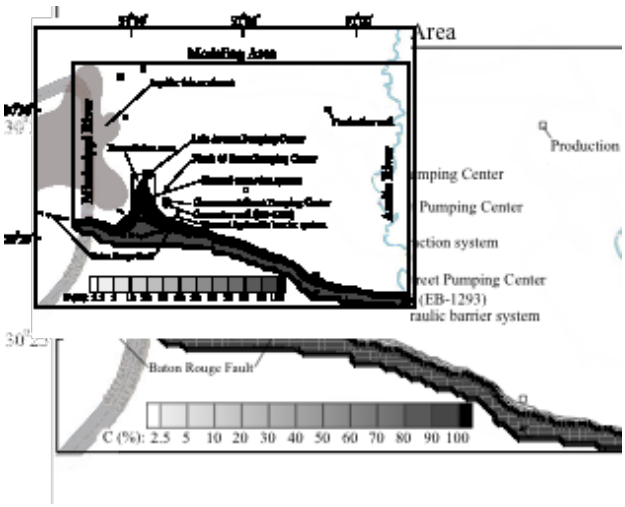


Figure 1: The study area of "1,500-foot" sand aquifer in the Baton Rouge area, Louisiana. The contour lines represent saltwater concentration (%) distribution at the beginning of 2005.

Methodology

A management model is developed using injection-extraction approach to protect the production wells from saltwater intrusion. This study considers joint operations of the hydraulic barrier system and the extraction system shown in Figure 1 to (i) intercept incoming saltwater plume toward the production wells and (ii) reduce brackish water north of the fault. The injection wells align to form a hydraulic barrier to reduce saltwater movement towards the production wells. The pumping wells are placed at the pathway of the brackish water in order to remove the

brackish water from the aquifer and to prevent northward movement of the brackish water pushed by the hydraulic barrier system. The locations of these well pumps are fixed in this study.

(1) Genetic Algorithm for Injection-Extraction Management Model

The overriding objective of the management model is to minimize the total amount of injected and extracted water as follows

$$\min_{\substack{z_{i,n}^R \in \{0,1\}, q^R \\ z_{j,n}^P \in \{0,1\}, q^P}} \sum_i \sum_n z_{i,n}^R q^R \Delta t_n + \sum_j \sum_n z_{j,n}^P q^P \Delta t_n , \tag{1}$$

The range of injection and extraction rates is constrained by

$$\begin{aligned} 0 \le q^R \le q_{\max}^R \\ 0 \le q^P \le q_{\max}^P \end{aligned} , \tag{2}$$

where q^R and q^P are the injection rate and the extraction rate, respectively. $q_{\max}^R$ and $q_{\max}^P$ are the maximum injection rate and extraction rate, respectively. $z_{i,n}^R$ and $z_{j,n}^P$ are the scheduling binary variables for spatial and temporal allocation of the pump rates at injection site i, pumping site j, at time period n. Δt_n is the time interval for the period n. To reduce operation complexity, this study searches for optimal constant injection rate and constant extraction rate and optimal operation schedule to determine well pump activities.

The concentration at the Lula Avenue pumping center (see Lula wells in Figure 1) is constrained by the maximum permissible level (MPL):

$$C\left(\mathbf{x} = \mathbf{x}_{Lula}, t \in \left[t_0, t_T\right]; z_{i,n}^R, q^R, z_{j,n}^P, q^P\right) \le C_{MPL}, \tag{3}$$

where C is the predicted concentration by the simulation models, C^{tar} is the maximum permissible level (MPL) of concentration, $\mathbf{x}_{Lula}$ is the location of Lula wells, t_0 is the starting time of remediation horizon, and t_T is the ending time of the remediation horizon. The concentration in the remediation area is also constrained by the MPL:

$$C\left(\mathbf{x} \in \Omega_R, t = t_T; z_{i,n}^R, q^R, z_{j,n}^P, q^P\right) \le C_{MPL}, \tag{4}$$

where Ω_R is the domain of remediation area (see Figure 1). The joint operations of hydraulic barrier and extraction systems present a mixed integer nonlinear programming (MINLP) problem, which involves the ground water model and transport model. This study employs a genetic algorithm (GA) with binary chromosomes to search for optimal pump rates as well as optimal binary values of scheduling variables. Using the GA, the constraints are moved as the penalty terms to the objective function. Then, a multiobjective function is formulated:

$$
\begin{aligned}
\min_{\substack{z_{i,n}^R \in \{0,1\}, q^R \\ z_{j,n}^P \in \{0,1\}, q^P}} \quad & w_1 \left(\sum_i \sum_n z_{i,n}^R q^R \Delta t_n + \sum_j \sum_n z_{j,n}^P q^P \Delta t_n \right) + \\
& w_2 \int_{t_0}^{t_T} \max \left[C\left(\mathbf{x} = \mathbf{x}_{Lula}, t; z_{i,n}^R, q^R, z_{j,n}^P, q^P\right) - C_{MPL}, 0 \right] dt + , \\
& w_3 \int_{\Omega_R} \max \left[C\left(\mathbf{x}, t = t_T; z_{i,n}^R, q^R, z_{j,n}^P, q^P\right) - C_{MPL}, 0 \right] d\mathbf{x}
\end{aligned}
\tag{5}
$$

where w_1, w_2, w_3 are the weights to reflect the priorities, which in this study are in order of minimizing the concentration violation at Lula wells, minimizing the concentration violation in the remediation area, and minimizing the total amount of water injected and extracted.

(2) Concentration Prediction using Bayesian Model Averaging under Uncertainty of Head Boundary Values and Semivariograms for Hydraulic Conductivity

The optimized joint operations are subject to the uncertainty of model structure that can cause large constraint violations. To assess the robustness of the optimized operations, this study introduces the Bayesian model averaging (BMA) (Hoeting et al. 1999) to obtain the predicted concentrations to evaluate the violations at Lula wells and in the remediation area.

Let $\mathbf{M} = \left\{ \mathrm{M}^{(p)}; p = 1, 2, \ldots \right\}$ be a set of saltwater intrusion simulation models based on different boundary values of ground water heads. Each simulation model may have different semivariogram models to estimate hydraulic conductivity, which is denoted as $\boldsymbol{\theta} = \left\{ \theta_q^{(p)}; q = 1, 2, \ldots \right\}$. Given data $\mathbf{D}$, the expectation and covariance of chloride concentrations using multiple models can be obtained as follows:

$$
\mathrm{E}\left(\mathbf{C} \mid \mathbf{D}\right) = \sum_p \Pr\left(\mathrm{M}^{(p)} \mid \mathbf{D}\right) \sum_q \Pr\left(\theta_q^{(p)} \mid \mathrm{M}^{(p)}, \mathbf{D}\right) \mathrm{E}\left(\mathbf{C} \mid \mathrm{M}^{(p)}, \theta_q^{(p)}, \mathbf{D}\right), \tag{6}
$$

$$
\begin{aligned}
\mathrm{Cov}\left(\mathbf{C} \mid \mathbf{D}\right) = & \mathrm{E}_{\mathrm{M}\theta} \mathrm{E}_{\theta} \left[\mathrm{Cov}\left[\mathbf{C} \mid \mathrm{M}^{(p)}, \theta_q^{(p)}, \mathbf{D}\right] \right] + \mathrm{E}_{\mathrm{M}\theta} \mathrm{Cov}_{\theta} \left[\mathrm{E}\left[\mathbf{C} \mid \mathrm{M}^{(p)}, \theta_q^{(p)}, \mathbf{D}\right] \right], \\
& + \mathrm{Cov}_{\mathrm{M}\theta} \mathrm{E}_{\theta} \left[\mathrm{E}\left[\mathbf{C} \mid \mathrm{M}^{(p)}, \theta_q^{(p)}, \mathbf{D}\right] \right]
\end{aligned}
\tag{7}
$$

where $\mathrm{E}_{\mathrm{M}\theta} \mathrm{E}_{\theta} \left[\mathrm{Cov}\left[\mathbf{C} \mid \mathrm{M}^{(p)}, \theta_q^{(p)}, \mathbf{D}\right] \right]$ is the within-covariance of concentration, $\mathrm{E}_{\mathrm{M}\theta} \mathrm{Cov}_{\theta} \left[\mathrm{E}\left[\mathbf{C} \mid \mathrm{M}^{(p)}, \theta_q^{(p)}, \mathbf{D}\right] \right]$ is the covariance of concentration due to different semivariogram models in simulation models, and $\mathrm{Cov}_{\mathrm{M}\theta} \mathrm{E}_{\theta} \left[\mathrm{E}\left[\mathbf{C} \mid \mathrm{M}^{(p)}, \theta_q^{(p)}, \mathbf{D}\right] \right]$ is the covariance of concentration due to different simulation models. $\Pr\left(\mathrm{M}^{(p)} \mid \mathbf{D}\right)$ is the posterior probability of simulation model p and $\Pr\left(\theta_q^{(p)} \mid \mathrm{M}^{(p)}, \mathbf{D}\right)$ is the posterior probability of semivariogram model q used in simulation model p.

The likelihood value, $\Pr\left(\mathbf{D} \mid \theta_q^{(p)}, \mathrm{M}^{(p)}\right)$, is needed in order to calculate the posterior model probabilities and is approximated using the Bayesian information criterion (BIC) (Raftery 1995; Madigan et al. 1996): $\Pr\left(\mathbf{D} \mid \theta_q^{(p)}, \mathrm{M}^{(p)}\right) \approx \exp\left(-\frac{1}{2} \mathrm{BIC}_q^{(p)}\right)$, where the BIC is

$$\mathrm{BIC}_q^{(p)} = -2\ln\Pr\left(\mathbf{D}\middle|\mathrm{M}^{(p)}, \boldsymbol{\beta}_q^{(p)}, \hat{\boldsymbol{\beta}}_q^{(p)}\right) + m_q^{(p)} \ln L. \tag{8}$$

where $\hat{\boldsymbol{\beta}}_q^{(p)}$ is the maximum-likelihood estimated unknown parameters, $m_q^{(p)}$ is the dimension of $\hat{\boldsymbol{\beta}}_q^{(p)}$, and L is the size of the data $\mathbf{D}$. In this study, $\boldsymbol{\beta}_q^{(p)}$ refers to the data weighting coefficients in the GP methods used to estimate hydraulic conductivity (Tsai 2006).

Therefore, one can assess the constraint violations by using the BMA expectation for concentration prediction as follows

$$\begin{aligned} \min_{\substack{z_{i,n}^R \in \{0,1\}, q^R \\ z_{j,n}^P \in \{0,1\}, q^P}} \quad & w_1 \left(\sum_i \sum_n z_{i,n}^R q^R \Delta t_n + \sum_j \sum_n z_{j,n}^P q^P \Delta t_n \right) + \\ & w_2 \int_{t_0}^{t_T} \max\left[C_{BMA}\left(\mathbf{x} = \mathbf{x}_{Lula}, t; z_{i,n}^R, q^R, z_{j,n}^P, q^P\right) - C_{MPL}, 0 \right] dt + , \\ & w_3 \int_{\Omega_R} \max\left[C_{BMA}\left(\mathbf{x}, t = t_T; z_{i,n}^R, q^R, z_{j,n}^P, q^P\right) - C_{MPL}, 0 \right] d\mathbf{x} \end{aligned} \tag{9}$$

where C_{BMA} is obtained by Eq. (6) using the variance window (Tsai and Li 2008a,b), which is

$$C_{BMA} = \frac{\sum_p \sum_q \mathrm{E}\left(C \middle| \mathrm{M}^{(p)}, \boldsymbol{\beta}_q^{(p)}, \mathbf{D}\right) \exp\left(-\frac{1}{2}\alpha \Delta \mathrm{BIC}_q^{(p)}\right)}{\sum_p \sum_q \exp\left(-\frac{1}{2}\alpha \Delta \mathrm{BIC}_q^{(p)}\right)}. \tag{10}$$

This optimization problem is very time-consuming because it involves many simulation models and semivariogram models in the management model.

Principal Findings and Significance

(1) Saltwater Intrusion Simulation Model and Management Model

A saltwater intrusion simulation model for the "1,500-foot" sand aquifer in the Baton Rouge area is further developed from the ground water flow model developed by Tsai and Li (2008a). The modeling area is shown in Figure 1. The model incorporates the connector well, EB-1293, which recharges ground water from the "800-foot" sand to the "1500-foot" sand. A recharge rate of 2,200 m^3/day of the connector well is determined based on the flow rates reported by Louisiana Capital Area Ground Water Conservation Commission. MODFLOW (Harbaugh et al. 2000) and MT3DMS (Zheng and Wang 1999) are employed, but uncoupled to simulate saltwater intrusion in the two-dimensional "1,500-foot" sand aquifer in the planar discretization.

In the management stage, the simulation model predicts saltwater intrusion for 15 years from January 1, 2005 to December 31, 2019 with 180 stress periods. Twenty (20) injection wells and 12 pumping wells are added into the study area (see Figure 1). The initial chloride concentration is shown in Figure 1. Due to very limited chloride concentration data, a mass flux boundary condition with $C = 1.0$ (or 100%) is assumed at the southern boundary of the modeling area. This study considers the maximum permissible level of chloride concentration to be 2.5%, i.e.,

$C_{MPL} = 0.025$. The time-varied monthly pumping rates in individual production wells were fixed to the average pumping rates of the last three years (2002-2004) in the calibration stage.

Although the boundary head values for the ground water model have been carefully determined, the values are not completely certain because the ground water head data are scarce. To assess the robustness of the optimized joint operations under this uncertainty, five ground water models are created, which have 0%, $\pm 10\%$, and $\pm 20\%$ changes of the predetermined head boundary values. Moreover, uncertainty in the semivariogram models for hydraulic conductivity estimation is considered. Three semivariogram models (exponential, spherical and Gaussian models) are considered. A total of $5 \times 3 = 15$ models are considered in the BMA. A variance window with a 5% significance level and two times the standard deviation of the data chi-squares distribution is adopted (Tsai and Li 2008a). The scaling factor is 0.080. Table 1 lists the model weights. The best model is ($\theta_3^{(3)}, \mathrm{M}^{(3)}$), denoted as Gau+0%

Table 1: BMA Model Weights (Posterior Model Probabilities) Using Variance Window.

	Simulation models with % change in head boundary values				
Semivariogram models	$\mathrm{M}^{(1)}$ (20%)	$\mathrm{M}^{(2)}$ (10%)	$\mathrm{M}^{(3)}$ (0%)	$\mathrm{M}^{(4)}$ (-10%)	$\mathrm{M}^{(5)}$ (-20%)
Spherical, $\theta_1^{(p)}$	23.67%	30.34%	29.45%	28.23%	28.58%
Exponential, $\theta_2^{(p)}$	3.03%	15.19%	30.13%	34.46%	26.08%
Gaussian, $\theta_3^{(p)}$	73.30%	54.47%	40.42%	37.31%	45.35%
$\Pr\left(\mathrm{M}^{(p)} \mid \mathbf{D}\right)$	0.00%	12.94%	53.31%	32.05%	1.71%

(2) Joint Operation Optimization

To reduce the complexity in the management model and to increase the efficiency of searching for optimal operations, the operation considers all injection wells and all pumping wells are active or inactive on a monthly basis for 15 years. Therefore, there are 180 scheduling variables for the injection wells and 180 scheduling variables for the pumping wells. A GA solver (Carroll 1996) is used to minimize the multiobjective function. The injection rate and extraction rate are given 12 bits. To prioritize the multiple objections, it sets $w_1 = 10^{-11}$, $w_2 = 100$, $w_3 = 1.0$ for the multiobjective function.

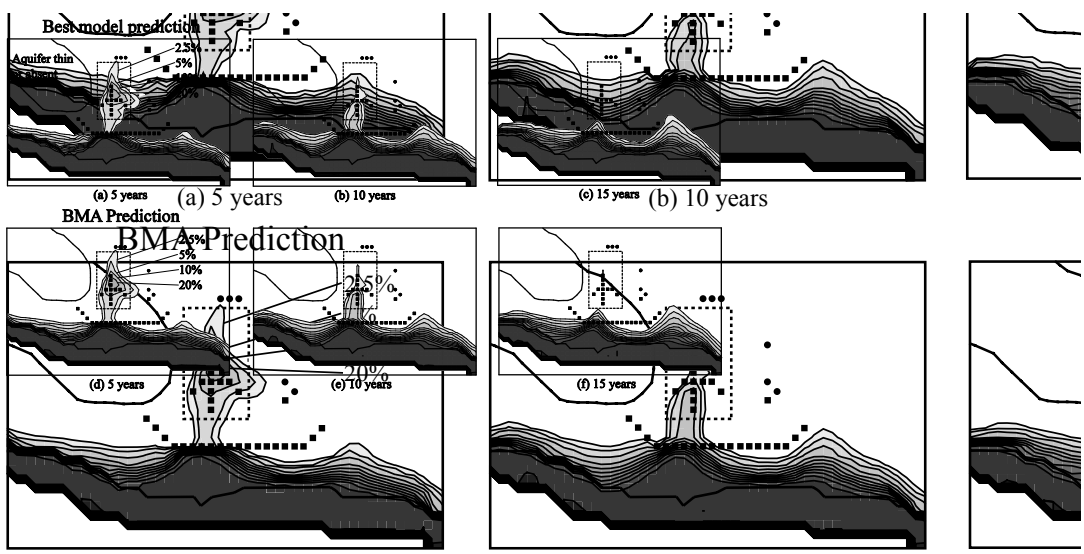
Two management models are compared to show the difference if model uncertainty is not considered. The optimization results are shown in Table 2. For the no-action scenario, there is no violation at Lula wells. However, the violations in the remediation area is very high. If considering the best model (Gau+0%) only in the management model, it shows the optimal injection rate to be 3,217 $\mathrm{m}^3/\mathrm{day}$ and the optimal extraction rate to be 2,448 $\mathrm{m}^3/\mathrm{day}$. No violations occur at Lula wells and in the remediation area at the end of the management period. The total amount of water injected and pumped is 331 MCM (million cubic meters). If the model uncertainty is considered, using the optimal operation from the best model produces a noticeable violation in the remediation area at the end of the management period. The violations are expected because this optimal operation from the best model neglects other good models and gives a biased solution.

Using the BMA to predict chloride concentration in the management model, the optimal injection rate is increased to 3,729 m^3/day and the optimal extraction rate is increased to 3,012 m^3/day in order to reduce the violations from other models. The total amount of water injected and pumped is 371 MCM. The increased injection and extracting rates reflect the need of "overdesigning" the strategy to insure reliability (Wagner and Gorelick 1987). Increasing injection and extraction rates become necessary in order to meet the remediation goal.

Table 2: Optimization results using the best model (Gau+0%) and the BMA.

Optimal operations	Models used for concentration prediction	Objective function values	Violations at Lula wells	Violations in the remediation area 5 years	10 years	15 years
No action:	Best model	17.51833	0.00000	12.59451	15.12390	17.51833
Injection rate = 0 m^3/day	BMA	17.20642	0.00000	12.46455	14.85176	17.20642
Extraction rate = 0 m^3/day						
Using the best model:	Best model	0.00331	0.00000	3.19431	0.74394	0.00000
Injection rate = 3,217 m^3/day	BMA	0.02888	0.00000	3.45558	0.81605	0.02557
Extraction rate = 2,448 m^3/day						
Using the BMA:	Best model	0.00371	0.00000	3.14401	0.90793	0.00000
Injection rate = 3,729 m^3/day	BMA	0.00465	0.00000	3.20692	0.92917	0.00095
Extraction rate = 3,012 m^3/day						

In Table 2, the optimal operation using the BMA shows no violations at Lula wells and presents an acceptable solution for both the best model prediction and the BMA prediction. Figure 2 shows the chloride concentration distributions using the best model and the BMA with this optimal operation (q^R = 3,729 m^3/day, q^P = 3,012 m^3/day).



(a) 5 years (b) 10 years (d) 5 years (e) 10 years

Figure 2: Isochlors predicted by the best model (Gau+0) at (a) 5 years, (b) 10 years, and (c) 15 years, and by the BMA at (d) 5 years, (e) 10 years, and (f) 15 years, given the optimal joint operation, injection rate = 3,729 m^3/day and extraction rate = 3,012 m^3/day, from the BMA.

(3) Summary

[1] Groundwater management is far more difficult and complex because of model structure uncertainty. Uncertain model structure often results in multiple possible simulation models. Management plans under the consideration of a single simulation model tends to bias optimized operations. To alleviate the biasedness, a reliable groundwater management model should take into account the predictions from multiple models.

[2] Bayesian model averaging (BMA) has been shown capable of integrating multiple models for prediction in the management model. Optimized operations based on the BMA predictions shows more reliable management outcomes than from one simulation model. However, the optimized operation is more expensive in order to reduce constraint violations elevated by considering many models.

[3] The study has demonstrated the importance of considering model structure uncertainty in a real-world case study. Using the best model underestimates the optimized injection rate and extraction rate for the hydraulic barrier and extraction systems. Using the BMA prediction for chloride concentration, the optimized injection and extraction rates increase to reduce the concentration violation in the remediation area.

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Electrical Resistivity Tomography (ERT) Laboratory Experiments on Saltwater Encroachment Tracking and Modeling in Saturated Heterogeneous Sediment

Basic Information

Title:	Electrical Resistivity Tomography (ERT) Laboratory Experiments on Saltwater Encroachment Tracking and Modeling in Saturated Heterogeneous Sediment
Project Number:	2008LA57B
Start Date:	3/1/2008
End Date:	2/28/2009
Funding Source:	104B
Congressional District:	6
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Solute Transport, Methods
Descriptors:	
Principal Investigators:	Frank Tsai

Publication

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2. Tsai, F. T.-C., and M. Pillala, Subsurface characterization using electrical resistivity tomography, ASCE/EWRI World Water & Environmental Resources Congress, Kansas City, Missouri, May 17-21, 2009.
3. Tsai, F. T.-C., and M. Pillala, Electrical resistivity tomography using MODFLOW, American Geophysical Union 2008 Fall Meeting, San Francisco, CA, Dec 15-19, 2008.

SYNOPSIS

Title: Electrical Resistivity Tomography (ERT) Laboratory Experiments on Saltwater Encroachment Tracking and Modeling in Saturated Heterogeneous Sediment
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Focus Category: Ground Water, Solute Transport, Methods, Models
Descriptors: Geophysics, Electrical Resistivity, Tomography, MODFLOW, Optimization
Primary PI: Frank T.-C. Tsai

Problem and Research Objectives

Rapid population growth and economic development in southeastern Louisiana have led to increased ground water demand. The East Baton Rouge (EBR) population has been almost doubled since Hurricane Katrina. Moreover, since October 2005, Southern Louisiana has been suffered from the extreme drought. Most of the southern half of the State has averaged just 21 inches of rain, down from the usual 40-inch average. EBR is facing a water demand challenge while experiencing drought. With small to zero expansion of the surface water treatment plants, excessive withdrawal of ground water in the Capital Area is anticipated and will accelerate the existing saltwater encroachment in EBR. Protecting ground water from further saltwater intrusion is an important issue to sustain the economic welfare of the state's citizens.

The goal of this study is to develop an electrical resistivity tomography (ERT) technique to better understand saltwater encroachment in the aquifer. Electrical resistivity tomography (ERT) is a geophysical imaging method which calculates the electrical resistivity distribution in the subsurface environment from a large number of electric potential made from electrodes. ERT has been widely used and successfully explore, monitor subsurface hydrogeological information (USDOE, 2000). ERT is able to determine chloride concentrations in the subsurface (Singha and Gorelick, 2005), flow pathways in the porous media (Daily et al., 1992), and magnitude of hydraulic conductivity (Urish, 1981). ERT was also used as a monitoring tool in the subsurface environmental restoration process to determine the cleanup performance (Ramirez et al., 1993). ERT provides dramatically increased resolution and sensitivity at low cost. Furthermore, ERT is advantageous in characterizing saline tracer at the field site and provides a large number of data with significantly less experiment efforts than those required by the traditional sampling methods (Singha et al., 2003). Moreover, ERT is able to produce two- and three-dimensional images when traditional methods in lab and field measurement allow only limited one-dimensional data.

The objectives of this project include (1) development of ERT experiments, and (2) development of ERT image reconstruction algorithm.

Methodology

(1.1) ERT experiments

This project considers two types of ERT experiments. One is a non-invasive approach through boundary voltage measurement. The other is an invasive approach through measuring voltages at boreholes. The non-invasive approach is shown in Figure 1(a), which measures voltages at electrodes around the boundary of a vessel. The borehole approach is shown in Figure 1(b), which places electrodes along boreholes under the surface. To obtain electric potentials (volts) at electrodes for ERT inversion, given a pair of source electrode and sink electrode (one current pattern), a direct current (DC) power supply injects direct current (amperes) of constant intensity into conductive material to develop an electric potential field. Then, a digital multimeter (DMM) is used to measure voltages (volts) at electrodes with respect to a reference electrode. By assigning zero potential at sink electrode, potentials at all electrodes can be calculated. Numerous electric potential data can be obtained by systematical changing locations of source and sink electrodes (many current patterns) and repeating the measuring protocol.

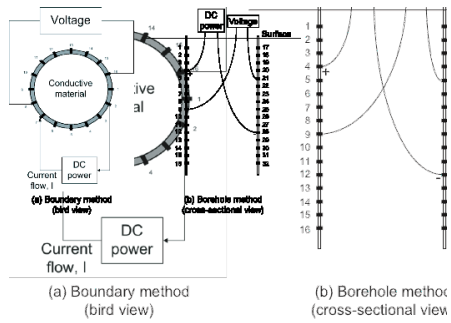

Figure 1: (a) boundary method, and (b) borehole method.

(1.2) ERT devices

A data acquisition (DAQ) system is developed to automatically change locations of source and sink electrodes, take voltage measurements at electrode locations, and record voltages and electric currents to spread sheets. Table 1 lists each device and corresponding function for ERT experiments.

Table 1: Devices for ERT Experiments.

Device	Manufacture	Capacity	Function for ERT	Quan.
EZ Digital GP-1503TP	EZ Digital, Inc.	Max. current output: 3A Max. voltage out: 50V	DC power supply to generate constant voltages or constant currents	1
M9803R	Mastech	Bench-type True RMS Multimeter with RS232 PC interface	DMM for measuring and recording currents	1
NI PCI-4060	National Instruments	5½-digit measurement	DMM for measuring and recording voltages	1
NI SCXI-1127	National Instruments	64-channel multiplexer	1 for switching source electrode locations 1 for switching sink electrode locations 2 for switching electrode locations, where voltages are measured	4
SCXI-1331	National Instruments	64-channel terminal block	Connect wires to SCXI-1127	4
SCXI-1000	National Instruments	4 slots	Chassis for housing multiplexers	3

DMM NI PCI-4060 is installed as an interface card in a personal computer (PC). The PC operation system (OS) is Windows XP Professional Edition. The CPU is Intel Pentium 4 with 3.00GHz. The RAM is 2GB with 2.99GHz. NI LabVIEW8 is used to control the NI devices.

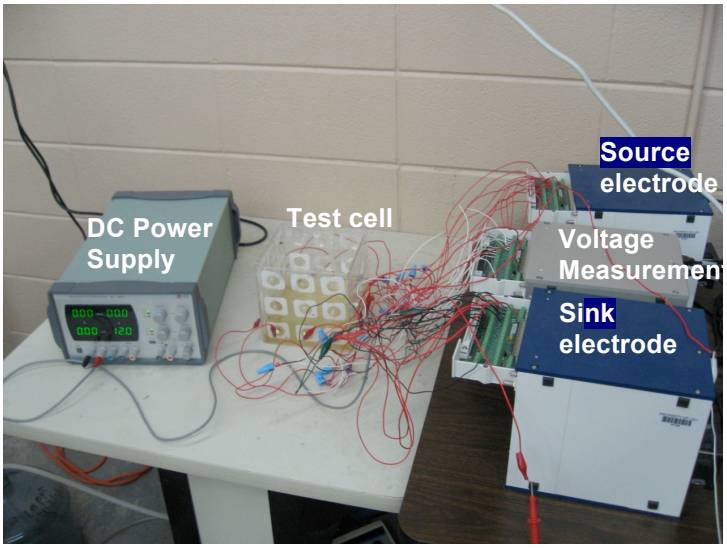

Figure 2: ERT apparatus.

As shown in Figure 2, NI PCI-4060 is connected to one SCXI-1000 chassis (middle) that houses two NI SCXI-1127 switches for measuring voltages. One SCXI-1000 (top) houses one NI SCXI-1127 for changing locations of source electrode. One SCXI-1000 (bottom) houses one NI SCXI-1127 for changing locations of sink electrode. NI LabVIEW8 controls these two switches for sink and sources electrode locations via NI USB-1357 cables.

(1.3) Electric potential modeling (forward problem)

To model electric potential distribution produced by constant DC in a conductive material, this study follows the potential-resistivity differential equation (Vauhkonen et al., 1998), but considers current source term in the governing equation. Let Ω be the domain of conductive material to be imaged and $\partial\Omega$ be the boundary of the domain. The governing equation is

$$\nabla \bullet \left(\rho^{-1} \nabla \phi\right) = I\delta\left(\mathbf{x} - \mathbf{x}_{SO}\right) \quad \text{in } \Omega \tag{1}$$

where ϕ is the electric potential, ρ is the spatially distributed electrical resistivity, I is the constant current, $\mathbf{x}_{SO}$ is the location of source electrode, and δ is the Dirac delta function. The following constraints need to be satisfied

$$\rho^{-1}\frac{\partial \phi}{\partial n} = 0 \quad \text{on } \partial\Omega \setminus \cup_{\ell=1}^{L} e_\ell \tag{2}$$

$$U_\ell = \phi + z_\ell \rho^{-1}\frac{\partial \phi}{\partial n}, \ell = 1, 2, \cdots L \tag{3}$$

$$I_\ell = \int_{e_\ell} \rho^{-1}\frac{\partial \phi}{\partial n} dS \quad \text{where } \ell = 1, 2, \cdots, L \tag{4}$$

where e_ℓ are the electrodes with a surface area S; z_ℓ are the effective contact impedance [ohm-m^2]; U_ℓ are the potentials at electrodes, I_ℓ are the entering or leaving currents through electrodes; and n is the outward normal unit. Eq. (2) represents no potential gradient at the boundary other than at the electrode sites. For electric current conservation, we need to make sure $\sum_{\ell=1}^{L} I_\ell = 0$. Moreover, a zero potential is assigned to the sink electrode.

Equation (1) is identical to the steady-state ground water flow equation with a constant injection rate at source location. Therefore, it is very straightforward for this study to use MODFLOW (Harbaugh et al. 2000) to solve equations (1)-(4). In order to make consistent use of units between the electricity flow and ground water flow, Table 2 lists the analogy of the governing equations and units.

Table 2. Analogy of Electricity Flow and Ground Water Flow

Flow of electricity	Flow of ground water
Ohm's Law: $\vec{J} = -\sigma\nabla\phi = -\rho^{-1}\nabla\phi$ J – current density (ampere/m^2) ρ – electrical resistivity (ohm-m) σ – electrical conductivity (siemen/m) ϕ – electric potential (volt)	Darcy's Law: $\vec{q} = -K\nabla\phi$ q – Darcy's velocity (m/sec) K – hydraulic conductivity (m/sec) ϕ – ground water head (m)
Electric potential equation: $\nabla\bullet\left(\rho^{-1}\nabla\phi\right) = I$ I – electric current (ampere) per material volume	Steady-state ground water flow equation: $\nabla\bullet\left(K\nabla\phi\right) = Q$ Q – volumetric flow rate (m^3/sec) per aquifer volume

(1.4) Effective contact impedance

To model the effective contact impedance in equation (3) in MODFLOW, this study considers the Horizontal Flow Barrier (HFB) Package (Hsieh and Freckleton 1993) and uses the hydraulic characteristic (HC) [1/sec] to mimic the contact impedance. The HC is defined as the barrier hydraulic conductivity divided by the width of the horizontal-flow barrier (Hsieh and Freckleton 1993; Harbaugh, 2005). For a two-dimensional problem, Figure 3 shows the source electrode at one computation cell (source cell). The surface of the source electrode is S_ℓ. The total surface of computation cells (three cells in this figure) with uniform HC surrounding the source cell is $A = A_1 + A_2 + A_3$. Using the concept of equivalent

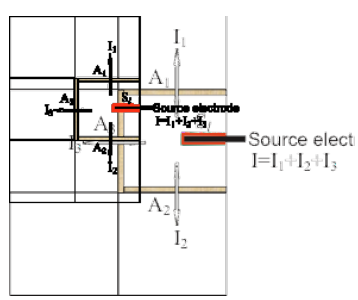

Figure 3: hydraulic characteristic (HC) surrounding the cell of source electrode.

hydraulic conductivity (McDonald and Harbaugh 1988), this study finds the relationship

$$z_\ell = \frac{1}{HC_\ell}\frac{A}{S_\ell} \tag{5}$$

The contact impedance can be calculated once the hydraulic characteristic is obtained.

(2.1) ERT inversion (inverse problem)

Using electric potential data, this study reconstructs the electrical resistivity distribution by minimizing the sum of errors between calculated potentials and measured potentials at electrode locations for all current patterns:

$$\min_{\sigma(\mathbf{x})} \quad E = \sum_{p=1}^{P}\sum_{\ell=1}^{L}\left(\phi_{p,\ell} - \phi_{p,\ell}^{obs}\right)^2 \tag{6}$$

where $\phi_{p,\ell}$ is the calculated potential at electrode ℓ with current pattern p; and $\phi_{p,\ell}^{obs}$ is the measured potential at electrode ℓ with current pattern p. Since electrical conductivity is reciprocal of electrical resistivity, this study estimates electrical conductivity for each computation cells Many studies have suggested regularization terms to ERT inversion (Zhang et al., 1995; Dickin and Wang, 1996; Vauhkonen et al., 1998). This study does not consider regularization.

(2.2) Adjoint-state method

This study adopts an adjoint-state method to calculate the gradients, $\frac{\partial E}{\partial \sigma}$, for a gradient-based optimization method because of its computational efficiency. Using adjoint-state techniques in Sun (1994), one can obtain the adjoint state equation for equation (1) with current pattern p:

$$\nabla\bullet\left(\sigma\nabla\psi_p\right) = -2\sum_{\ell=1}^{L}\left(\phi_{p,\ell} - \phi_{p,\ell}^{obs}\right)\delta\left(\mathbf{x} - \mathbf{x}_{p,\ell}\right) \tag{7}$$

where ψ_p is the adjoint state variable for current pattern p. The boundary condition is $\sigma\nabla\psi_p\bullet\vec{n} = 0$. Moreover, $\psi_p = 0$ is assigned to the sink electrode.

Equation (7) is mathematically identical to equation (1) and can be solved by MODFLOW. One just needs to replace the single source term in equation (1) with 2 times misfit error in equation (7) at each electrode location. Then, the gradients are

$$\frac{\partial E}{\partial \sigma_j} = \sum_{p=1}^{P}\int_{\Omega_j}\left[\nabla\psi_p\bullet\nabla\phi_p\right]d\Omega \tag{8}$$

where Ω_j is the influence domain of unknown σ_j.

For a total of P current patterns, one needs to execute $2P$ runs of MODFLOW in order to calculate all gradients for one optimization iteration.

Principal Findings and Significance

Case 1: Estimating contact impedance of electrodes

The first case is to estimate HC values for contact impedance of electrodes via the boundary method. Figure 4(a) shows a test cell with three layers of electrodes. The electrodes were made of stainless steel screws (18-8 SS Cup Point Socket Set Screw, 10-24 Thread, 1 in. long) from McMASTER-CARR. Each layer contains 12 electrodes. The dimension of the test cell is 6 in. by 6 in. by 6 in. The spacing between electrodes at each side of the box is 2 in. The spacing between the electrodes of the bottom layer and the bottom of the test cell is 1 in. For a two-dimensional ERT experiment, a 2 in. of tap water in depth is considered in the test cell, which submerged the electrodes of the bottom layer. The electrical conductivity of tap water is 0.042 S/m, measured by Extech EC400 Conductivity/TDS/Salinity Meter.

For the ERT data, 12 electrodes give the maximum of 132 ($=12\times11$) current patterns. Figure 4(b) represents 11 current patterns, where source electrode stays at #1 while sink electrode is moving from #2 to #12. Each pattern has constant DC of 5 mA. A total of 1452 potential data are obtained. This case considers an unknown conductivity for homogeneous tap water and 12 unknown HC values for 12 electrodes. Therefore, there are 13 unknown values needed to be estimated.

For ERT inversion, the model domain was discretized into 37 by 37 square computation cells. The thickness of the model domain is 2 in. Figure 4(c) shows the model discretization and the location of electrodes. We adopted a BFGS (Broyden-Fletcher-Goldfarb-Shanno) solver (Byrd et al., 1994), a quasi-Newton method, to solve equation (6). The estimated electrical conductivity is 0.045 S/m. The estimated HC values varied from 1.4 to 2.3 sec^{-1}.

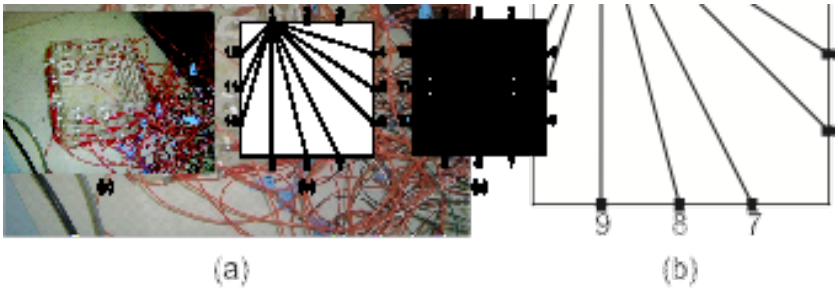

Figure 4: (a) test cell, (b) 11 current patterns (source electrode at #1 and sink electrode moves from #2 to #12), and (c) domain discretization.

Case 2: Two-dimensional numerical study

To better understand the capability of estimating electrical conductivity for each computation cell, this case conducted a numerical experiment using the same settings in the first case. Figure

5(a) shows the true conductivity field, where a high conductive zone (0.95 S/m) is inside a low conductive area (0.05 S/m). Again, the domain is discretized into 37 by 37 computation cells. Therefore, there are 1369 unknowns. With 132 currents, there are 1452 potential data. The HC valued identified in the first case was used. Figure 5(b) shows the estimated conductivity distribution. Figure 5(c) shows the decreasing fitting error over the number of called objective functions. Even though the fitting error is small, the estimated conductivity field is not close to the true solution. However the location of relative high conductivity zone indicates the capability of the ERT inverse technique. The poor result is due to the ill-posted inverse problem in this case, where the number of unknowns is very close to the number of data. This indicates an over parameterization problem.

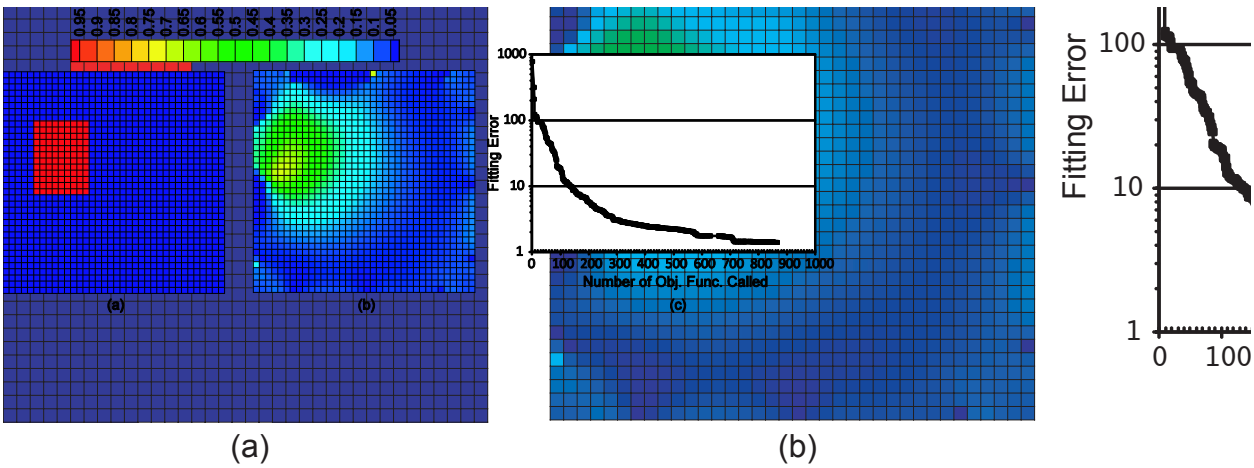

Figure 5: (a) true conductivity (S/m) distribution, (b) estimated conductivity distribution, and (c) fitting error.

Case 3: Numerical study on borehole approach

To ensure a good ERT image for the borehole approach, this case considers a numerical study on a two-dimensional field with a dimension of 50 cm wide by 100 cm deep. The true conductivity field is shown in Figure 6(a), where a square block with 0.95 S/m and a rectangular block with 0.15 S/m are inside a background material with 0.05 S/m.

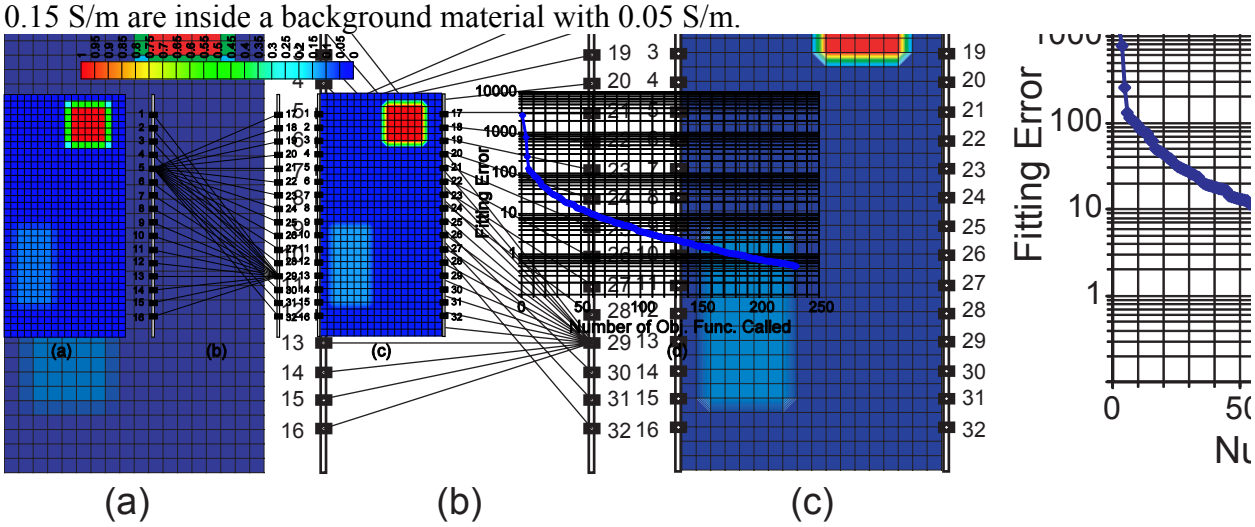

Figure 6: (a) true conductivity field (S/m), (b) source electrode at #5 and sink electrode moving from #17 to #32 and source electrode at #29 and sink electrode moving from #1 to #16, (c) estimated conductivity field, and (d) fitting error.
Two boreholes shown in Figure 6(b) are designed such that each borehole has 16 electrodes. The spacing between electrodes in each borehole is 5 cm. This case considered 512 ($= 32 \times 16$) current patterns. Constant DC of 2 mA was applied. Therefore, a total of 15872 potential data are obtained.

For ERT inversion, the domain was discretized into 37 by 19 computation cells. Unknown conductivity values for 703 computation cells were estimated by 15872 potential data. Clearly, Figure 6(c) shows a good ERT image. Figure 6(d) shows the fitting error minimization process.

Case 4 ERT using borehole approach
With the same settings in Case 3, the ERT technique was applied to a sand tank fill with sand and tap water. The dimension of the sand tank is 100 cm by 100 cm by 5 cm. Two reservoirs are at right and left sides (See Figure 7(a)). The sand has a uniform coefficient of 1.8. The grain size d_{50} is 0.45 mm. The porosity is 0.4. A falling head test was conducted to obtain saturated hydraulic conductivity to be 20.35 m/day.

A block of wood is buried inside the sand tank between two boreholes of electrodes, whose spacing is 50 cm. Their locations are shown in Figure 7(a). Using the same inverse technique in Case 3, Figure 7(b) shows a good ERT image, which locates the wood block.

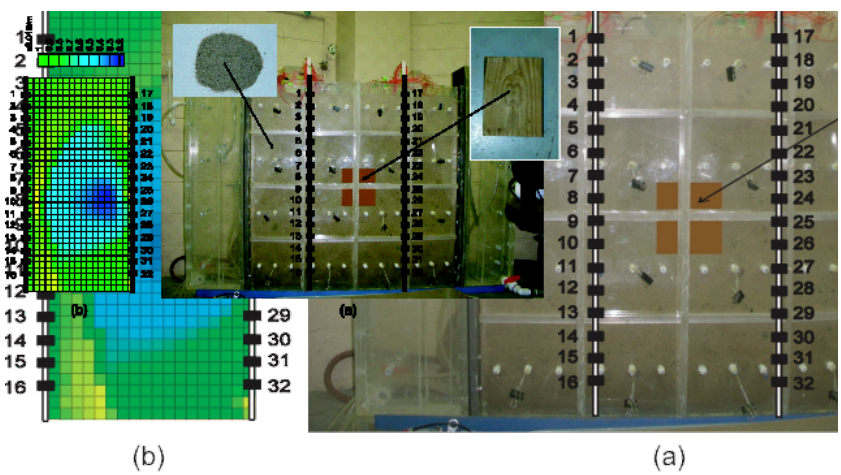

Figure 7: (a) sand tank, and (b) ERT image.

Summary

[1] This project has demonstrated the ERT to be a potential geophysical technique to monitor subsurface environment. ERT is low cost and produces abundant data for the inverse problem.
[2] This project has extended MODFLOW applicability to solve the potential-resistivity model for ERT applications. Particularly, this study utilizes the hydraulic characteristic in the Horizontal Flow Barrier (HFB) Package to represent effective contact impedance of electrodes.
[3] The ERT inversion is conducted by a simulation-optimization approach that links MODFLOW with a BFGS optimization solver. The adjoint state method presents an efficient method to obtain gradient for each computation grid.
[4] The quality of ERT images depends on many factors, including the quality and quantity of measured voltages, the considered resolution of resistivity, the current patterns, the electrode locations. The most challenge task is the interpretation of electrical resistivity to hydraulic property. These issues require further extensive study.

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Uncertainty-based TMDL Calculations for Dissolved Oxygen in Amite River

Basic Information

Title:	Uncertainty-based TMDL Calculations for Dissolved Oxygen in Amite River
Project Number:	2008LA58B
Start Date:	3/1/2008
End Date:	2/28/2009
Funding Source:	104B
Congressional District:	6
Research Category:	Water Quality
Focus Category:	Water Quality, Solute Transport, Models
Descriptors:	
Principal Investigators:	Zhi-Qiang Deng

Publication

1. Deng, Z. and Jung, H.-S. (2009). “Variable residence time based model for solute transport in streams.” Water Resources Research, 45, W03415.
2. Deng, Z. and Jung, H.-S. (2009). “Scaling dispersion model for pollutant transport in rivers.” Environmental Modelling & Software, 24(5), 627-631.
3. Mishra, P. K. and Deng, Z. (2009). “Sediment TMDL development for the Amite River.” Water Resources Management, 23(5), 839-852.
4. Deng, Z., de Lima, João L.M.P., and Jung, H.-S. (2008). “Sediment Transport Rate-based Model for Rainfall-induced Soil Erosion.” Catena, 76(1), 54-62.

Uncertainty-Based TMDL Calculations for Dissolved Oxygen in Amite River

SYNPOSIS

Title:	Uncertainty-based TMDL Calculations for Dissolved Oxygen in Amite River
Project Number:	2008LA58B
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Funding Source:	104B
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Research Category:	Water Quality
Focus Category:	Water Quality, Solute Transport, Models
Descriptors:	Dissolved Oxygen, Streams, Uncertainty, TMDL
Principal Investigators:	Zhi-Qiang Deng

RESEARCH

Problem and Research Objectives

The U.S. Environmental Protection Agency and the states are faced with developing tens of thousands of TMDLs with a margin of safety (MOS). In almost all cases, MOS is defined arbitrarily, without consideration for the actual uncertainty in the likelihood of achieving water quality objectives. This can lead to two outcomes: (1) if MOS is too small, the TMDL has a high probability of not meeting its designated use; (2) if MOS is too large, the cost of implementing the TMDL will be much higher than necessary. Thus, a scientifically sound approach to determining MOS is required for all impaired water bodies, including the Amite River that is impaired by low dissolved oxygen (DO).

The primary goal of this project is to develop and demonstrate an effective approach to identifying uncertainty sources and to quantifying the TMDL uncertainty arising from these sources through TMDL development for dissolved oxygen in the Amite River. To achieve the goal four objectives are proposed: (1) uncertainty analysis of model input data with emphasis on temporal and spatial scale-induced uncertainties, (2) uncertainty propagation through model parameters and structure, (3) uncertainty analysis of model output-based load duration curves, (4) total uncertainty-based margin of safety, and (5) TMDL calculations for dissolved oxygen in the Amite River.

Methodology

The HSPF (Hydrologic Simulation Program Fortran) simulations were performed to obtain the time-series data of water quality parameter in the Amite River at Port Vincent, LA, as shown in Figure 1. In HSPF, key input parameters are weather and landuse data. The hourly weather time-series data for the period of 1970-1995 were collected from USEPA, that included rainfall, air temperature, wind, evapo-transpiration, humidity, dew-point temperature, solar

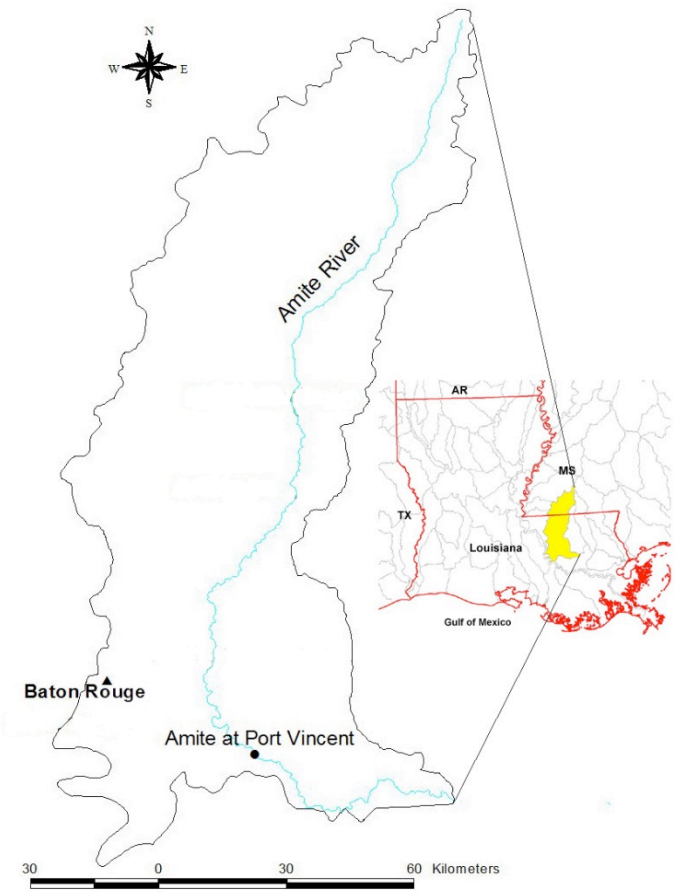


Figure 1. Map of the Amite River Basin.

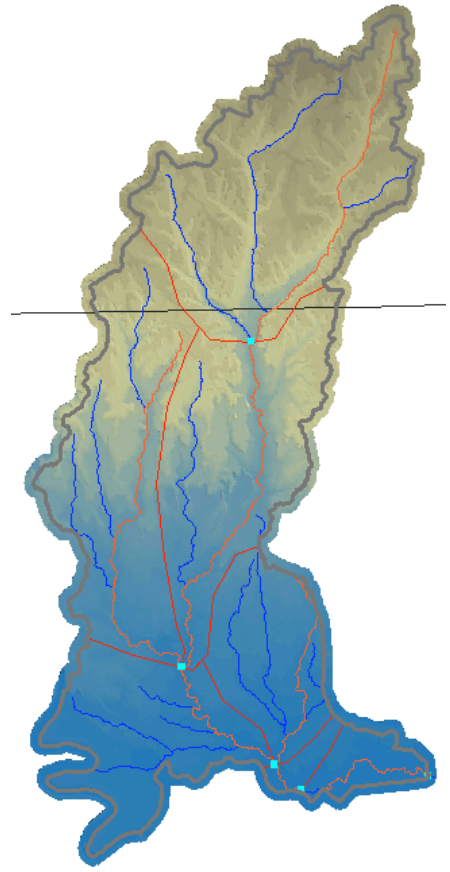


Figure 2. Sub-watersheds used in HSPF model.

radiation, and cloud cover. The landuse data was developed using Landsat TM imagery data (30 m resolution) for year 1992 acquired from Global Land Cover Facility (GLCF) at University of Maryland. The landuse data was classified into 25 classes by using un-supervised classification. These classes were then categorically classified using visual interpretation to re-classify it into six major classes as per HSPF requirement. This input data and methodology was used as base scenario for further simulations. The model was calibrated and validated using observed data at Port Vincent obtained from LDEQ (Louisiana Department of Environmental Quality). While calculating the sampling induced uncertainty the other parameters including the spatial and temporal data were kept similar and vice-versa. The input data uncertainty was estimated by first calculating the sampling induced uncertainty, then temporal scale and resolution induced uncertainties. The subroutine OXRX of HSPF model was used for the analysis of uncertainty propagation through model parameters and structure. Load duration curves for dissolved oxygen were produced using HSPF simulated data with different temporal scales to determine the uncertainty involved in the load duration curves. The probability distribution functions derived for input data uncertainty, model structure uncertainty, and model output uncertainty were

utilized in a Bayesian analysis to determine the total uncertainty and the margin of safety for DO TMDL. Application of HSPF involves the segmentation of the Amite River watershed, preparation of input data, and model calibration. The sub-watersheds were generated using the delineation tool in BASINS. Sub-watershed delineation and creation of river-reach segments utilized the NED (national elevation dataset) digital elevation model (DEM) and national land cover data (NLCD) representing land use type in 1992 for computing watershed boundaries, overland flow-path length and slopes, stream segment slopes, and pervious and impervious surface areas and forested areas in each delineated sub-watershed, as shown in Figure 2.

PRINCIPAL FINDINGS AND SIGNIFICANCE

1. Temporal Scale Induced Uncertainty in Temperature and Rainfall Input Data

The temporal scale analysis was conducted using the coefficient of variation (CV = standard deviation/mean). Figures 3a and 3b show that the coefficients of variation (CV) in both temperature (3a) and rainfall (3b) decrease with increasing temporal scale varying from hourly scale to monthly scale.

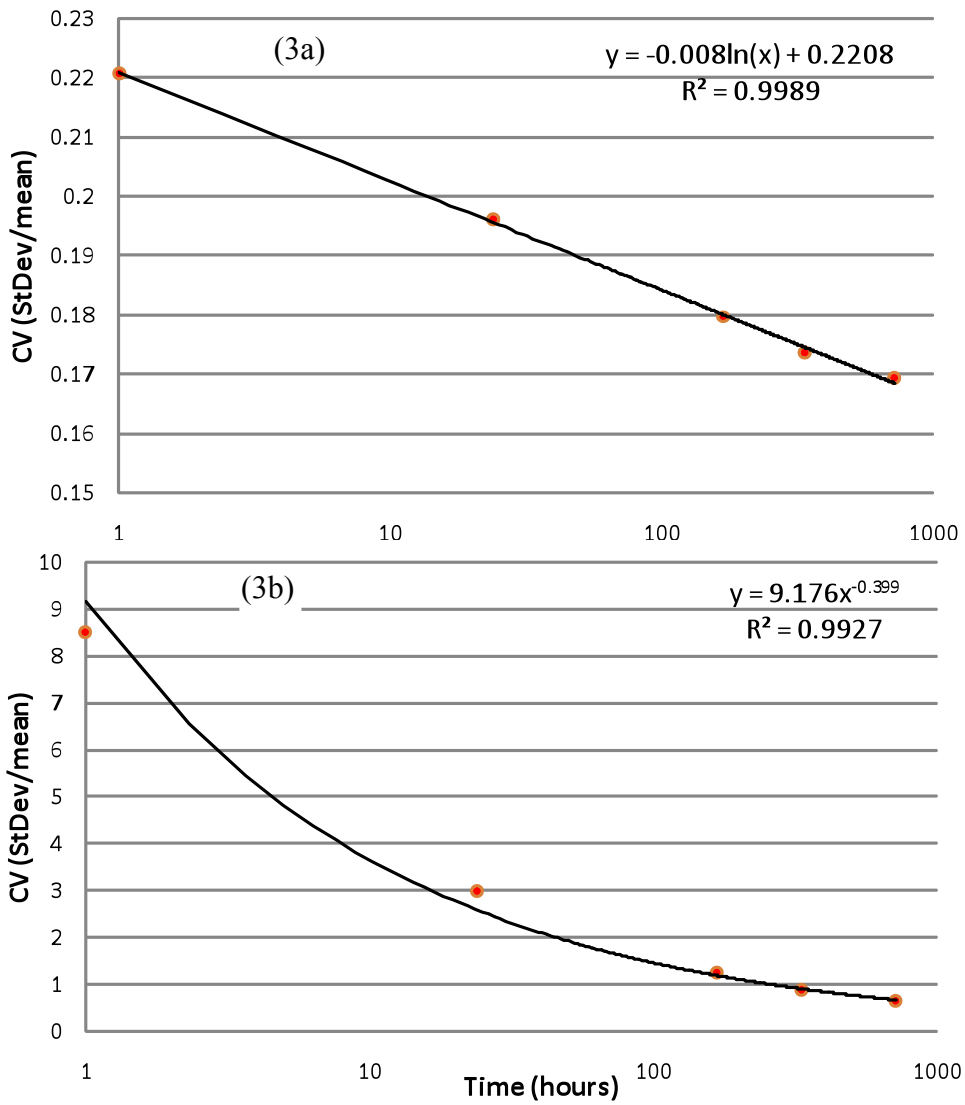


Figure 3. Temporal scale induced error in input data of (a) temperature and (b) rainfall.

The temporal uncertainty in the temperature data followed a non-symmetric, general extreme value distribution while the temporal scale-induced uncertainty in rainfall followed a power law distribution.

2. Spatial-resolution of Landuse Data Induced Uncertainty in Dissolved Oxygen

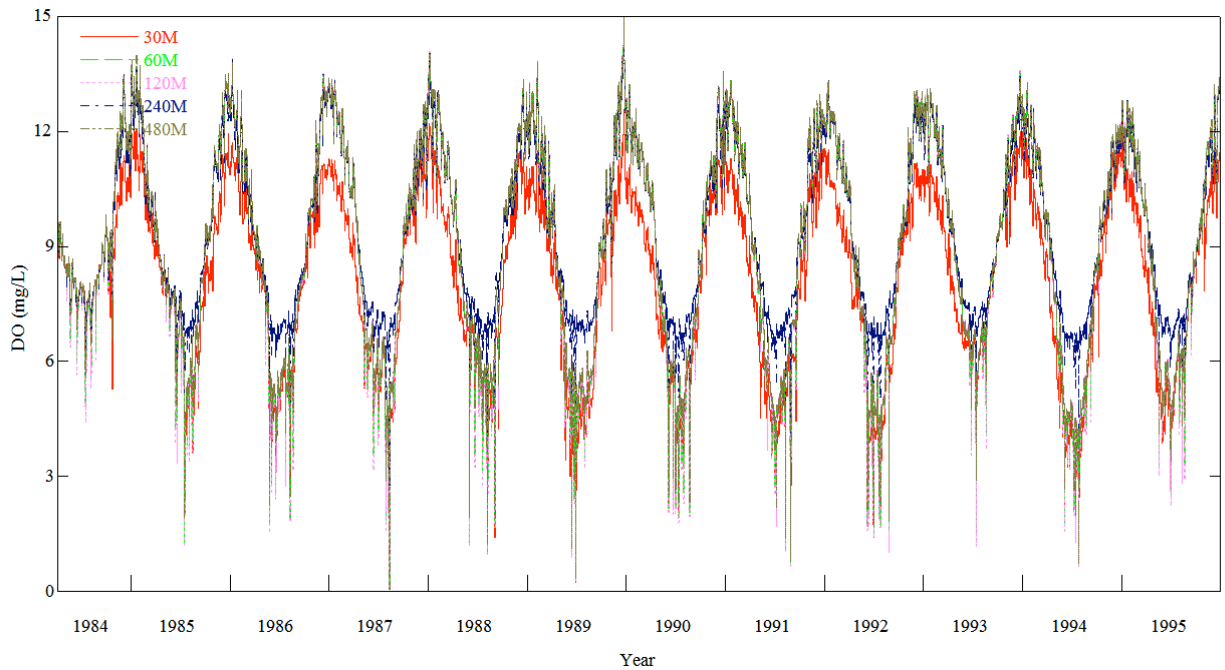


Figure 4. Effect of resolution induced error on dissolved oxygen.

The spatial-resolution-induced uncertainty in dissolved oxygen simulation was observed to follow a general extreme value distribution.

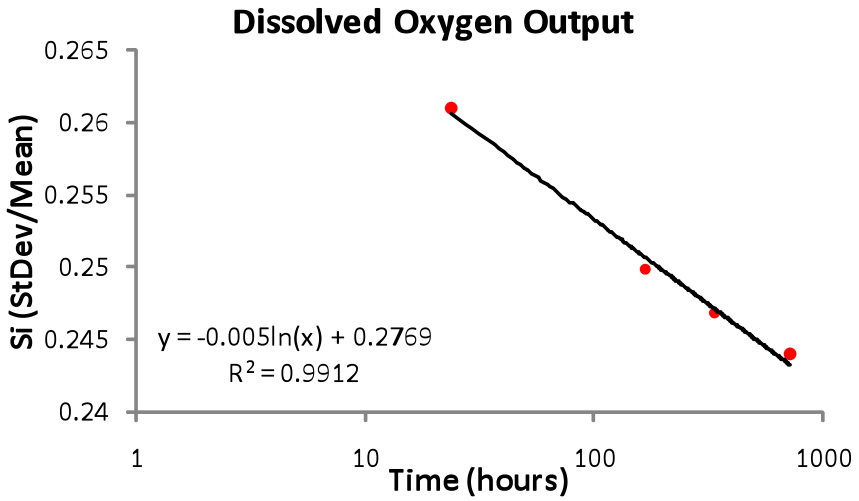
3. Uncertainty Propagation through Model Parameters and Structure

The uncertainty propagation in the model structure of dissolved oxygen follows a normal distribution:

$$f\left(M_{errorprop}\right) = \frac{\exp\left[-\frac{1}{2}\left(\frac{x-8.08}{0.427}\right)^2\right]}{0.427\sqrt{2\pi}} \quad (1)$$

This equation can be used in the estimation of the total uncertainty using Bayesian analysis.

4. Uncertainty-Involved in Model Output-Based Load Duration Curves



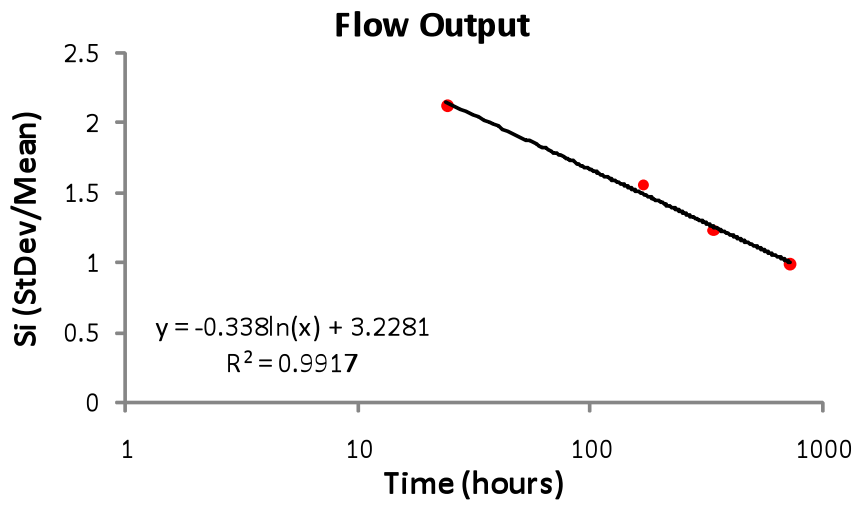


Figure 5. Temporal scale-induced uncertainty in output data computation for (A) dissolved oxygen and (B) flow data.

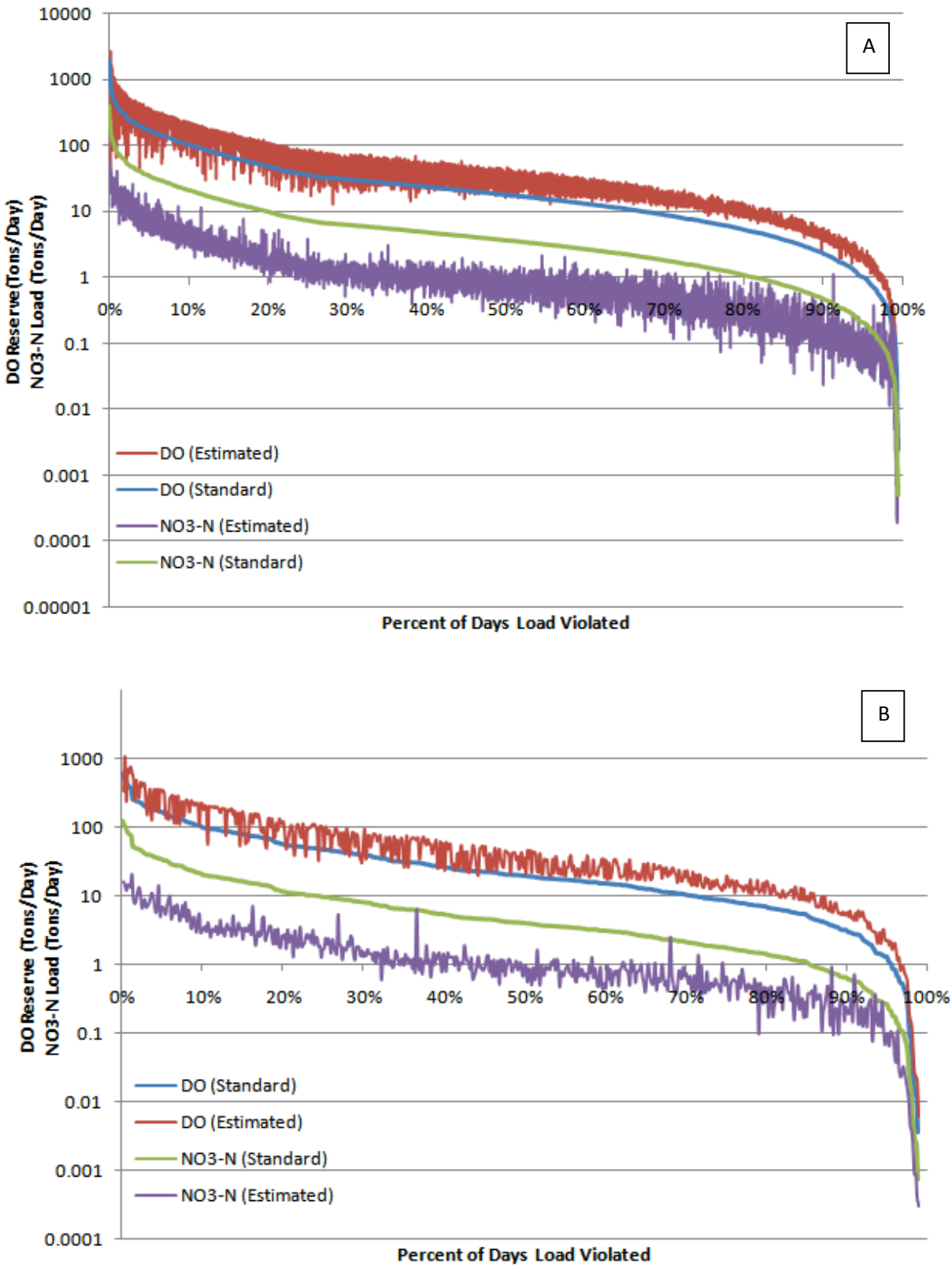


Figure 6. Duration curves developed using (A) daily data and (B) weekly data.

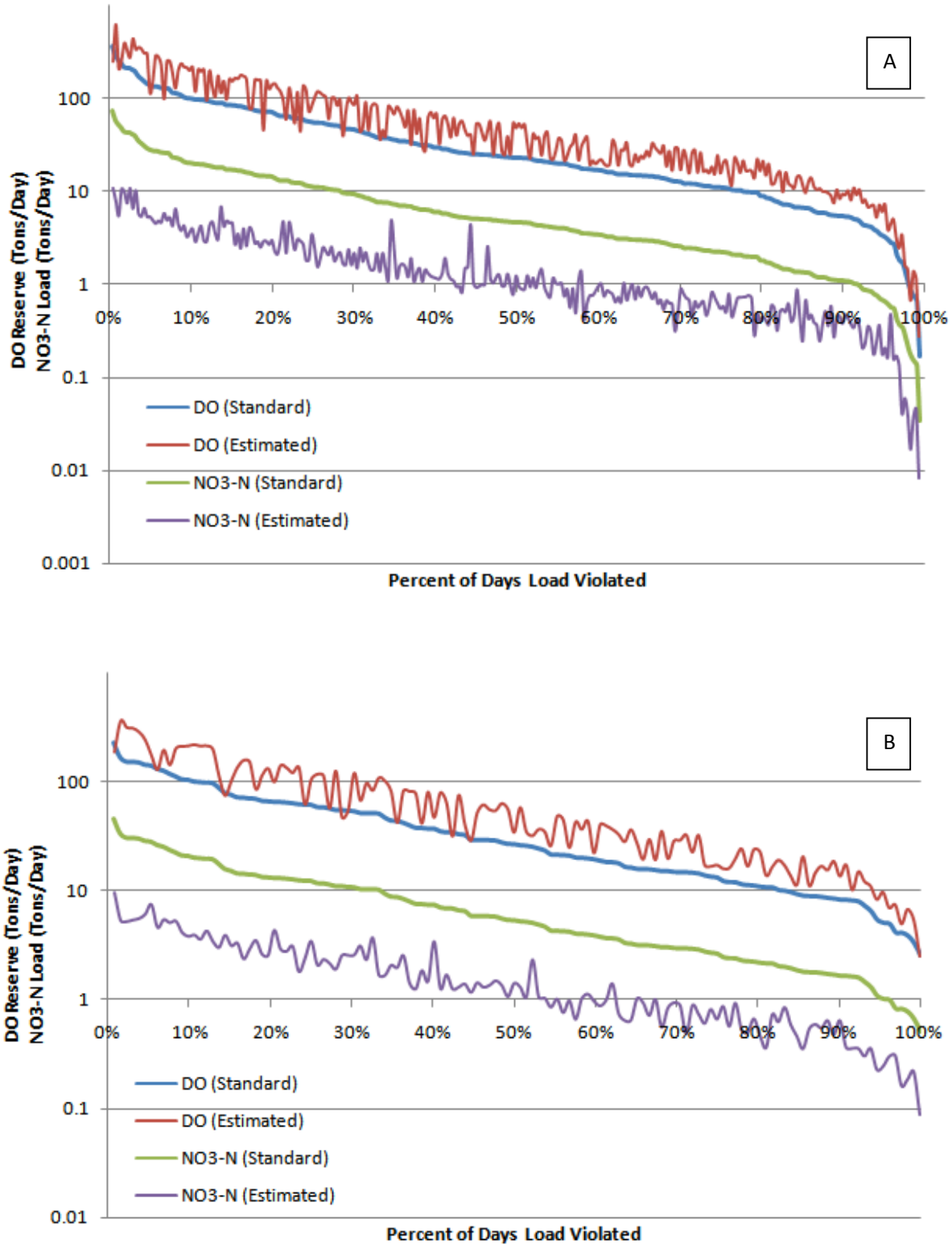


Figure 7. Duration curves developed using (A) bi-weekly data and (B) monthly data.

It is found from Figures 5 – 7 that:

1) Temporal scale of flow and water quality data controls the uncertainty in estimated loads of water quality parameters. While DO reserve (load) meets water quality standard under any flow conditions when monthly mean data is utilized, DO impairment occurs frequently during moderate-to-high flow conditions if daily mean data is employed, indicating the necessity of using near real time data in TMDL development.
2) The coefficient of variation (Si = CV = ratio of the standard deviation to the mean) is introduced to describe the temporal scale-induced uncertainty in load calculations and thus TMDL development. It is found that the parameter CV is linearly and inversely correlated with the logarithm of the time scale. Regression equations are developed to describe the correlations between the time scale and the parameter CV for DO and flow discharge. The regression equations can be employed to extrapolate near real time flow and water quality data, greatly simplifying flow and water quality monitoring and reducing the cost involved in the monitoring.
3) The standard deviation of dissolved oxygen follows a general extreme value distribution while the standard deviation of flow exhibits a normal distribution.
4) The correlation between the dissolved oxygen reserve and river flow can be better described using a power law relationship with a RMS of 0.679.

5. Estimation of Total Uncertainty Using Bayesian Analysis and DO TMDL

The probability distribution function for the natural variability in the dissolved oxygen is given by,

$$f(DO_{natural}) = \frac{\exp\left[-\frac{1}{2}\left(\frac{x-6.42}{1.88}\right)^2\right]}{1.88\sqrt{2\pi}} \tag{2}$$

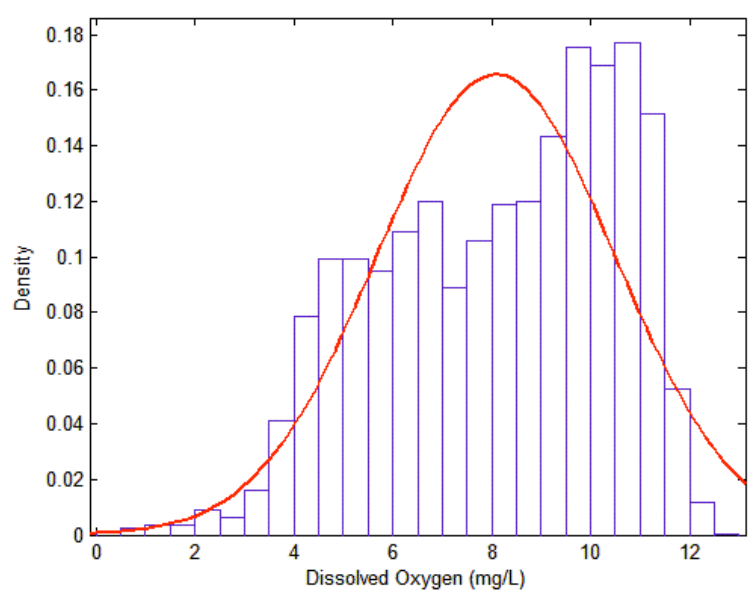


Figure 8. Daily average dissolved oxygen distribution in summer.

The likelihood function for dissolved oxygen is given as,

$$P(I|DO) = \frac{1}{\sqrt{2\pi 0.753}} exp\left[-\frac{1}{2}\sum_{i=1}^{n}\left(\frac{e_i}{0.753}\right)^2\right] \quad (3)$$

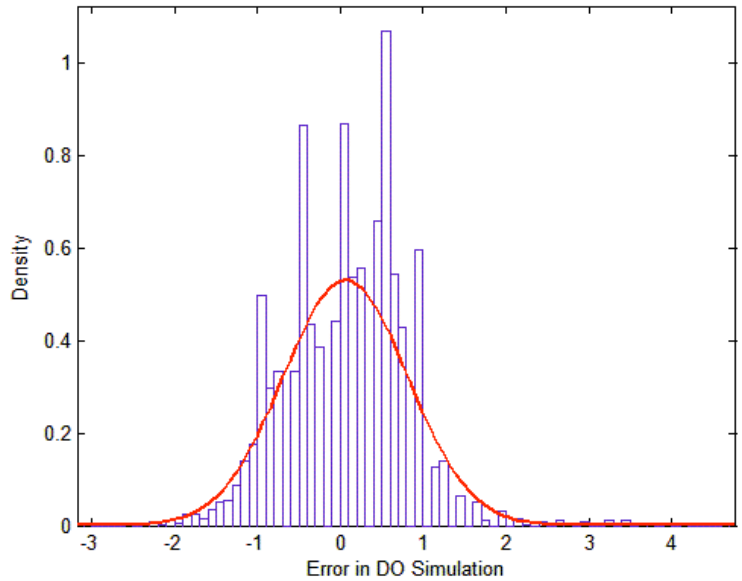


Figure 9. Error distribution for dissolved oxygen

The posterior (modified probability density function) for the dissolved oxygen can be represented by following equation:

$$P(DO|M,T,R,E,C) = \frac{\frac{1}{\sqrt{2\pi 0.753}} exp\left[-\frac{1}{2}\prod_{i=1}^{n}\left(\frac{e_i}{0.753}\right)^2\right] \cdot \frac{1}{1.88\sqrt{2\pi}} exp\left[-\frac{1}{2}\prod_{i=1}^{n}\left(\frac{x-6.42}{1.88}\right)^2\right]}{3.874} \quad (4)$$

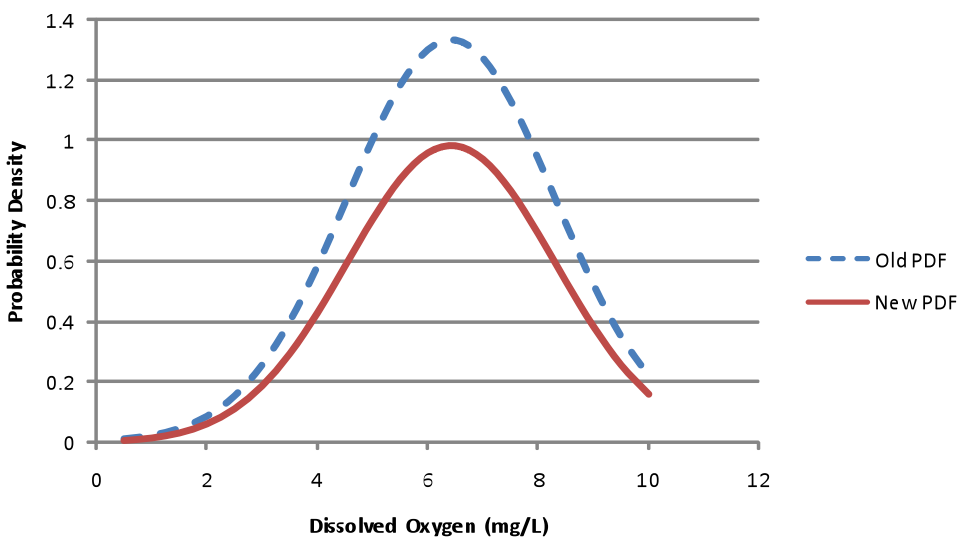


Figure 10. Prior and Posterior distributions of dissolved oxygen in the Amite River.

According to the newly developed method, the dissolved oxygen load in the Amite River is estimated to be 399.262 T/Day. Based on LDEQ standards, the dissolved oxygen load in the Amite River needs to be maintained above 440.210 T/Day. Therefore, a 40.948 T/Day of dissolved oxygen load needs to be restored to maintain a healthy aquatic system.

INFORMATION TRANSFER

The findings and methods for uncertainty-based TMDL development will be transferred to the Louisiana Department of Environmental Quality (LDEQ) for applications in TMDL developments and stream restoration.

Field Monitoring of Environmental Contaminants of Toxic Metals in Lake Pontchartrain and Ground Water

Basic Information

Title:	Field Monitoring of Environmental Contaminants of Toxic Metals in Lake Pontchartrain and Ground Water
Project Number:	2008LA59B
Start Date:	3/1/2008
End Date:	8/30/2009
Funding Source:	104B
Congressional District:	1
Research Category:	Ground-water Flow and Transport
Focus Category:	Toxic Substances, Surface Water, Methods
Descriptors:	
Principal Investigators:	Ju Chou

Publication

Field Monitoring of Environmental Contaminants of Toxic Metals in Lake Pontchartrain and Ground Water

Final Report

SYNPOSIS

Title:	Field Monitoring of Environmental Contaminants of Toxic Metals in Lake Pontchartrain and Ground Water
Project Number:	2008LA59B
Start Date:	3/1/2008
End Date:	2/28/2009
Funding Source:	104B
Congressional District:	1
Research Category:	Water Quality
Focus Category:	Methods, Toxic Substances, Surface Water
Descriptors:	Field analysis, toxic metals, surface water, groundwater, portable instrument
Principal Investigators:	Ju Chou, Southeastern Louisiana University

Problem and Research Objectives

Lead, a ubiquitous and versatile metal, is considered a significant environmental threat in the global region. Even at low levels of lead exposure, there are serious side effects including kidney damage, learning disabilities, and brain damage, especially in children. The threat of arsenic pollution in drinking water is a serious environmental and health concern because of the toxicity of arsenic on human and on other living organisms. Arsenic contamination is a serious problem in many parts of the world. Even at low level arsenic exposure various skin lesions appear in human. In 2006, the US EPA lowered the maximum containment level (MCL) for arsenic in drinking water to 10 μg/L from the previous standard of 50 μg/L. The US EPA set a new MCL has created an urgent need to identify public health threats caused by environmental contaminant of arsenic.

Since Hurricane Katrina, environmental contaminants in New Orleans have attracted

national attention as environmental contaminants such as lead, arsenic elevated in floodwater and sediments. The concentrations of lead and arsenic detected in many samples in eastern New Orleans exceeded EPA drinking water standards. Toxic metal exposure, especially lead and arsenic, in New Orleans increased after Hurricane Katrina. Environmental threats from lead and arsenic are a serious problem in the New Orleans area.

Lake Pontchartrain is a large and shallow estuary and has a surface area of 1632 km^2, an average depth of 4 m. For many years, Lake Pontchartrain has been a sink for environmental contamination primarily because it receives all the drainage from New Orleans' industry and populations. The contaminations in New Orleans will eventually contaminate Lake Pontchartrain and its natural habitat. Thus it is important to regularly monitor lead and arsenic concentrations in Lake Pontchartrain.

It is very important to identify contaminated areas where water levels exceed EPA standard for both lead and arsenic in New Orleans and Lake Pontchartrain.

Our overall objectives are to conduct an environmental assessment and to identify public heath threats caused by exposure to environmental contaminants such as lead and arsenic. This research focused on detection of environmental contaminant metals mainly lead and arsenic in water in Lake Pontchartrain and New Orleans.

Methodology

When we started this project, we had a problem with another funding agency that was supposed to fund to purchase a portable element detector. Since a portable equipment was not able to be purchased as planed and our original plan on monitoring toxic metals was modified. All element analysis was performed in the research lab and all results reported here were based on lab analysis, not by a portable element detector.

Concentrations of toxic metals such as Pb, As, Cd, Cr and other nonmetals such as Ca, Mg, Cu, P were analyzed by inductively coupled plasma- atomic emission spectroscopy (ICS-AEM, available at LSU). This equipment has a high sensitivity on toxic metals. One of advantage of using ICP-AES is that it can detect many elements spontaneously.

Principal Findings and Significance

Pb and Ar in water samples in New Orleans

A total of 30 locations were selected in the greater New Orleans area for water analysis. Since groundwater is not a supply for drinking water in New Orleans, we did not collect groundwater. Instead we collected water samples from ponds, rivers, lakes in New Orleans. One of our focus areas was on the eastern side of New Orleans as these areas are known to contain dangerous lead level and were heavily damaged during Hurricane Katrina.

Samples were collected from rivers, lakes, and along industrial canal from the Chalmette area all the way to the lake front. A Geographic Position System (GPS) was used to record latitudes and longitudes of the sampling locations so that these sample sites can be displayed in a regional map. Water samples from the greater New Orleans

Area were collected and filtered immediately by a 0.45 µm syringe filter after these water samples were brought into the research lab. This purpose of the filtration was to get rid of all sediments to eliminate any experimental error cause by sediments. The filtered water samples were added three drop of 1M HNO_3 and stored in a refrigerator until analysis.

The filtered water samples were then analyzed by an inductively coupled plasma–atomic emission spectroscopy (ICP-AES) which is commonly used for quantitative analysis of toxic metals. About 30 water samples were collected in the greater New Orleans area and their locations were shown in Figure 1a and 1b. Each dot in the map was determined by latitudes and longitudes recoded by the GPS. Concentrations of Pb and As were analyzed by ICP-AES at LSU lab. Concentration of As was displayed in the local map shown in Figure 1. Color of different dots represents concentration range of As. The green dots in the map in Figure 1 represent As concentration below the detection limit (20 ppb) and the red dots denote As concentration above 20 ppb. This concentration also exceeds the USEPA standard for drinking water (10 ppb) for As. About 9 out of 30

water

Figure 1a. The map of arsenic distribution in the greater New Orleans area
Key: Red dot: > 20 µg/L (ppb); Green dot < 20 µg/L (ppb)

East N.O. map

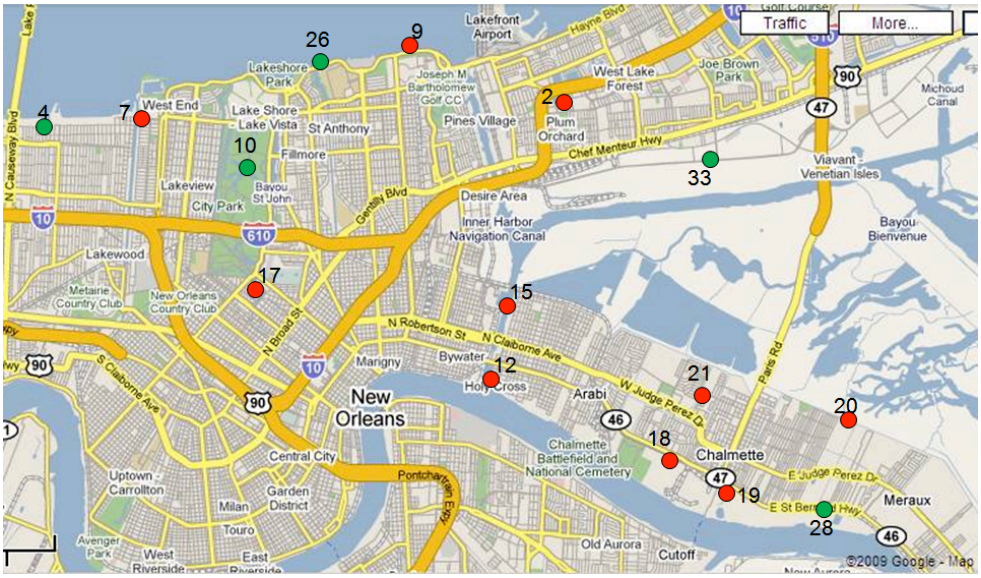


Figure 1b. The map of arsenic distribution in the greater New Orleans area
Key: Red dot: > 20 µg/L (ppb); Green dot < 20 µg/L (ppb)

samples in the greater New Orleans area were below the detection limit (20 µg/L = 20 ppb). However, since the detection limit of the ICP-AES employed is higher than the EPA standard (10 ppm), for above nine locations, we could not tell if they exceed the EPA standard or not. Among 21 out of 30 water samples, the arsenic concentration is higher than 20 ppb which is above the USEPA standard for drinking water. As shown in Figure 1b, in eastern New Orleans, water samples (location 12, 15, 18, 19,20, 21) exceeded USEPA standard for drinking water. It is important to note that water may flow into Lake Pontchartrain and this may contaminate the lake. Among 30 water sample locations, 21 water locations in the map exceeded US EPA standard (10 ppb). These data indicate that there is a widespread occurrence of arsenic in New Orleans. However none of arsenic concentrations were higher than 50 ppb, the EPA previous allowable maximum containment level.

For lead, among 30 water samples collected from above locations, there is no detectable lead in water samples and none of water samples exceeds the USEPA standard for drinking water (US EPA Pb standard: 15 µg/L).

Lake Pontchartrain

Since Lake Pontchartrain is a shallow lake, we are able to collect deep water in the lake. For Lake Pontchartrain, for each location, both surface water and deep water were collected repeatedly. Surface water was sampled directly by a pre-cleaned glass bottle. The deep water was collected by a Van Dorn horizontal sampler which can be used to collect deep water in the lake.

Industrial discharge is likely to contribute to increase lead contaminations and six locations along the spillway area were choosen since where they are close to Shell and

Exxon. The six locations present the impact of industrial discharge. There was a main reason to focus this area because of the opening of *Bonnet Carré* Spillway between April to May in 2008. The spillway was opened for the first time since 1997. Its purpose was to alleviate the flooding of the New Orleans area by the Mississippi River by opening up to 350 bays. The opening the spillway allows the river waters to flow directly into Lake Pontchartrain. The opening of the spillway is expected to lead to changes in nutrition and salinity in Lake Pontchartrain because of a rush of fresh water into the normally brackish lake. Because the Mississippi River is often polluted with agricultural runoff and factory discharge, historically, the opening of the spillway has led to eutrophication in Lake Ponchartrain and massive death of fish during the hot summer. Thus, this event enhanced the interest of environmental analysis in Lake Pontchartrain and provided us an opportunity to study the impact of the opening of the spillway on water quality in the lake.

In contrast, several locations in the central area away from industrial areas and spillway area were selected for comparison. Seven locations from the mid-lake were sampled as those areas were also highly affected by the opening of the spillway, but would likely to have different patter from the *Bonnet Carré* spillway area. All locations from Lake Pontchartrain were shown in Figure 2.

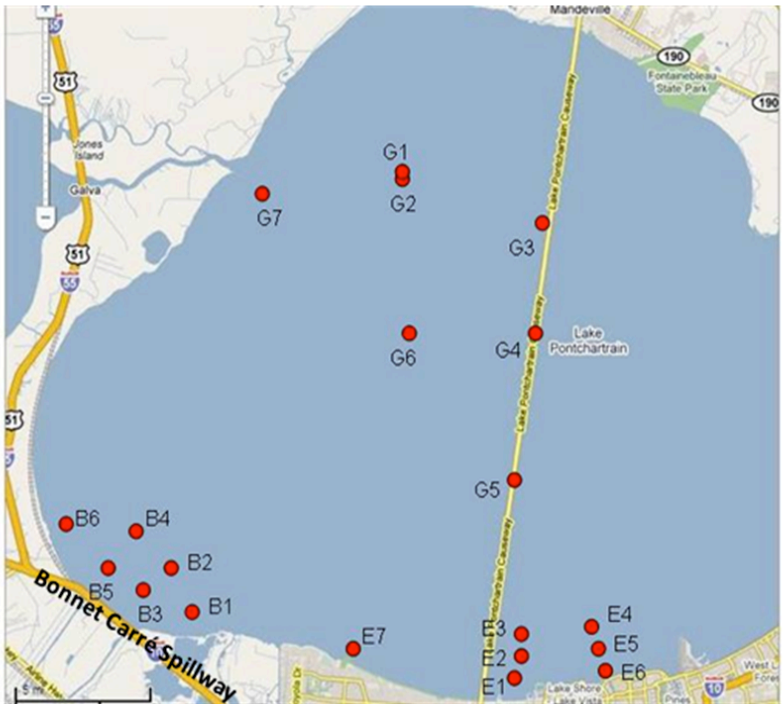
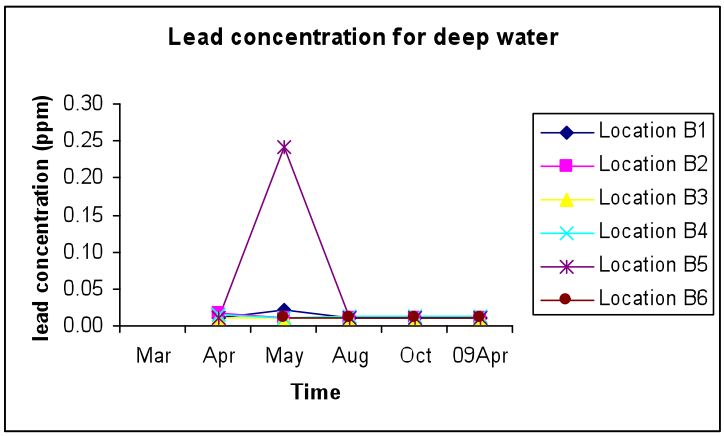


Figure 2. The sample sites in Lake Pontchartrain

Pb and As analysis

The concentrations of lead versus time were plotted for *Bonnet Carré* spillway area as shown in Figure 3A (A: surface water) and 3B (deep water). In all collect samples, only

samples collected in May 2008 exceeded the EPA standard for drinking water. This high concentration of lead was observed in both deep water and surface water. The increase of lead concentration may associate with the opening of the spillway which it started from April 11, 2008. The lead concentration was dropped to lower detection limit again in August, indicating that high Pb concentration is only a transition. Since data were collected from April 2008 to April 2009, Figure 3 also illustrate seasonal changes has no effect on environmental pollutants based on our one-year data.



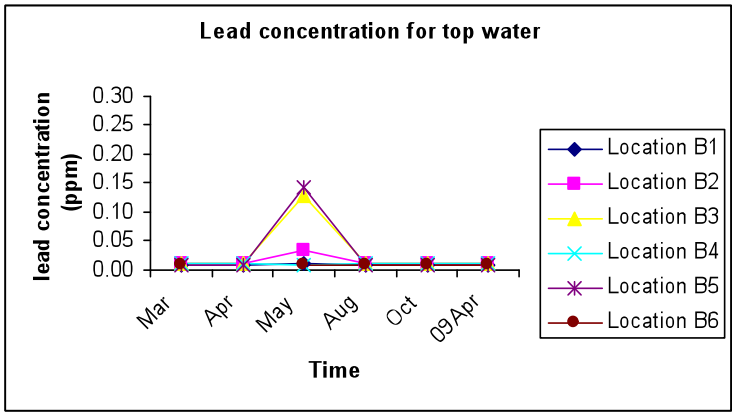


Figure 3. Lead concentration versus month in the *Bonnet Carré* spillway area. Top. Surface water; Bottom. Deep water

The lead concentration in all 7 locations in the central lake area collected at different time was lower than detection limit.

For arsenic, the concentrations of arsenic in all locations including both *Bonnet Carré* spillway and the central lake area at different time were below the detection limit of the instrument. So far, there is no correlation between seasonal changes or weather pattern associated with environmental pollutant from Pb and As based on one-year data analysis.

Conductivity and other element analysis

As mentioned above, the *Bonnet Carré Spillway* was opened in April in 2008 to prevent the Mississippi River from spilling water into surrounding areas. The opening of

the spillway is expected to lead to changes in nutrition and salinity in Lake Pontchartrain because of a rush of fresh water from the Mississippi River into the normally brackish lake. We also monitored conductivities and other nutrients such as Na, Ca, Mg, P etc.

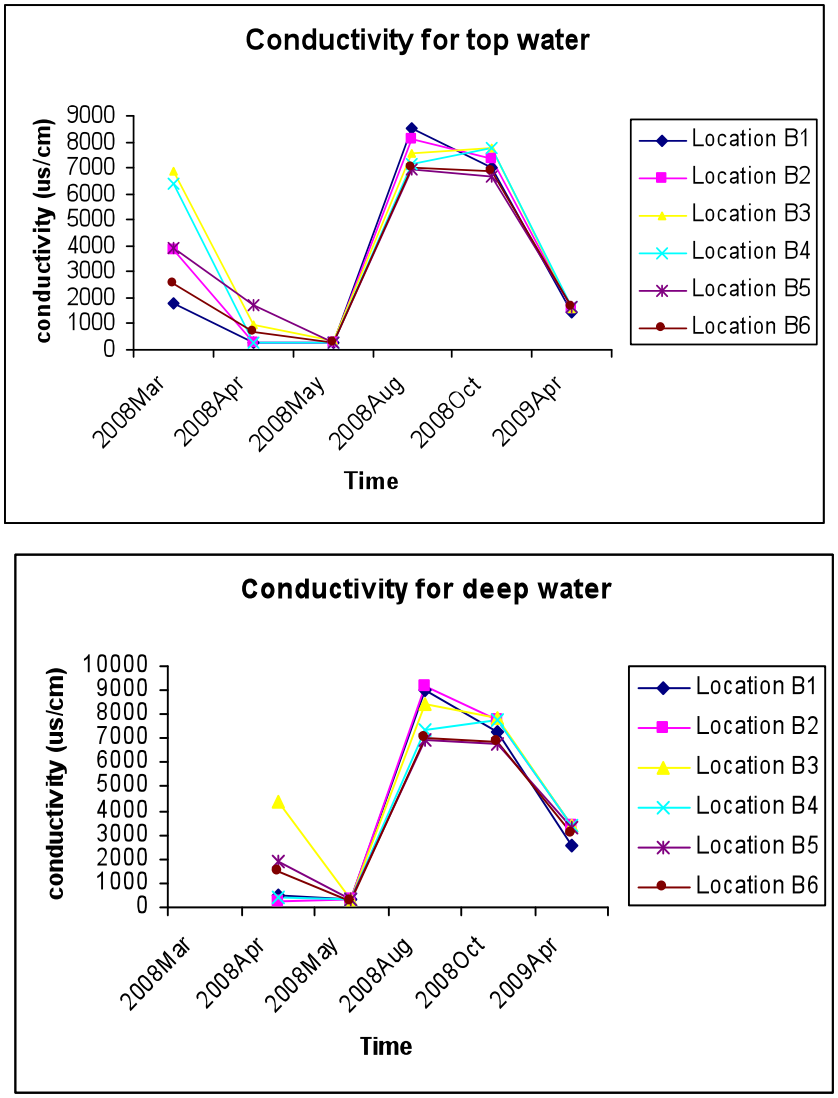
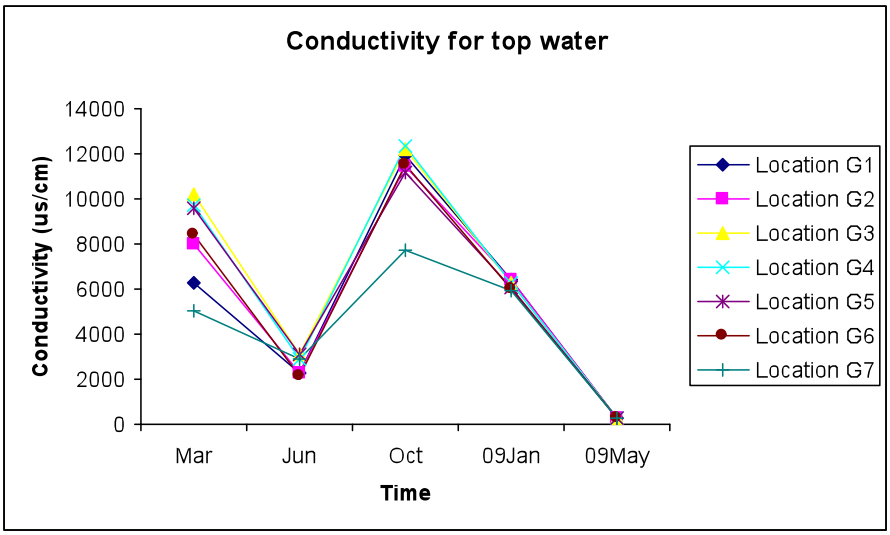


Figure 4. Conductivity versus time in the *Bonnet Carré* spillway area.

Top: Surface water; Bottom: Deep water

The conductivity versus time was plotted for the *Bonnet Carré* spillway area and was shown in Figure 4 (top: surface water; bottom: deep water). Conductivity in the *Bonnet Carré* spillway area changed dramatically from March 2008 to April 2009. The conductivity of surface water decreased from March to May, and then increased from May to August and dropped again from October 2008 to April 2009. The first drop in conductivity might be associated with the opening of the spillway as we expected. Fresh water from the Mississippi River flew into the normally brackish lake. Thus the opening of the spillway is expected to decrease the conductivity in the brackish lake. The second

drop of conductivity might be associated with the weather changes since heavy rains were observed right before sample collected in January and May in 2009. In order to see weather change pattern, more data will be collected.



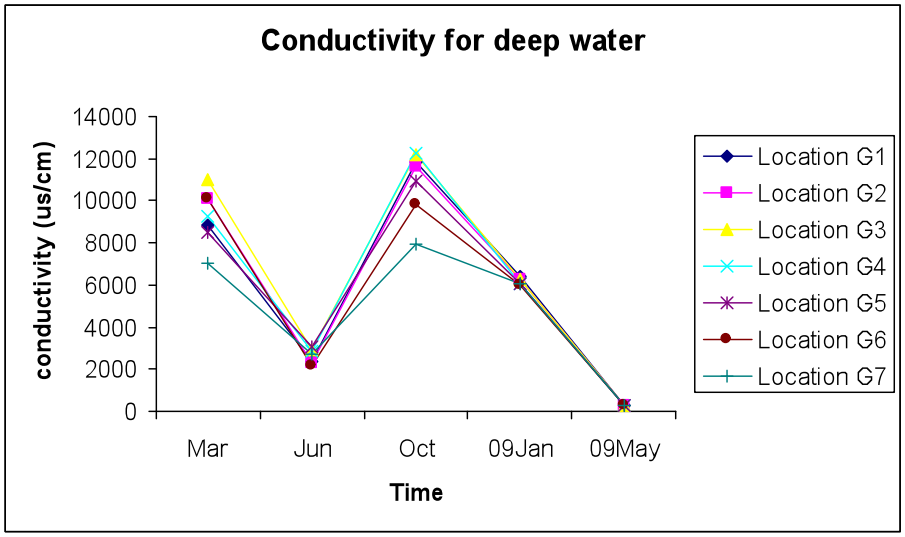


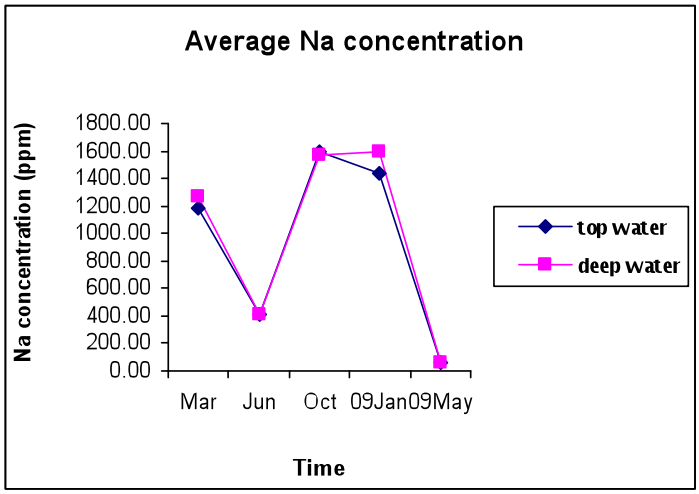
Figure 5. Conductivity versus month in the mid-lake area.
Top: Surface water; Bottom: Deep water

Conductivity changes in deep water in the *Bonnet Carré* spillway were similar to the trend of surface water in the same area.

Conductivity versus time in the central lake area was plotted and shown in Figure 5 (top: surface water; bottom: deep water). Similar to the *Bonnet Carré* spillway area, conductivity in the mid-lake area altered significantly from March 2008 to April 2009. In the mid-lake area, for both surface water and deep water, the conductivity changes followed the same pattern. The conductivity decreased from March to June, and then increased back to normal value in October and then dropped again from October 2008 to May 2009. The first drop in conductivity is again associated with the opening of the

spillway as expected. The second drop of conductivity might be caused by the weather changes since heavy rains were observed right before sample collected in January and May in 2009. Like mentioned early, in order to see weather change pattern, more data should be collected and longer period should be studied.

Some other elements and nutrients such as Na, Mg, Ca and P were also determined by ICP-AES simultaneously. Only Na concentration was reported here since salinity in Lake may vary followed the opening of the spillway. The average of Na concentration was calculated for each area and then plotted against time. Figure 6 show average of Na concentration versus time in the *Bonnet Carré* spillway and the mid-lake area. For both areas, the average of Na concentrations has the same trend as shown in Figure 6. Compare to the conductivity trend in both areas, the average of Na concentration followed the trend as conductivity in the two areas as we expected.



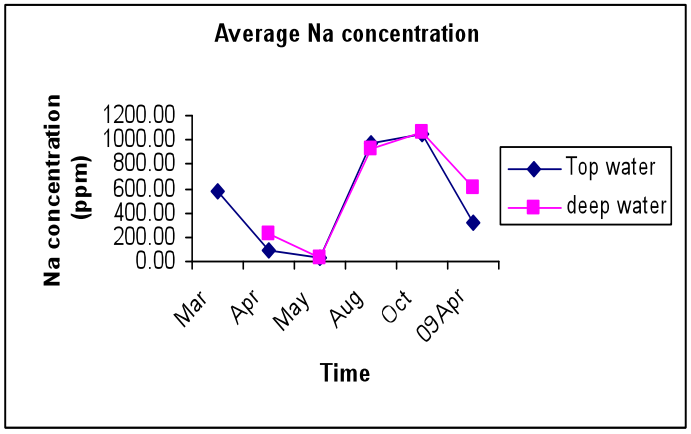


Figure 6. Average of Na concentration versus month in the mid-lake area (top) and *Bonnet Carré* spillway (bottom).

Some Photos on Samples Collecting in Lake Pontchartrain and New Orleans

Sample Collecting in Lake Pontchartrain

Water sample collecting in New Orleans

Information Transfer Program Introduction

The Louisiana Water Resources Research Institute made a concerted effort in recent funding cycles to improve and expand outreach efforts to increase visibility in the Louisiana water/environmental community. In Louisiana, limited opportunities exist for exchange between university water scientists, state and federal agencies over water issues. A state "water" conference or summit has not been organized and only the state environmental agency, the Louisiana Department of Environmental Quality, sponsors a scientific/policy conference on environmental issues, some of which involve water. After discussions with the advisory board, the Institute thought this could best be accomplished by sponsoring shorter symposia/workshops to focus on a specific science/engineering issue important to the state.

The following workshops have been supported by this effort:

2007: The 2007 Mitigating Storm Surge with Vegetation symposium addressed Louisiana's coastal restoration and the effect of wetlands on hurricane storm surge. Wetland vegetation can help protect coastal communities by dampening waves and by the frictional resistance of the plants, themselves, reducing the energy and depth of the water. Hydraulic engineers have studied the flow through vegetation for many years, in the context of overbank flooding, but connecting these approaches with coastal restoration scientists is needed. Key scientific questions include: What are the appropriate quantitative procedures for frictional resistance and wave dampening of different wetland types? What types of wetlands provide ability to mitigate surge? The conference attracted over 100 water professionals to hear keynote and other invited presentations and to discuss the current state of the art. Dr. Heidi Nepf from MIT and Dr. Robert Kadlec formerly at University of Michigan were invited to present their perspective on this important problem for the state.

2008: Transatlantic Water Symposium: Water, Friend or Foe This conference in early Spring 2008 was held between US scientists and those from the Ruhr area of Germany under the umbrella of an organization that pools University resources in the region, ConRuhr. A scientist group from this region traveled to LSU and a formal symposium was held in addition to wide ranging talks on water issues between the 2 countries. The Rhien-Ruhr region shares features with areas of our state in that water resources are developed and managed against a backdrop of a heavy industrialized corridor with competing needs for the water. Both areas also have extensive flooding issues and accompanying flood control issues. The symposium was attended by ~50 scientists from both regions and a number of follow-up discussions have been held on ideas exchanged at the symposium.

Currently there are 2 active information transfer projects with LWRRI, both to support these conference efforts in the state:

2007LA52B: Information Transfer Symposia: Mitigation of Storm Surge using Vegetation (Spring, 2007) and Resilient Environmental Infrastructure for Coastal Communities (Fall, 2007)

2008LA56B 2008 Louisiana Water Symposia

Information Transfer Symposia: Mitigation of Storm Surge using Vegetation (Spring, 2007) and Resilient Environmental Infrastructure for Coastal Communities (Fall, 2007)

Basic Information

Title:	Information Transfer Symposia: Mitigation of Storm Surge using Vegetation (Spring, 2007) and Resilient Environmental Infrastructure for Coastal Communities (Fall, 2007)
Project Number:	2007LA52B
Start Date:	3/1/2007
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	06
Research Category:	Not Applicable
Focus Category:	Education, Management and Planning, Methods
Descriptors:	
Principal Investigators:	John Pardue, Nedra Davis Korevec

Publication

SYNOPSIS

Title: Information Transfer Symposia: Mitigation of Storm Surge using Vegetation (Spring, 2007) and Resilient Environmental Infrastructure for Coastal Communities (Fall, 2007)
Project Number: 2007LA52B
Start Date: 3/1/2007
End Date: 2/28/2010
Funding Source: 104B
Congressional District: 6
Research Category: NA
Focus Category: Education, Management and Planning; Methods
Primary PI: John Pardue

Problem and Research Objectives

The Louisiana Water Resources Research Institute made a concerted effort in recent funding cycles to improve and expand outreach efforts to increase visibility in the Louisiana water/environmental community. In Louisiana, limited opportunities exist for exchange between university water scientists, state and federal agencies over water issues. A state "water" conference or summit has not been organized and only the state environmental agency, the Louisiana Department of Environmental Quality, sponsors a scientific/policy conference on environmental issues, some of which involve water. After discussions with the advisory board, the Institute thought this could best be accomplished by sponsoring shorter symposia/workshops to focus on a specific science/engineering issue important to the state.

Two symposia have already been supported by this project: *Mitigating Storm Surge with Vegetation* (2007) and *Water: Friend or Foe*, a transatlantic symposium held jointly with ConRuhr (2008). Originally, a workshop on *Resilient Environmental Infrastructure for Coastal Communities* was proposed for Fall 2007. This was particularly relevant after Hurricane Katrina and Rita where many utilities were damaged after the storm. After several attempts to determine interest among utilities in our coastal communities, it was apparent that other organizations such as the American Water Works Association were meeting the immediate needs of information exchange for these groups. In conjunction with our advisory board, we decided, and received approval from USGS, to utilize the remaining funds to partner with other agencies to assist other educational efforts.

In this reporting cycle LSU cosponsored with the American Society of Civil Engineers (ASCE) the 2008 Louisiana Coastal Engineering Symposium. Over the past century, river management, coastal erosion, and subsidence have had a profound impact on river deltas worldwide, and the Mississippi River delta and the Louisiana coast are no exceptions. The 2005 hurricane season exacerbated these problems in Louisiana and put new focus on the consequences of increased risks to both the natural and built environments in the coastal zone. Sustaining the coastal deltaic landscape represents a major scientific and engineering challenge and is a problem that is fundamentally interdisciplinary. It is clear that discovering real, lasting solutions to these problems will require researchers to interweave a number of core disciplines including coastal and ecological engineering, restoration ecology, coastal, wetland and estuarine science, advanced

mathematical modeling and computational science. There is a great need in the state to begin developing capacity in the areas of coastal and ecological engineering in the existing water resources engineering community in the state. This symposium was directed at that goal.

Principal Findings and Significance

The objective the 2008 Louisiana Coastal Engineering conference was to continue to build capacity of the current Louisiana engineering and water resource community in the state. The conference was held in Baton Rouge at the Capitol City Hilton May 29 and 30th, 2008. The conference attracted over 100 engineering and water resources professionals for two days of invited and submitted talks. The two keynote speakers, Dr. David Basco from Old Dominion and Dr. David Randall from Texas A&M were joined by the head of Louisiana's Governor's Office of Coastal Affairs, Garrett Graves. The conference was another effort by LWRRI to contribute to the efforts related to understanding storm surge, the water implications for coastal restoration and protection and how to mitigate impacts from storm events. The full presentations are available on the LWRRI website (www.lwrri.lsu.edu).

2008 Louisiana Coastal Engineering Conference
Hilton Baton Rouge Capitol Center-Baton Rouge, Louisiana - Technical Transfer

Keynote Speakers:
Dr. David R. Basco, P.E., Ph.D
Old Dominion University, Department of Civil and Environmental Engineering
Dr. Robert E. Randall, Ph.D
Texas A&M University, Center for Dredging Studies

Agenda:**2008 Louisiana Coastal Engineering Conference**

Location: Hilton Baton Rouge Capitol Center Hotel, May 29-30, 2008, 7:00 AM-5:30 PM

Technical Transfer from Conference:

Keynote Speaker,Dr. David R. Basco, P.E., Ph.D
Old Dominion University, Department of Civil and Environmental Engineering
Coastal Processes

- Keynote Speaker,Dr. Robert E. Randall, Ph.D
  Texas A&M University, Center for Dredging Studies
  Dredging Equipment and Costs

- Dr. Q. Jim Chen, Ph.D
  Louisiana State University, Department of Civil and Environmental Engineering
  Fundamentals of Wave Theory and Tides

- Keynote Speaker: Garret Graves
  Director of the Governor's Office of Coastal Affairs

- Geotechnical Engineering Applications in Coastal Design
  Charles L. Eustis, P.E. - Capozzoli/GeoEngineers

- Dr. Guoping Zhang, Ph.D - Louisiana State University,
  Dept. of Civil and Environmental Engineering- Settlement Analysis for Marsh Creation

- Computer Modeling Capabilities in Coastal Design
  Santiago Alfageme, P.E. and Rafael Canizares, P.E., Ph.D
  Moffat & Nichol

- Erosion Control and Sediment Budget Analysis: Grand Isle Barrier Shoreline Stabilization Study
  Josh Carter, P.E.
  Coast & Harbor Engineering

- The Future of Coastal Engineering Efforts at the Louisiana Department of Natural Resources
  Christopher P. Knotts, P.E.
  Louisiana Department of Natural Resources, Coastal Engineering Division

- Case Study on Barrier Island Design: Barataria Barrier Island Complex Project
  Gordon G. Thomson, P.E. and Tom Campbell, P.E., Ph.D
  Coastal Planning & Engineering, Inc.

- Case Study on Shoreline Protection Design: Lake Borgne Shoreline Protection
  Shannon Haynes, P.E.
  Louisiana Department of Natural Resources, Coastal Engineering Division

- Case Study on Marsh Creation Design: Little Lake Dedicated Dredging/Marsh Creation
  Luke E. Le Bas, P.E.
  Louisiana Department of Natural Resources, Coastal Engineering Division

- The Mississippi River and its Role in Restoration Efforts
  Dr. Clinton S. Willson, P.E., Ph.D
  Louisiana State University, Department of Civil and Environmental Engineering

2008 Louisiana Water Symposia

Basic Information

Title:	2008 Louisiana Water Symposia
Project Number:	2008LA56B
Start Date:	3/1/2008
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	6
Research Category:	Water Quality
Focus Category:	Education, Management and Planning, Methods
Descriptors:	
Principal Investigators:	John Pardue, Nedra Davis Korevec

Publication

SYNOPSIS

Title: Information Transfer Symposia: Louisiana Water Conference
Project Number: 2008LA56B
Start Date: 3/1/2008
End Date: 2/28/2011
Funding Source: 104B
Congressional District: 6
Research Category: NA
Focus Category: Education, Management and Planning; Methods
Primary PI: John Pardue

Problem and Research Objectives

The Louisiana Water Resources Research Institute made a concerted effort in recent funding cycles to improve and expand outreach efforts to increase visibility in the Louisiana water/environmental community. In Louisiana, limited opportunities exist for exchange between university water scientists, state and federal agencies over water issues. A state "water" conference or summit has not been organized and only the state environmental agency, the Louisiana Department of Environmental Quality, sponsors a scientific/policy conference on environmental issues, some of which involve water. After discussions with the advisory board, the Institute thought this could best be accomplished by sponsoring shorter symposia/workshops to focus on a specific science/engineering issue important to the state.

Three symposia have already been supported by this project: *Mitigating Storm Surge with Vegetation* (2007) and *Water: Friend or Foe*, a transatlantic symposium held jointly with ConRuhr (2008) and the *Louisiana Coastal Engineering Conference*, jointly supported by LWRRI in summer 2008. This project was initiated to plan and execute a statewide water conference to bring focus to the state's water problems.

Principal Findings and Significance

The project has made progress in support for a statewide water conference. At the point of scheduling the conference for late 2009 we lost our long-serving staff conference coordinator and a state hiring freeze has prevented filling the position. We anticipate holding the conference in 2010 and will report the results of the conference in the next cycle. The project is currently on a no-cost extension.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	6	1	0	0	7
Masters	1	1	0	0	2
Ph.D.	3	3	0	0	6
Post-Doc.	0	2	0	0	2
Total	10	7	0	0	17

Notable Awards and Achievements

LWRRI has been active with NIWR in the yearly efforts to maintain the 104 funding within USGS's budget. We have been active informing the Louisiana delegation about the benefits of the program and we have obtained legislative support for our efforts. LWRRI has been active this funding cycle in connecting state scientists and engineers with specific needs within the Senator's office

LWRRI co-sponsored the 2008 Coastal Engineering Conference. The conference featured keynotes from Dr. David Basco from Old Dominion and Dr. David Randall from Texas A&M and the head of Louisiana's Governor's Office of Coastal Affairs, Garrett Graves. LWRRI will continue to work to integrate science into Louisiana's Coastal Plan by sponsoring information exchange like this event.

LWRRI sponsored a Water Film Series at LSU in Spring 2009. Three films were screened; Flow, Liquid Assets, and The American Southwest: Are We Running Dry. Films were screened, 1 per night over a 3 week period followed by a discussion lead by LSU faculty. All were well attended and we plan to make this an annual Spring event in the Institute. This event was inspired by the screening of these films in DC for congressional staffers as discussed at the last NIWR meeting.

The Director, John Pardue, continues to lead the formation of a Coastal and Ecological Engineering degree program at LSU. The degree proposal was submitted during this cycle and the degree is expected to be in place in Fall 2010.

Dr. Pardue was named one of LSU's 100 Rainmakers in 2008, a designation for its most productive researchers

LWRRI's post-Katrina efforts continued during this funding cycle with funding from the Oil Spill Coordinators Office to examine remediation of crude oil spilled in canals in Meraux, LA, presentations of Katrina data at various conferences and other venues and consultation with industry and government agencies on lessons learned.

Dr. Zhi-Qiang Deng received follow-up support for his project from NASA.

Title: Development of Remote Sensing Information System for Water Quality Monitoring; PI: Zhi-Qiang Deng; Funding Agency: NASA (National Aeronautics and Space Administration) and LaSPACE (Louisiana Space Consortium); Duration: 04/01/2009 – 03/31/2010; Amount: $33,985