# Probabilistic Assessment of the Effectiveness of BMPs in Coastal Louisiana

## Basic Information

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## Publication


1. Zhang, L. and V.P. Singh, 2006, Bivariate Rainfall Frequency Distribution Using Archimedean Copulas. Journal of Hydrology, in press.
2. Zhang, L. and V.P. Singh, 2006, Trivariate Rainfall Frequency Analysis Using the Copula Method. Journal of Hydrologic Engineering, ASCE, in press.
3. Zhang, L. and V.P. Singh, 2006, Trivariate Flood Frequency Analysis Using the Copula method. Journal of Hydrologic Engineering, ASCE, in press.
4. Singh, V.P. and L. Zhang, 2005, Multivariate Stochastic Hydrologic Analysis. Proceedings, International Workshop on Watershed Management in Dry Areas: Challenges and Opportunities, Djerba, Tunisia, 2005.
5. Singh, V.P. and Zhang, L., 2005, Stochastic Air Quality. in Environmental Exposure and Health, edited by M.M. Aral, Brebbia, C.A., Maslia, M.L. and Sinks, T., pp. 3-12, WIT Press, Southampton, U.K.

## Probabilistic Assessment of the Effectiveness of BMPs in Coastal Louisiana

## Problem and Research Objectives

Louisiana is naturally blessed with an abundance of aquatic systems, including bayous, brooks, streams, rivers, lakes, and aquifers, which provide Louisiana's citizens with fishing, hunting, boating, and recreational opportunities and contribute to the state's wealth and economic growth in agriculture, fisheries, recreation, energy, tourism, and transportation. While the state has more surface water available for its current use (84%) than any other state in the U.S., rapid urbanization and intensive agricultural and forest practices have increased the potential for reduction in the quality of the state's surface waters. Studies on hypoxia in the northern Gulf of Mexico have shown that an average midsummer hypoxic zone of 8,000-9,000 $km^2$ during 1985-1992 increased to 16,000-20,700 $km^2$ during 1993-2001 on the Louisiana/Texas continental shelf (Rabalais & Turner, 2001). This 3-fold increase of hypoxic zone over a relatively short period of time has been attributed to the increase of river-borne nutrients that can exacerbate coastal water eutrophication, favor harmful algal blooms, aggravate oxygen depletion, and alter marine food webs (Rabalais et al., 2002).

The northern Gulf of Mexico is found to be the second largest zone of coastal hypoxia in the world (Rabalasis et al., 2002). This oxygen-depleted phenomenon is attributed to nutrient enrichment in the waters of the northern Gulf of Mexico, and it is especially profound from spring through late summer. Agriculture is considered as a major source of nutrient enrichment from the Mississippi River basin (Burkart and James, 1999; Ferber, 2001; Howarth, 2001; Winstanley, 2001; Snyder, 2001). Atmospheric deposition of nitrogen is seen as another significant source to nitrogen limited estuaries and coastal waters (Paerl et al., 2002).

In January 2001, an action plan with the major goal of reducing nitrogen discharge through Best Management Practices from the inland water into the Gulf was endorsed by the state, tribal, and federal agencies and delivered to Congress (U.S. EPA, 2001). The action plan envisages a 30% nitrogen load reduction that is required to ensure a reduction of 5-year running average of the Gulf hypoxia zone to less than 5,000 $km^2$ by 2015. While this action plan called for an implementation of BMPs based on voluntary, incentive-based sub-basin strategies, several key questions that will influence the success of this plan need to be unanswered: (1) How effective are the current BMP guidelines in protecting stream water quality from agricultural and forest activities? (2) How can one quantitatively assess the effectiveness of BMPs? (3) What is the relationship between BMPs and hydrologic and water quality parameters? (4) To what extent do hydrological and hydrometeorological conditions, such as rainfall and temperature, affect the variability of coastal inland stream water quality? (5) What are the sources and locations of pollution? These questions need to be addressed using the data from the Atchafalaya, Barataria, Calcasieu, Mermentau, Terrebonne, and Vermillion-Teche River basins.

A recent study by Thomson et al. (2002) reported that rainfall deficits accumulated since 1998 in Louisiana have culminated in a twofold increase in the mean annual salinity in the Lake Pontchartrain estuary. Using monthly measurements selected from 25 subbasins in Louisiana over a period of 1978–2001, Xu (2003) showed that the nutrient loads, total suspended solids, and dissolved oxygen concentrations all varied widely in the monitored streams and across seasons. However, monthly routine monitoring seems to work well for characterizing base flow conditions, but may not be adequate to characterize rapidly changing conditions in response to storm events. An understanding of hydrologic influences on water quality indicators at the watershed scale is apparently needed, and such an understanding is especially critical for the coastal regions of Louisiana where storm weather occurs throughout the year.

Thus the objective of the proposed project was to probabilistically assess the effectiveness of BMPs and their relationship with stream water quality changes with hydrological and hydrometeorological conditions in Louisiana's six major basins close to the Gulf of Mexico. The project utilized existing long-term water quality data, hydrometeorological data, and stream discharge data maintained by Louisiana Department of Environmental Quality, Southern Regional Climate Center, U.S. Geological Survey, and U.S. Army Corps of Engineers. Specifically, the project had the following objectives:

1. To probabilistically assess the effectiveness of BMPs in reducing the deterioration of water quality in the major stream/rivers on Louisiana's lower coastal plain, including Atchafalaya, Barataria, Calcasieu, Mermentau, Terrebonne, and Vermillion-Teche rivers;

2. To determine the relationship between BMPs and water quality variability and hydrometeorological regime, such as storm weather conditions, rainfall intensity, and temperature fluctuation;

3. To identify the linkage between the probability distributions of water quality parameters and the source, location and extent of pollution

4. To assess the impacts of land use activities on water quality of the coastal streams, wetlands, and estuaries in Louisiana under various hydrologic conditions.

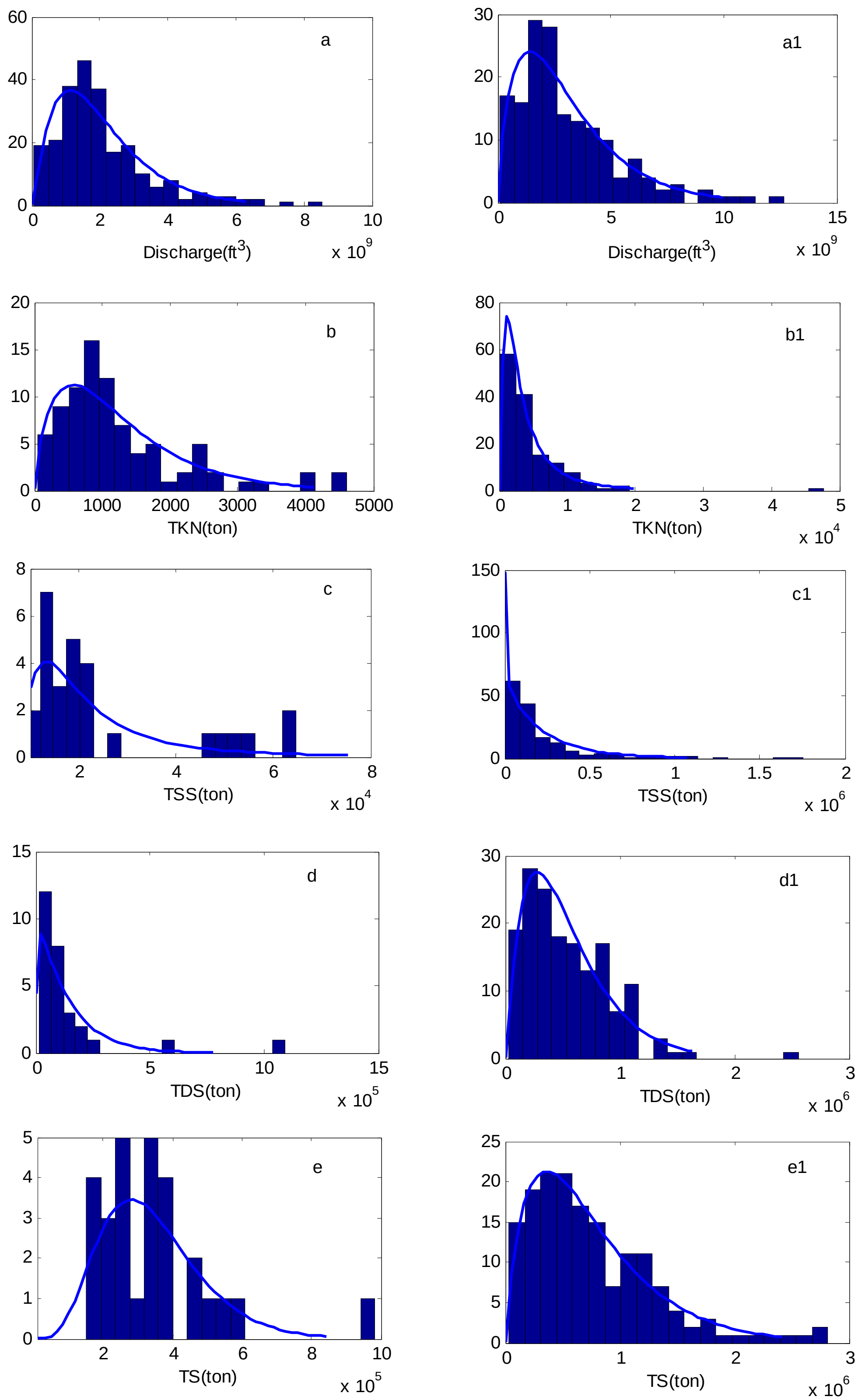


Figure 1. Probability density plots of Vermilion River (a, b, c, d, e: upstream; a1, b1, c1, d1, e1: downstream).

Information on land use activities and timber harvesting from the watersheds would also be gathered to investigate the magnitude of hydrological influences on water quality under various land use activities and BMPs.

## Methodology

This project utilized existing long-term datasets collected from six coastal basins in Louisiana. Despite a large number of studies conducted on water quality in Louisiana's shore of the Gulf of Mexico during the past 2 to 3 decades, little knowledge has been actually gained about the impact of land use change and BMPs on the dynamics of water quality indicators. Many studies have been conducted, and many are being conducted on various aspects ranging from restoration of bottomland forests to microbiology of the coastal estuaries, inland streams and bayous. As a result, there exists a large amount of data that has not yet been fully analyzed, whereas fortunately USGS and LDEQ continue collecting water quality and streamflow data in real time across the state's rivers and bayous.

To achieve the project objectives, the following tasks were accomplished:

1. Water quality, stream discharge, and climatic data from all monitoring stations within the Atchafalaya, Barataria, Calcasieu, Mermentau, Terrebonne, and Vermillion-Teche river basins were gathered;

2. Spatial and temporal characteristics in water quality and hydrological and hydrometeorological conditions in the drainage basins were identified;

3. The variability of monthly water quality loadings and sediment runoff in relation to the variability of hydrological and hydrometeorological conditions was assessed;

4. Probabilistic analyses were performed for water quality parameters; and

5. Probabilistic analyses for assessing the effectiveness of the BMPs and the effect of land use change were developed.

Because of the lack of land use data the following tasks could not be accomplished:

1. Development of probabilistic analyses for assessing the effectiveness of the BMPs and the effect of land use change;

2. Development of the relationship between BMPs and hydrologic and water quality parameters;

3. Determination of locations, extent and sources of pollution from probability distributions;

4. Recommendations on the adequacy of water quality monitoring networks;

5. Recommendations on changes in BMPs if needed; and

6. Determination of land use impacts on water quality changes under hydrometeorological conditions across landscapes.

Thus, the project could not determine critical areas of water quality deterioration and the causes- land use and anthropogenic, and industrial. This information is considered pivotal to defining BMPs and assessing their effectiveness.

## Principal Findings and Significance

The principal findings from the study on spatio-temporal characterization of water quality in coastal watersheds of the Atchafalaya, Barataria, Calcasieu, Mermentau, Terrebonne, and Vermillion-Teche rivers were: (1) The probability distributions of monthly discharge (cubic feet), total suspended solids (TSS), total solids (TS), total K nitrogen (TKN), and total dissolved sediment (TDS), all in tons, are different from one another. (2) These distributions significantly change from an upstream location to a downstream one on the same river, as shown for Vermilion River as an example in Figure 1. (3) For the same water quality parameter, as the probability distribution changes from exponential to gamma or lognormal from an upstream location to a downstream location, meaning that pollution is derived from several places and is not concentrated in one part of the watershed and many tributary watersheds are contributing to it. (3) The probability distributions are significantly affected by hydrologic and hydrometeorologic conditions. (4) All 6 rivers exhibit different hydrologic and water quality responses. (5) For the same frequency, water quality loadings for a river are much higher at a downstream location than would be the case after accounting for increased drainage area. A closer look at the probability distributions reveals that either the BMPs are not being as effective or else land use change is introducing far greater pollution. By comparing the probability distributions in space and time and correlating them with land use as well as BMPs, one can quantify the effectiveness of BMPs.

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