2003 Proceedings

Mississippi Water Resources Conference

Conference Sponsors:

Mississippi Water Resources Research - GeoResources Institute

U.S. Geological Survey, Mississippi District Office

Mississippi Department of Environmental Quality's Offices of Land and Water Resources and Pollution Control

Mississippi Water Resources Association

Proceedings Compiled by Debbie McBride, GRI Publications Coordinator

Preface

The 33rd Annual Mississippi Water Resources Conference was held April 23-24, 2003 at the Eagle Ridge Conference Center in Raymond, Mississippi.

Conference Sponsors:

Mississippi Water Resources Research - GeoResources Institute
U.S. Geological Survey, Mississippi District Office
Mississippi Department of Environmental Quality's Offices of Land and Water Resources and Pollution Control
Mississippi Water Resources Association

Conference Moderators:

Jamie Crawford, Office of Land and Water Resources, Mississippi Department of Environmental Quality
Richard Coupe, U.S. Geological Survey
Deirdre McGowan, Mississippi Water Resources Association
Glenn Odom, Surface Water Quality Division, Mississippi Department of Environmental Quality
Chris Bowen, Pat Harrison Water District
Sam Testa, USDA-ARS, National Sedimentation Laboratory
Jerry Banks, Office of Pollution Control, Mississippi Department of Environmental Quality
Mickey Plunkett, District Chief, U.S. Geological Survey

Conference Speakers:

Jamie Crawford, Mississippi Department of Environmental Quality
Jeremy Korzenik, U.S. Department of Justice
Bryon Griffith, Gulf of Mexico Program Office
Russell Beard, U.S. Department of Commerce, NOAA
Elizabeth Guynes, USACOE, Vicksburg District
Al Garner, USDA, Natural Resources Conservation Service
Norwyn Johnson, USACOE, Vicksburg District
Greg Jackson, Mississippi Department of Environmental Quality
Jim Morris, Mississippi Department of Environmental Quality
Charles Chisolm, Mississippi Department of Environmental Quality
David Shaw, GeoResources Institute, Mississippi State University
Jim Ellington, Mississippi Legislature House Conservation Committee
David Mockbee, Mockbee, Hall & Drake

The *Proceedings* were compiled from papers as furnished by the authors. If no paper was provided, the abstract is included.

LIST OF PAPERS

Criminal Enforcement of the Clean Water Act: Jeremy Korzenik, U.S. Department of Justice

Homeland Security – National Coastal Data Development Center (NCDDC): Russell Beard, U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA)

Field Sampling of Soil and Surface Water at and Near Small Arms Training Areas: Michael Bestor, Chemical Engineering, Mississippi State University

The Mississippi Geospatial Sub-Watershed Boundary: Michael G. Clair, II, U.S. Geological Survey

Assessing Functional Integrity of Moist-Soil Managed Wetlands by Comparison with Nearby Non-Managed Systems: Gary N. Ervin, Biological Sciences, Mississippi State University

Phosphorus Inactivation and Odor Control in Animal Waste Lagoons, Growing Facilities, and Natural Surface Water: Christopher B. Lind, General Chemical Corporation

Reduced Water Use and Methane Emissions from Rice Grown Using Intermittent Irrigation: Joe Massey, Plant and Soil Sciences, Mississippi State University

CYP1B mRNA Expression and Estrogen Metabolism in Channel Catfish Collected From Mississippi Delta: Monali Patel, Pharmacology, University of Mississippi

Monitoring the Quality of Water in the Unsaturated Zone at Camp Shelby and Camp McCain, Mississippi: Larry J. Slack, U.S. Geological Survey

Adaptive Hydrologic and Meteorologic Instrumentation for Flood Warning in the Limpopo River Basin of Botswana: Shane Stocks, U.S. Geological Survey

Spatial Technologies Assessing Rural Septic Systems (STARSS): Katy Wright, Civil Engineering and John Cartwright, Geosciences, Mississippi State University

Hydrogeologic Significance of Pesticide and Nutrient Concentrations in the Water Table Aquifers and Memphis Sand Aquifers in the Memphis, Tennessee Area: Jeannie R. Bryson, U.S. Geological Survey

Water Monitoring Program in a Recharge Area of the Guarany Aquifer in South America: Antonio Luiz Cerdeira, Brazil

Fish Tissue Contaminant Concentrations in Regions of the Yalobusha River and Grenada Reservoir Watershed: Charles M. Cooper, USDA Agricultural Research Service, National Sedimentation Laboratory

Spatial Technologies Assessing Rural Septic Systems (STARSS): Chuck O'Hara, GeoResources Institute, Mississippi State University

The Role of the Nature Conservancy in Water Quality Protection: Matthew Hicks, Nature Conservancy

Sediment Loads and Turbidity at Deer Creek at Leland, Mississippi: Michael S. Runner, U.S. Geological Survey

Sampling Strategy for the Deer Creek Mississippi Synoptic Study: Richard A. Rebich, U.S. Geological Survey

Surface Water Sampling and Analysis for Comparisons with the USDA's AGNPS Model Predictions for the Upper Pearl River Watershed: Mary Love Tagert, GeoResources Institute, Mississippi State University

Development of Watershed and Sub-Watershed Boundaries of Mississippi: Michael G. Clair, II, U.S. Geological Survey

Project Integration for Basin Management: Mississippi's Upper Pearl River Basin: W. Daryl Jones, GeoResources Institute, Mississippi State University

Development of a Program for Improved Flood Preparedness, Warning, and Response in the Limpopo River Basin of Botswana: D. Phil Turnipseed, U.S. Geological Survey

Channel Changes and Human Impacts in the Leaf River, Mississippi: Joann Mossa, Department of Geography, University of Florida

Hydrologic Controls on Bald Cypress Growth in Seasonally Inundated Wetlands: Gregg Davidson, Geology and Geological Engineering, University of Mississippi

Macroinvertebrates Associated with Headwater Streams at Camp McCain Training Site, MS: Earl Ducote, Biological Sciences, University of Southern Mississippi

Community Composition of Sand-Dwelling Chironomids in Three Blackwater Streams: Robert C. Fitch, Biological Sciences, University of Southern Mississippi

Evaluation of Headwater Streams on the Camp Shelby Training Site in South Mississippi Based on the EPT Complex (Ephemeroptera, Plecoptera, and Trichoptera): Amy Wilberding, Biological Sciences, University of Southern Mississippi

Chemical Oxidation Priming for Enhancing Petroleum Hydrocarbon Removal in Soils by Biological Treatment: Rafael Hernandez, Chemical Engineering, Mississippi State University

The Use of Phosphates to Reduce Lead Mobility at Military Small Arms Training Ranges: Mark Bricka, Chemical Engineering, Mississippi State University

Phosphorus Inactivation and Odor Control in Animal Waste Lagoons, Growing Facilities, and Natural Surface Water: Christopher B. Lind, General Chemical Corporation

The Civil Works Program and Planning Process: A Greener Corps in 2003: Norwyn Johnson, Chief, Environmental and Economic Analysis Branch, US Army Corps of Engineers, Vicksburg District

THE 33RD ANNUAL MISSISSIPPI WATER RESOURCES CONFERENCE
Eagle Ridge Conference Center - Raymond, Mississippi

WEDNESDAY, APRIL 23, 2003

7:30 REGISTRATION AND CONTINENTAL BREAKFAST (The Gallery Area)

OPENING PLENARY SESSION (Auditorium)
Moderator: Jamie Crawford, MDEQ

8:45 Opening Remarks: Jamie Crawford, Director, Office of Land and Water Resources, MDEQ

9:00 Keynote Address: Criminal Enforcement of the Clean Water Act: Jeremy Korzenik, U.S. Department of Justice

9:45 Current Issues Under Study Through the Gulf of Mexico Program Office: Bryon Griffith, Gulf of Mexico Program Office

10:30 Homeland Security – National Coastal Data Development Center (NCDDC): Russell Beard, U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA)

11:00 BREAK

11:15 POSTER SESSION (The Gallery Area)

Field Sampling of Soil and Surface Water at and Near Small Arms Training Areas: Michael Bestor, Chemical Engineering, Mississippi State University

The Mississippi Geospatial Sub-Watershed Boundary: Michael G. Clair, II, U.S. Geological Survey

Assessing Functional Integrity of Moist-Soil Managed Wetlands by Comparison with Nearby Non-Managed Systems: Gary N. Ervin, Biological Sciences, Mississippi State University

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Spatial Technologies Assessing Rural Septic Systems (STARSS): Katy Wright, Civil Engineering and John Cartwright, Geosciences, Mississippi State University

12:00 LUNCHEON: Elizabeth Guynes, Chief, Regulatory Branch USACOE, Vicksburg District "Corps Program Overview"

CONCURRENT SESSION A: Water Contaminants I (Auditorium)
Moderator: Richard Coupe, U.S. Geological Survey

1:00 **Hydrogeologic Significance of Pesticide and Nutrient Concentrations in the Water Table Aquifers and Memphis Sand Aquifers in the Memphis, Tennessee Area:** Jeannie R. Bryson, U.S. Geological Survey

1:20 **Water Monitoring Program in a Recharge Area of the Guarany Aquifer in South America:** Antonio Luiz Cerdeira, Brazil

1:40 **Fish Tissue Contaminant Concentrations in Regions of the Yalobusha River and Grenada Reservoir Watershed:** Charles M. Cooper, USDA Agricultural Research Service, National Sedimentation Laboratory

2:00 **Spatial Technologies Assessing Rural Septic Systems (STARSS):** Chuck O'Hara, GeoResources Institute, Mississippi State University

2:20 **BREAK**

CONCURRENT SESSION B: Water Policy (Eagle I and II)
Moderator: Deirdre McGowan, Mississippi Water Resources Association

1:00 **Corps Program Overview):** Elizabeth Guynes, Regulatory Branch, USACOE, Vicksburg Branch

1:30 **Flood Control:** George Grugett, Mississippi Valley Flood Control Association

2:00 **The Role of the Nature Conservancy in Water Quality Protection:** Matthew Hicks, Nature Conservancy

2:20 **BREAK**

CONCURRENT SESSION C: Water Contaminants II (Auditorium)
Moderator: Glenn Odom, Surface Water Quality Division, MDEQ

2:40 **Sediment Loads and Turbidity at Deer Creek at Leland, Mississippi:** Michael S. Runner, U.S. Geological Survey

3:00 **Sampling Strategy for the Deer Creek Mississippi Synoptic Study:** Richard A. Rebich, U.S. Geological Survey

3:20 **Surface Water Sampling and Analysis for Comparisons with the USDA's AGNPS Model Predictions for the Upper Pearl River Watershed:** Mary Love Tagert, GeoResources Institute, Mississippi State University

CONCURRENT SESSION D: Surface Water Management (Eagle I and II)
Moderator: Chris Bowen, Pat Harrison Water District

2:40 **Development of Watershed and Sub-Watershed Boundaries of Mississippi:** Michael G. Clair, II, U.S. Geological Survey

3:00 **Project Integration for Basin Management: Mississippi's Upper Pearl River Basin:** W. Daryl Jones, GeoResources Institute, Mississippi State University

3:20 **Development of a Program for Improved Flood Preparedness, Warning, and Response in the Limpopo River Basin of Botswana:** D. Phil Turnipseed, U.S. Geological Survey

3:40 **Channel Changes and Human Impacts in the Leaf River, Mississippi:** Joann Mossa, Department of Geography, University of Florida

CONCURRENT SESSION E: Aquatic Ecology (Auditorium)
Moderator: Sam Testa, USDA-ARS, National Sedimentation Laboratory

3:40 **Hydrologic Controls on Bald Cypress Growth in Seasonally Inundated Wetlands:** Gregg Davidson, Geology and Geological Engineering, University of Mississippi

4:00 **Macroinvertebrates Associated with Headwater Streams at Camp McCain Training Site, MS:** Earl Ducote, Biological Sciences, University of Southern Mississippi

4:20 **Community Composition of Sand-Dwelling Chironomids in Three Blackwater Streams:** Robert C. Fitch, Biological Sciences, University of Southern Mississippi

4:40 **Evaluation of Headwater Streams on the Camp Shelby Training Site in South Mississippi Based on the EPT Complex (Ephemeroptera, Plecoptera, and Trichoptera):** Amy Wilberding, Biological Sciences, University of Southern Mississippi

CONCURRENT SESSION F: Remediation (Eagle I and II)
Moderator: Jerry Banks, Hazardous Waste Division, Office of Pollution Control, MDEQ

4:00 **Chemical Oxidation Priming for Enhancing Petroleum Hydrocarbon Removal in Soils by Biological Treatment:** Rafael Hernandez, Chemical Engineering, Mississippi State University

4:20 **The Use of Phosphates to Reduce Lead Mobility at Military Small Arms Training Ranges:** Mark Bricka, Chemical Engineering, Mississippi State University

4:40 **Phosphorus Inactivation and Odor Control in Animal Waste Lagoons, Growing Facilities, and Natural Surface Water:** Christopher B. Lind, General Chemical Corporation

5:00 **SOCIAL ON THE PATIO (Hosted by General Chemical Corporation)**

THURSDAY, APRIL 24, 2003

7:30 **CONTINENTAL BREAKFAST (The Gallery Area)**

CLOSING PLENARY SESSION: (Auditorium)
Moderator: Mickey Plunkett, District Chief, U.S. Geological Survey

8:00 **Farm Bill 2002:** Al Garner, Assistant State Conservationist, USDA, Natural Resources Conservation Service

8:45 **The Civil Works Program and Planning Process: A Greener Corps in 2003:** Norwyn Johnson, Chief, Environmental and Economic Analysis Branch, US Army Corps of Engineers, Vicksburg District

9:30 **BREAK**

9:45 **TMDL:** Greg Jackson, TMDL / WLA Section Chief, MDEQ

10:25 **Storm Water Phase II:** Jim Morris, Chief, General Permits Branch, MDEQ

11:05 **Issues Facing MDEQ:** Charles Chisolm, Executive Director, MDEQ

11:45 **Closing Remarks:** David Shaw, Director, GeoResources Institute, Mississippi State University

12:00 **LUNCHEON: Honorable Jim Ellington, Chairman, Mississippi Legislature House Conservation Committee**

Afternoon Session: CEU Program for Professional Engineers

1:30-3:30 **Ethics Training – David Mockbee, Attorney at Law, Mockbee Hall & Drake**

KEYNOTE ADDRESS

CRIMINAL ENFORCEMENT OF THE CLEAN WATER ACT

Jeremy Korzenik
Senior Trial Attorney
U.S. Department of Justice
Environmental Crimes Section
PO Box 23985
Washington, DC 20026-3985
Phone: (202) 305-0325

Environmental Crimes Section
Senior Trial Attorney - February 1998 to Present
Trial Attorney - April 1991 to February 1998

Investigated and tried federal environmental criminal cases nationally. Prosecutions include charges under statutes regulating hazardous waste, water pollution, air pollution, pesticides, wildlife, and pollution of public lands, as well as charges of mail fraud, conspiracy, false statements, and other federal criminal offenses. Coordinated investigations with state and federal law enforcement agencies. Prosecuted cases or assisted in prosecutions with approximately twenty United States Attorney Offices. Cases include:

US v. Central Industries, Inc. et. al. (Mississippi)
Conviction of corporation and four corporate officers for over two decades of Clean Water Act violations involving wastewater discharges from a large poultry rendering plant. Sentence imposed: $14 million in fines and restitution against the corporation and various additional fines and periods of detention for corporate officers.

US v. Morton International, Inc. (Mississippi)
Conviction of chemical manufacturer for violations of hazardous waste and water pollution control statutes. Joint civil and criminal resolution of the case involved $38 million in fines, restitution, and remedial projects. Morton's environmental manager was convicted of falsifying wastewater discharge reports and sentenced to prison.

US v. Truck, Trailer, & Equipment, Inc. (Mississippi)
Conviction of corporation, three corporate official, and an employee for dumping waste solvents into wetlands and woods near a truck repair facility in Pearl, Mississippi. Prison term imposed.

US v. Robert Kelly, Jr. (Tennessee)
Conviction for violations of pesticide control laws involving the application of a highly dangerous pesticide to hundreds of Memphis area homes. Prison term imposed.

US v. Paul Walls & US v. Doc Eatman (Mississippi)
Convictions in separate trials for violations of pesticide control laws arising from the application of toxic pesticides to hundreds of Mississippi gulf coast homes causing the largest EPA emergency evacuation in history and requiring an estimated $70 million federal cleanup. Prison terms imposed.

NOTES:

HOMELAND SECURITY

National Coastal Data Development Center (NCDDC)

Russell Beard
U.S. Department of Commerce
National Oceanic And Atmospheric Administration (NOAA)
National Environmental Satellite, Data and Information Service
Bldg. 1100, Room 101
Stennis Space Center, MS 39529
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The National Oceanic and Atmospheric Administration (NOAA) is responsible for environmental prediction, assessment, and the conservation and management of coastal and oceanic resources. The NOAA National Coastal Data Development Center (NCDDC), Stennis Space Center, Ms., provides access to coastal data to support environmental forecast, scientific analyses, and formulation of public policy. Much of this data is stored at geographically distributed repositories in a variety of formats. NCDDC works closely with many federal, state and local agencies, academic institutions, and the private sector to create a unified, long-term database of coastal data sets. NCDDC employs established and emerging technologies to catalog coastal data sets and create a virtual network of data repositories. The center is involved in several ecosystem management programs, e.g., Coastal Ecosystems, Harmful Algal Blooms, Marine Invasive Species, Coral Reef Program, and others. Additionally, NCDDC is involved in Homeland Security issues with programs in place- the Integrated Ocean Observing Systems (IOOS), the Coastal Risk Atlas, and a developing initiative COAST VIEW a project designed to create a US Coastal Imagery Library of satellite and other imagery data sets. COAST VIEW provides a coastal imagery library to government, state, and local agencies to support ecosystem management and characterization, risk mitigation, preparedness, response & recovery decision support systems or applications for terrorism, emergency, and disaster events or environmental studies. Requirements for a coastal data set of images come from the need to characterize coastal regions that envelop extremely dynamic and complex ecosystems. Coastal constituent members and emergency managers have documented imagery requirements in workshops and other venues. Key NOAA customers are NMFS (Ecosystems), NOS (Coastal Services Center), NCOSC Labs, e.g., CCEBHR, Marine Sanctuary Program, Integrated Ocean Observing System, NGS shoreline-mapping program, OAR (OE), U.S. Navy, NASA, EPA, FEMA, other federal agencies, state, and local entities.

NOTES:

FIELD SAMPLING OF SOIL AND SURFACE WATER AT AND NEAR SMALL ARMS TRAINING AREAS

Michael Bestor and Mark Bricka
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The purpose of this presentation is to discuss the impacts of lead as a result of small arms training to the environment. The malleability, resistance to corrosion, and abundance of lead made it an obvious choice for ammunition. However, studies conducted over the past two decades have shown that there may exist a threat to humans and wildlife due to the toxicity associated with lead. More recently, interest has increased regarding the effects of solubility and transport of lead particles from soil into surrounding watersheds.

The focus of this investigation was to observe lead concentrations in the soils and watersheds surrounding areas of suspected contamination. Soil samples were collected from areas suspected of containing elevated levels of lead. Water and sediment samples were collected from streams where surface runoff and drainage from the areas of concern was observed. This investigation also sought to collect data focusing on the change in dynamics effecting lead movement brought on by rain events. Storm water samples were collected using an automatic sampling device. The results indicate only trace amounts of lead movement from areas of elevated lead concentrations during normal conditions, but higher levels were detected during periods of high rainfall.

NOTES:

THE MISSISSIPPI GEOSPATIAL SUB-WATERSHED BOUNDARY

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Since the passage of the Clean Water Act in 1972, the need for digital hydrologic data by Federal, State, and local agencies as well as scientists and consultants in the private sector to make decisions, do analyses, and to model water-quantity and quality issues on a watershed basis has grown rapidly. Both raster- and vector-based geospatial data are needed to accomplish such tasks as establishing and implementing Total Maximum Daily Loads (TMDLs) and source-water protection. Digital drainage-area data, at the watershed scale, are not available in many States.

In 1999, the U.S. Geological Survey (USGS), in cooperation with the U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS); the U.S. Department of Agriculture, Forest Service; the Mississippi Department of Environmental Quality, Office of Pollution Control (MSDEQ-OPC); and the Mississippi Automated Resources Information Service (MARIS); began development of geospatial techniques to create a digital watershed boundary dataset (MS-WBD) for the State of Mississippi. The MS-WBD was derived from published 1:24,000-scale 7.5-minute topographic quadrangle sheets on which sub-watershed boundaries had been delineated. Watershed and sub-watershed boundaries were digitized and entered into a geospatial database. Environmental System Research Institute's (ESRI) Arc/Info software and its ArcEdit module (the use of firm, trade and (or) brand names in this report is for identification purposes only, and does not constitute endorsement by the U.S. Geological Survey). were used to capture and process the digitized data. Als+o using Arc/Info software, the MS-WBD was attributed with information such as:

- Watershed sub-watershed names
- Hydrologic unit code
- Drainage areas

This finalized MS-WBD will present information on drainage and hydrography in the form of hydrologic boundaries of water-resource regions, sub-regions, accounting units, cataloging units, watersheds, and sub-watersheds. The final MS-WBD will be added, along with appropriate metadata, to the USGS National Elevation Dataset (NED) and National Hydrography Dataset (NHD) to help scientists and engineers address issues in watershed management, water-+quantity and quality initiatives, and watershed modeling. Arc Macro Language (AML) is also being used to develop applications to determine geomorphological characteristics such as slope and mean channel length for use in flood frequency and low-flow duration computations for the State. This map and associated watershed and sub-watershed boundaries will provide a standardized base for use by water-resource managers, engineers and planners in locating, storing, retrieving and exchanging hydrologic data.

NOTES:

ASSESSING FUNCTIONAL INTEGRITY OF MOIST-SOIL MANAGED WETLANDS BY COMPARISON WITH NEARBY NON-MANAGED SYSTEMS

Gary N. Ervin, Jason Bried, Brook Herman,
Department of Biological Sciences, Mississippi State University
and
Darrel Schmitz
Department of Geosciences, Mississippi State University

ABSTRACT

Our objective was to evaluate impacts of moist-soil habitat management on water quality and biological communities in wetland areas at the Strawberry Plains Audubon center in Holly Springs, MS. The study area is a 1000-ha farm presently undergoing conversion from agricultural land to wildlife habitat under the supervision of Audubon personnel, who assumed management of the property in 1998. In assessing the ecological status of the study wetlands, we evaluated a suite of physical water quality parameters (dissolved oxygen, turbidity, conductivity, pH, alkalinity, and temperature); concentration of nutrients, sediment, and chlorophyll *a* within surface waters; and plant cover, biomass, and species richness.

Certain attributes of these systems (dissolved oxygen, turbidity, and conductivity) did indicate differences among the wetlands under investigation. Among these, turbidity seemed most closely correlated with initial management activities. However, perturbations, as indicated by increased turbidity during installation of water control structures, were short-lived, presumably because of post-agriculture recovery already underway in the watersheds surrounding the study sites.

Based on data collected during the year prior to active wetlands management by Audubon, six impoundments were selected for continued monitoring following installation of standpipe control structures and initial management activities. These sites include four farm ponds (two unmanaged and two that will be managed to enhance moist-soil habitat), one natural beaver impoundment, and one created riparian wetland (Study Sites, at right). Recovery of the managed wetlands will be assessed in comparison with non-managed sites at Strawberry Plains, including the on-site beaver impoundment.

INTRODUCTION

This project was conducted in cooperation with the National Audubon Society to evaluate effects of moist-soil habitat management practices on water quality and other wetland functions. The study site is a 1000-ha farm near Holly Springs, MS, presently undergoing conversion from agricultural land to wildlife habitat under the supervision of Audubon personnel. Part of the Audubon management plan at Strawberry Plains is the enhancement of ecotonal areas (margins of forests, ponds, and streams) for bird and other wildlife use. In addition to a number of streams that make up a substantial portion of the Coldwater River headwaters, aquatic resources on the reserve include numerous farm ponds installed to aid in erosion control. Center managers plan to install or enhance water control structures along one major stream and around two farm ponds in order to increase moist-soil resources for waterfowl and other aquatic animal species, such as amphibians, fish, and mammals.

The aim of moist-soil management is to recreate more-or-less natural hydrologic cycles in managed wetlands to increase the diversity and production of plant and animal species for wildlife food and habitat (Fredrickson, 1996). Under moist-soil manipulation, water levels are lowered during the growing season to stimulate seed germination of wetland-adapted plants and to increase the oxygenation of soils to stimulate plant productivity. In autumn, water levels are raised to discourage establishment of non-wetland plant species and increase habitat diversity for invertebrate animals that serve as food for waterfowl and other aquatic wildlife, in addition to seeds that are produced by the moist-soil plant community. Water level manipulations often are accompanied by soil manipulations, such as tilling or disking, that maintain high plant species diversity and high seed production for wildlife (Fredrickson, 1996; Gray et al., 1999). Moist-soil management practices at Strawberry Plains will include mowing, tilling, and planting in shallow areas of each of three man-made impoundments to enhance early-successional herbaceous plant species for increased seed and invertebrate production.

Despite the substantial amount of land being converted to and managed as moist-soil waterfowl habitat (more than 80,000 ha throughout Arkansas, Louisiana, Mississippi, and Tennessee), there are no published comprehensive estimates on the effects of this manipulation on water quality and wetland plant communities. Data presented in this paper will serve as indicators of baseline conditions during our multi-year examination of the ecological impact of Audubon moist-soil habitat management.

MATERIALS AND METHODS

A total of nine sites were initially included in pre-management monitoring (Fig. 1, plus an additional riverine beaver impoundment on a large tributary to the Coldwater River). Depending on site hydrology, one to three inflow and outflow collection points were established in March of 2002 for measurement of: nitrogen (ammonia, nitrate, nitrite) and phosphorus (phosphate) concentration; sediment load within surface waters; dissolved oxygen, turbidity, conductivity, pH, and temperature; and wetland plant assemblage (Table 1). Inflow samples were collected in areas with obvious surface hydrologic inputs, and outflow samples were collected at the mouth of the water control structure on the wetland side of the levee or at obvious outflow points along the levee or beaver dam. The multiple measurements were used to calculate average values for water quality parameters measured at each site.

Field measurements

Approximately monthly field measurements were conducted to evaluate patterns in dissolved oxygen, conductivity, pH, temperature, and turbidity of water in each wetland. Each of these parameters provides important information regarding ecological health of the wetland in performing its natural water filtration functions (Table 1). Dissolved oxygen, conductivity, pH, temperature, and turbidity were measured with a Yellow Springs Instruments (YSI) handheld multi-probe environmental monitoring system.

Organic and inorganic sediment accretion was measured by anchoring sediment traps atop the existing soil/sediment along two random transects through each wetland area (methodology similar to Brueske and Barrett, 1994 and Fennessy et al., 1994). Transects were established at depths of 30cm and 60cm, and each consisted of 4 sediment collection traps (a total of 8 traps per wetland). Each trap was built from a pre-weighed, wide-mouth plastic bottle, anchored to the sediments with a plastic stake. At the time of placement, traps were filled with frozen tap water to prevent deposition of the disturbed sediments within traps. Traps were collected once water levels subsided such that some trap mouths became exposed to air. After settling of contents, water was siphoned from each trap, and the bottle and contents dried (105°C for 24h) to determine dry mass of sediment deposition.

Laboratory analyses

Ammonia, nitrite, nitrate, and phosphate concentrations were measured by standard colorimetric methods (APHA et al., 1998), through the use of pre-mixed, self-filling reagent vials (CHEMetrics VACUvials®) and spectrophotometric determination of nutrient concentrations, based on analyses of a known standard curve.

Alkalinity was measured by direct titration of water samples with standard acid to the phenolphthalein and total alkalinity endpoint (LaMotte alkalinity kit).

Concentration of suspended solids in the water column was measured by filtering water samples through pre-combusted (500°C), pre-weighed 0.7 mm glass fiber filters. Filters were dried at 105°C and re-weighed after drying to yield mg dry matter per mL water (APHA et al., 1998).

Water column algal biomass was represented by chlorophyll *a* concentration. Chlorophyll *a* content (mg chl *a* per mL) was determined by the phytoplankton method of Wetzel and Likens (2000), as follows. Water was collected at each sampling point and filtered through 0.7 μm glass fiber filters. These filters were then placed into glass centrifuge tubes and ground in 3 mL alkaline 90% acetone to extract pigments. Pigment concentration was then assayed by measuring absorbance of the centrifuged extract (before and after acidification) at 665 nm (chl a) and 750 nm (turbidity correction); these values were used in the equations provided by Wetzel and Likens (2000) to determine mg chlorophyll *a* per mL water.

Plant Community

Permanent line transects and quadrats were established in the wetland zone of each impoundment to monitor development of the plant community. Two transects were placed in each wetland: one longitudinal transect extending from the inflow sample collection site(s) toward the outflow and one transect along the land-water interface at time of transect set-up. The length of each transect intercepting plant canopies was recorded by plant species. These data were used to calculate species richness and percent cover by species for each wetland.

In addition to evaluation of wetland vegetative cover along these transects, two square $1m^2$ quadrats were established at randomly selected locations near the inflow data collection points. These quadrats were used to collect percent coverage and biomass data. Biomass harvest was made in late August to determine mean above-ground biomass of the plant communities. All above-ground plant material located within these quadrats was harvested, separated into species, dried (105°C, 24h), and weighed.

Statistical analyses

Water quality field parameter data were analyzed by repeated-measures multivariate analysis of variance (RM MANOVA). Other data were examined by principle components analysis and cluster analysis to determine which parameters, of the many evaluated, contributed most to differences among sites and to determine which sites were most similar to one another, based on the most informative parameters.

Principle components factor analysis was used to evaluate which parameters were most informative of differences among sites. These PC analyses were conducted with correlation matrices, using a minimum eigenvalue of 1.0 as a cut-off for selecting important PCA axes. Euclidean distances were used to determine separation of sites among clusters determined by Ward's linkage estimation (McCune et al., 2002).

RESULTS

Field-measured water quality (WQ) data provided insight into two aspects of the study: comparisons among sites (and guidance for grouping sites for our continued investigations) and responses of these ponds and associated wetlands to initial disturbance involved with initiating moist-soil management (Figs. 2-4).

Repeated-measures MANOVA of WQ data indicated significant differences among sites for pH, temperature, and conductivity during the June through February period (for the eight complete sets of data available for all sites) (Fig. 2A, C, E). Dissolved oxygen saturation also might have been considered marginally different among sites during this period ($P = 0.07$; Fig. 2B). However, in Jan & Feb 2003, after preparative drawdown, only conductivity and DO % saturation were significantly different among sites (Fig. 2B, E).

Despite differences based on WQ parameters, cluster analyses (guided by PC analysis of the full set of WQ parameters listed above) indicated that the sites for which data are presented were most similar among the nine surveyed for pre-manipulation baseline data (Fig. 3). Those nine sites included sites A, B, and 1-6 from Fig. 1 and an additional beaver pond along a 3rd-4th order tributary to the Coldwater River. The cluster tree represented was derived from data collected in March and May through September 2002. Results indicated that the sites most closely resembling the upland impoundments designated for management were upland sites 3 and 4.

Biotic data illustrated additional similarities among the six sites selected for continued investigation. Avifauna use information was unavailable for all nine sites; data were collected for only three of the sites examined in 2002-2003 (Table 2). These data showed that the two upland sites designated for manipulation are very similar in wildlife function to the natural beaver impoundment, with most species observed in the two upland sites also represented at the beaver impoundment. Presently, none of the bird species found to use the wetland areas of Strawberry Plains are sufficiently rare to be listed as threatened or endangered in the US, but some are of special conservation concern because of their exclusive use of wetland habitats (e.g., prothonotary warbler). Vegetation analyses also indicated similarities among the four upland sites (Table 3).

DISCUSSION

These data provided information on two important points regarding our study design and the management activities being employed by Audubon. First, we have grouped sites based on indications among the baseline data, whose patterns consistently demonstrated that the four farm ponds discussed here are most similar from among the six included in our baseline study. The most likely cause of the differences that were observed are the larger surface area of those ponds that were warmer and had higher dissolved oxygen concentrations and pH. The larger surface area permits greater insolation and higher total photosynthesis, which increases both DO and pH. Still, because of similarities in overall water quality among these sites, our continued monitoring should provide information on the potential impact of the management being implemented.

Secondly, the lower number of differences found among sites following the preparative drawdown indicates that the disturbed systems are recovering rapidly. Further, there is marked similarity in pH and dissolved oxygen between all four farm ponds and the beaver pond, also suggesting some degree of ecological integrity of those man-made ponds and their wetland fringes. These factors likely are the result of the protection provided to these ponds and wetlands by Audubon's removal of agriculture and grazing from the supplying watersheds in 1998. Vegetation succession in those uplands probably has resulted in substantial buffering against external perturbations.

It has been demonstrated repeatedly that biotic components of disturbed or created wetlands are highly variable in their capacity for recovery after perturbations. In a study of 10 natural and 10 restored wetlands, restored wetlands were found to be very similar in plant species composition three years after restoration was completed (Galatowitsch and van der Valk, 1996). Wetlands designed for treatment of mine drainage possessed reptile and amphibian communities very similar to those of nearby natural wetlands within 5 years after construction (Lacki et al. 1992); however, restored wetlands in New York did not perform similar habitat functions as local reference wetlands 2 years after restoration because bird communities, although similar in numbers of species and individuals, supported very different species compositions (Brown and Smith 1998).

Whereas biological communities may take 3 to 5 or more years to fully establish in created wetlands, water quality improvement may begin much more quickly. Henry et al. (1995) reported approximately 50% reduction in phosphorus concentration and a 50 to 70% reduction in ammonium concentrations within 2 years after stream channel restoration in a Rhône River restoration project. In two created wetlands in Ohio, phosphorus removal ranged from 45% to 89% during the first three years after construction, nitrogen removal from 25% to 49%, and turbidity reduction (light absorption by suspended and dissolved materials) ranged from 38% to 68% during this early period (Mitsch et al., 1998). Experimental created wetlands in Illinois showed removal rates of up to 99% of nitrogen, phosphorus, and suspended solids within 5 years after construction (Dey et al., 1994).

Thus, most studies indicate that while water quality improvements may be observed relatively quickly, especially where water quality is represented by such parameters as turbidity and dissolved nitrogen or phosphorus, changes in biotic assemblages require substantially more time. These are precisely the patterns we have observed in our first year of monitoring habitat recovery at Strawberry Plains. Although there was a great deal of variation in some biotic parameters among sites, there also was a significant amount of overlap between the managed and unmanaged sites in vegetation characteristics. Furthermore, water quality perturbations resulting from Audubon's early habitat manipulations have abated relatively quickly, presumably because of the four years of recovery experienced in the immediately surrounding watersheds of the study sites.

Typically, studies of wetland areas managed as wildlife habitat focus on factors of those ecosystems of direct influence on the species towards which management is targeted. Studies of fire as a management tool in coastal marshes of Louisiana demonstrated benefits to both plant and bird communities but failed to consider the effects of burning on water quality or other hydrologic factors (Gabrey et al., 2001). Similarly, most studies of moist-soil management for waterfowl evaluate management effects only on waterfowl food species such as moist-soil plants or aquatic invertebrates (Gray et al., 1999; Anderson and Smith, 2000), and even those studies are a recent addition to investigations of manipulation effects on wetland ecosystems (Anderson and Smith, 2000).

Data collected to date will serve as indicators of baseline conditions during our multi-year examination of the ecological impact of Audubon habitat management. Year two will coincide with initial implementation of moist-soil management practices, after the April 2003 installation of water control structures in the three impoundments designated for manipulation. Investigations during subsequent years will provide some of the first available information on the degree to which habitat manipulation affects ecological structure and function of the wetland areas. Similar investigations on the Missouri River floodplain are in progress, in which such comparisons are being conducted among different wetland basins, that are managed or unmanaged, but those studies are not yet complete (Leigh H. Fredrickson, Director, Missouri Agricultural Experiment Station Gaylord Wetland and Waterfowl Ecology and Management Laboratory, personal communication).

One study, however, has reported a benefit to no-till management of moist-soil overwintering habitat for waterfowl. Kaminski et al. (1999) reported that tillage in rice fields after harvest resulted in 1000 pounds per acre erosion, whereas untilled field lost only 31 pounds per acre over the winter. This single study indicates the potential for substantial impacts on water quality as a result of soil manipulation practices in moist-soil managed waterfowl habitat, especially in light of intensive management efforts to increase the acreage of these wetlands along migratory paths. For example, in recent years, Ducks Unlimited has installed or assisted in installation of around 85,400 hectares of winter habitat, including flooded cropland throughout Arkansas, Louisiana, Mississippi, and Tennessee (Tim Willis, MS DU Project Biologist, personal communication). Our continued monitoring of management and reclamation efforts by Audubon should provide much-needed information regarding the broader ecological impact of management activities on such lands.

ACKNOWLEDGEMENTS

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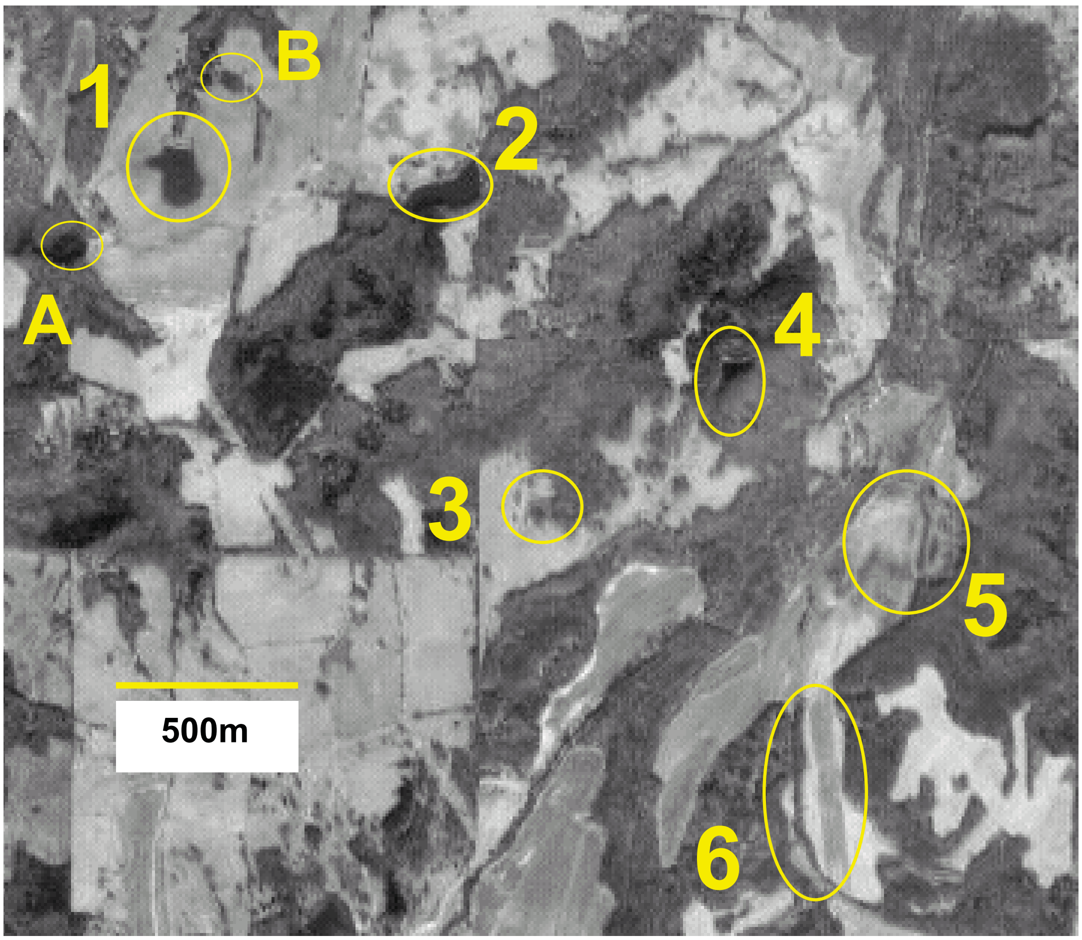

Figure 1. Location of the individual study sites at the Strawberry Plains Audubon Center, Holly Springs, MS. Sites are (A) Farm Pond 1; (B) Farm Pond 2; (1) Manipulated Pond 1; (2) Manipulated Pond 2; (3) Farm Pond 3; (4) Farm Pond 4; (5) Beaver Pond; (6) Created Riparian Impoundment.

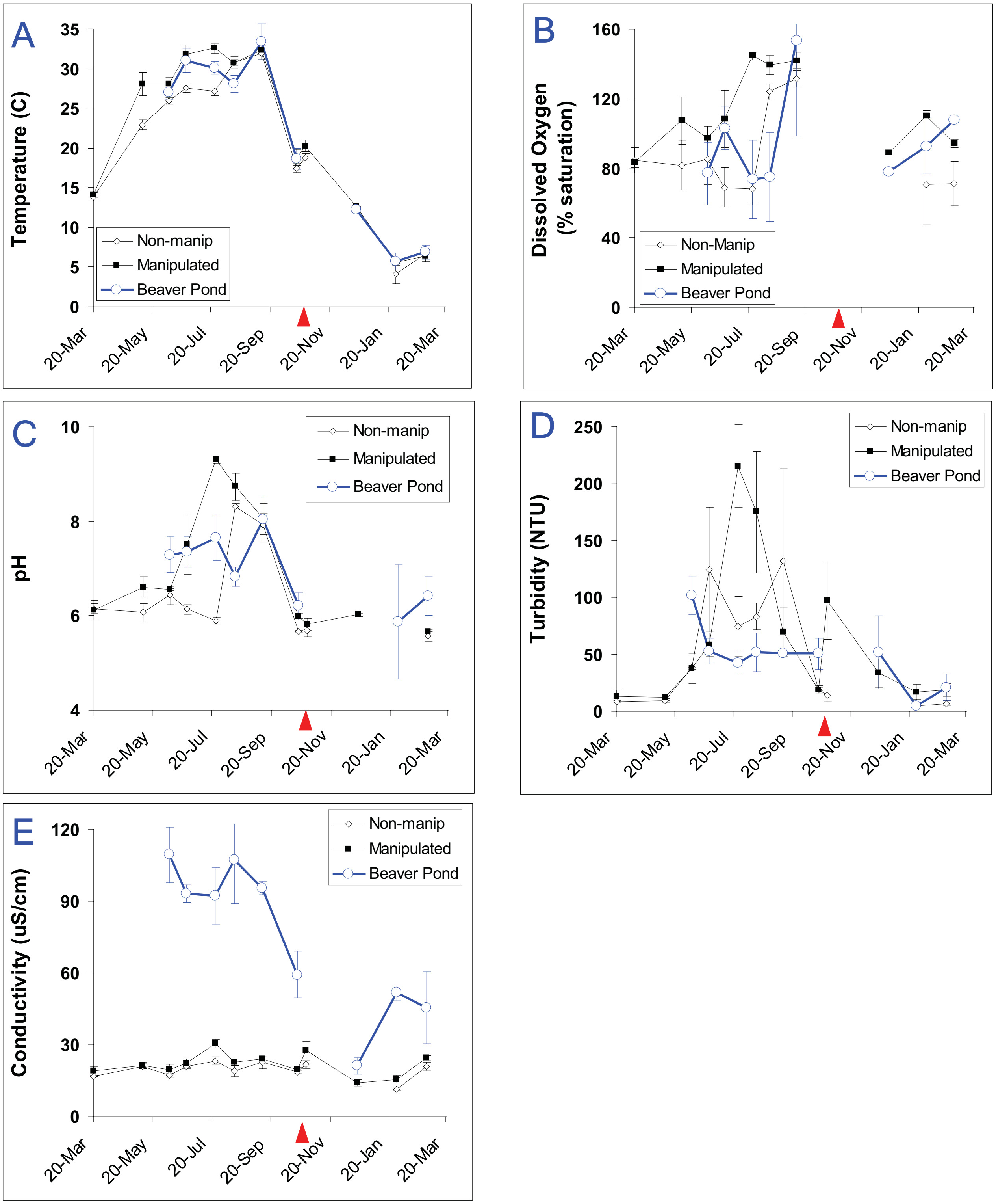

Figure 2. Basic water quality data (mean for all sampling pts per site ± 1SE) from the four upland sites, compared with on-site beaver pond. Non-manipulated sites are Farm Ponds 3 and 4, manipulated are nos. 1 and 2, and the beaver pond is site number 5 (Fig. 1). The red arrow indicates the date of drawdown for installation of riser-board standpipes. Data gaps resulted from difficulties with the field instrument.

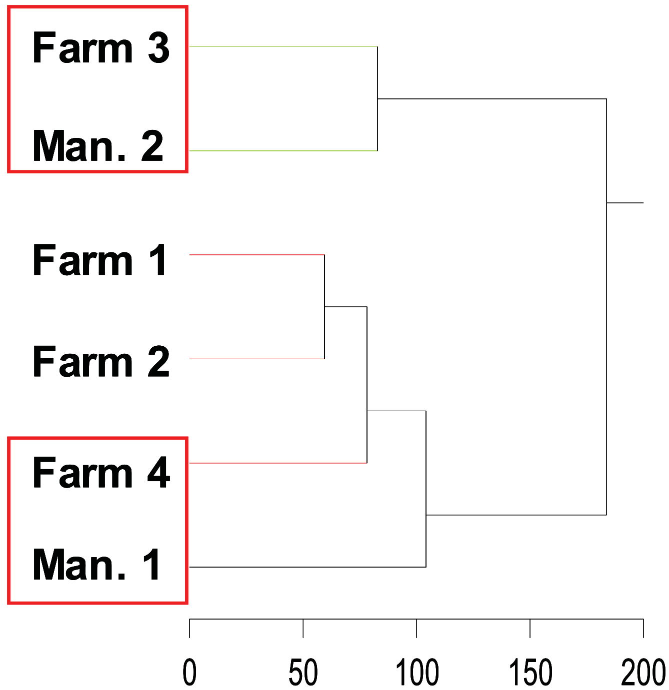

Figure 3. Cluster analysis of the six upland impoundments, based on water quality parameters indicated as most important through factor analysis of monthly measurements. Parameters included ammonium-N concentration, conductivity, dissolved oxygen, pH, phosphate-P concentration, sedimentation rates, and turbidity. Scale represents Euclidean distance along branches determined via Ward's linkage estimation (McCune et al., 2002).

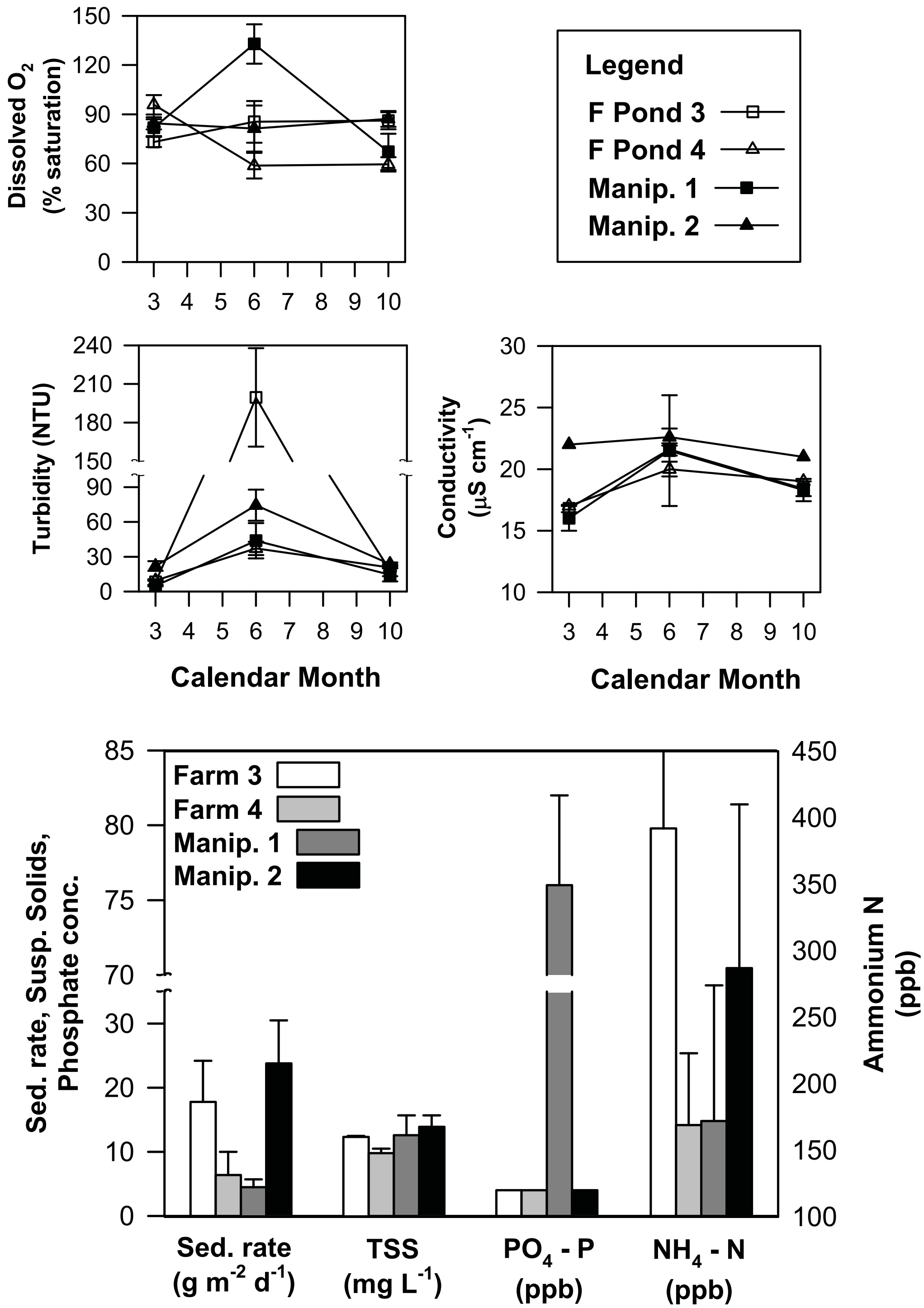

Figure 4. Values for water quality parameters used to determine sites to include in the second and third years of this study. These data were selected based on factor analyses from a suite of variables measured during March through October 2002 in each of six man-made impoundments. The four sites represented are described in Table 2. In three of the four sites, phosphate concentrations were at or below detection limit of 4 ppm. Sed. rate = sedimentation rate; TSS = total suspended solids.

Table 1. Water quality and biotic community parameters evaluated during year one of this study (March 2002 – March 2003).

Category	**Parameter**	**Significance to Wetland Function**
Water Quality	Dissolved oxygen	Oxygen concentration is important for metabolism of macro- and microorganisms that inhabit wetland
	Conductivity	An indirect measure of nutrient and other solute concentrations
	Temperature	Water temperature affects chemical and biological processes within the water
	pH, alkalinity	Measures of buffering capacity of the waters against detrimental effects of chemical contaminants
	Nitrogen and Phosphorus concentration	Indicates potential for pollutant transport or retention
	Suspended solids	Indicates potential for sediment transport or retention
	Sediment accrual	Increasingly developed sediments provide diverse microhabitats for microbial processing of transported materials
Biotic Communities	Plant community	A diverse assemblage of wetland-adapted plant species increases diversity of wetland function
	Algal biomass (chl *a*)	Water column productivity in wetlands enhances microbial degradation of pollutants
	Bird community *	Birds are important biotic indicators and a primary Audubon management objective

* Limited data on avian habitat utilization were collected by Audubon Society interns.

Table 2. Bird species encountered in surveys of three of the six sites to be monitored during years two and three. **Bold type** indicates species encountered in all three sites, *italics* indicate those present in only two sites. The beaver pond is one of the least disturbed areas on the Strawberry Plains property.

Manipulated Site 1	Manipulated Site 2	Beaver Pond
Semi-palmated sandpiper	Prothonotary warbler	Blue winged teal
		Least bittern
Belted kingfisher	**Belted kingfisher**	**Belted kingfisher**
Great blue heron	**Great blue heron**	**Great blue heron**
Green heron	**Green heron**	**Green heron**
Killdeer	**Killdeer**	**Killdeer**
Solitary sandpiper	**Solitary sandpiper**	**Solitary sandpiper**
Spotted sandpiper	**Spotted sandpiper**	**Spotted sandpiper**
Wood duck	**Wood duck**	**Wood duck**
Eastern bluebird		*Eastern bluebird*
Eastern kingbird		*Eastern kingbird*
Gadwall		*Gadwall*
Great egret		*Great egret*
Least sandpiper		*Least sandpiper*
Lesser yellowlegs		*Lesser yellowlegs*
Little blue heron		*Little blue heron*
Mallard		*Mallard*
Pectoral sandpiper		*Pectoral sandpiper*
Snowy egret		*Snowy egret*

Table 3. Summary data for plant communities at the four upland sites. Data are means ± standard error for all plots measured at each site.

Site	Tree BA (m^2 ha^{-1})	Herbaceous % Cover	Herbaceous Biomass (g m^{-2})	Species Richness (spp. m^{-2})
Farm Pond 3	11.2 ± 11.2	70.3 ± 9.8	711.1 ± 320.8	8.5 ± 0.5
Farm Pond 4	54.2 ± 18.6	12.5 ± 9.5	16.6 ± 4.0	5.5 ± 0.5
Man. site 1	no trees	52.5 ± 22.4	436.1 ± 135.0	6.5 ± 0.5
Man. site 2	21.5 ± 11.8	34.8 ± 19.7	43.5 ± 0.1	6.5 ± 2.5

PHOSPHORUS INACTIVATION AND ODOR CONTROL IN ANIMAL WASTE LAGOONS, GROWING FACILITIES, AND NATURAL SURFACE WATER

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Nutrient Inactivation, specifically Phosphorus Inactivation is the interception and chemical precipitation of phosphorus from the soluble reactive form into an insoluble un-bioavailable form. The algae responsible for eutrophication of surface waters need their nutrients soluble—they have no roots to chemically solubilize and absorb nutrients. Precipitation of phosphorus with aluminum and iron compounds has been an integral part of lake restoration since 1968. Over 200 lakes have been treated to eliminate P as a nutrient. Using the same chemistry animal wastes can be treated to precipitate P prior to final disposal, or better reuse. Ferric iron sulfate has the added benefit of precipitating the odiferous, toxic, and corrosive hydrogen sulfide (H_2S) from sludges and liquid streams. Hydrogen sulfide can also be effectively controlled by sodium nitrite. The use of alum or iron in waste streams will also control struvite. These chemicals, their applications and case studies will be presented in an overview format.

NOTES:

Reduced Water Use and Methane Emissions from Rice Grown Using Intermittent Irrigation

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Abstract

Current rice production techniques in the U.S. are water intensive and have led to groundwater depletion in some areas of the Mississippi Embayment aquifer system. Flooded rice culture also contributes to global climate change through the production of methane, a greenhouse gas. Our preliminary research indicates that intermittent rice irrigation techniques, where the height of floodwater cycles between 0 to 15 cm rather than being maintained at a constant height of about 15 cm, can reduce season-long water inputs by up to 50% over conventional (continuous flood) methods with only small reductions in yield. The production of methane gas was reduced by about 70% using intermittent irrigation compared to continuously flooded rice paddies. Future research needs to assess the utility of intermittent irrigation to maintain rice productivity while reducing water use and methane emissions across the various soil and climatic conditions in the Mississippi Embayment region.

Introduction

Demands placed on finite water resources will grow as the human population increases during the 21st century. In the US, irrigation is the single largest user of water. Most sources of freshwater have already been developed, and increased urban, thermoelectric, industrial and recreational water needs will largely be met through conservation and reallocation of existing irrigation water supplies (Gollehon and Quinby, 2000; Gollehon et al., 2002). As the amount of water dedicated to irrigation declines, *agriculture will have to use less water to meet increased global demands for food and fiber* (National Research Council, 1996). Thus, water savings through improved irrigation practices are essential to meeting the future water needs of both agriculture and other stakeholders (CAST, 1996).

Current U.S. rice production techniques are water intensive

Rice is unique among agronomic crops because it is typically grown in flooded paddies where floodwaters are maintained at a constant depth of ca. 8 to 15 cm. Flooding has traditionally been done to meet rice's relatively high water demand and to control broadleaf and grass weeds (Smith and Fox, 1973). Each of the roughly 1.26 million ha of rice harvested in the United States in 2000 required, on average, about 75 cm of water during the growing season, representing over 9.4 billion m^3 of fresh water. Most of this water was drawn from underground aquifers (Gollehon et al., 2002).

Irrigation practices have led to regional depletion of aquifers

More than 80% of the U.S. rice crop is grown in the Mississippi River alluvial plain. Underlying the fertile soils of this region is a series of six aquifers collectively known as the Mississippi Embayment aquifer system (USGS, 1998). The most intense rice production occurs in the Grand Prairie region of Mississippi River delta (Figure 1) where irrigation water is primarily derived from the Alluvial aquifer (ASWCC, 1997). However, due to groundwater overdraft, the Alluvial aquifer is not expected to sustain current extraction rates beyond 2015 (Scott et al., 1998; U.S. Corps of Army Engineers, 2000).

Increased pumping costs and lower water yields associated with declining water levels in the Alluvial aquifer have caused some farmers to install irrigation wells in the Sparta-Memphis aquifer which underlies the Alluvial aquifer. Currently, about 30 new agricultural irrigation wells per year are being drilled into the Sparta-Memphis aquifer (Charlier, 2002). This is of concern to regional municipalities since the Sparta-Memphis aquifer is the source of drinking water for over 350,000 people and, while it has purer water than the Alluvial aquifer, it has much less capacity to sustain heavy agricultural pumping rates (ASWCC, 1997). Thus, one of the consequences of intense rice production using current, water-intensive production practices is the potential for groundwater depletion and reduced agricultural sustainability over the long term.

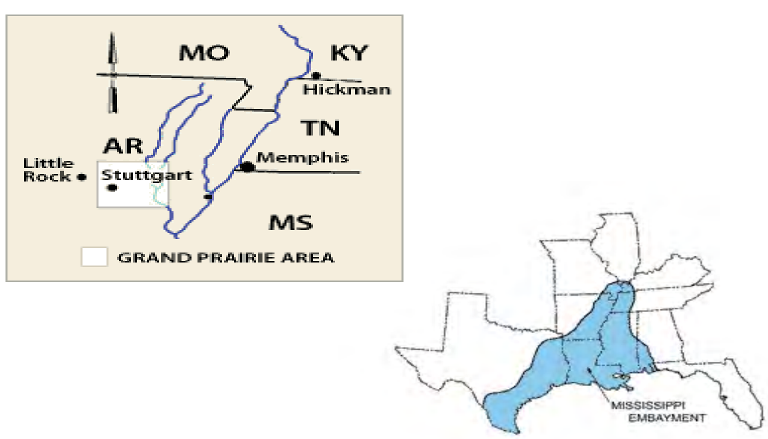

Figure 1. Over 80% of the nation's rice is grown using water from the Mississippi Embayment aquifer system. Depletion of the Alluvial aquifer in the Grand Prairie is a concern for producers, municipalities, and industries alike.

Improved irrigation practices reduce water use while maintaining rice yields

Many of the improvements in rice irrigation were pioneered in Asia. Beginning in the mid-1980's, China has lead research and implementation of water conservation to balance agricultural, urban, and industrial demands for limited water resources (Bouman et al., 2002; Dong et al., 2001). As ca. 90 percent of the available freshwater in southern China was being used for rice production, limited fresh water supply was the primary obstacle for economic, domestic, and agricultural development (Li, 2001).

Driven by needs to conserve water resources for agricultural, industrial and urban development and protect the Alluvial and Sparta-Memphis aquifers, University of Arkansas researchers have been investigating a variety of water-saving irrigation practices. Research conducted in 13 Arkansas counties on 33 different fields demonstrated that multiple inlet irrigation offers significant savings in water, inputs, and labor to rice growers (Tacker et al., 2002; Table 1).

Arkansas County	*Soil Texture*	*Results*
Arkansas	silt loam	19% less pumping hours 21% less water
Chicot	clay	29% less electric power
Crittenden	clay silt loam	29% less water 17% less water
Cross	silt loam	15% less initial flood time 16% less water 29% less labor

Table 1. Results for 2001 multiple inlet rice irrigation studies conducted in Arkansas (Tacker et al., 2002).

Irrigation Terminology

Water Saving Irrigation: Any practice that reduces infield consumption of water while sustaining acceptable agronomic yields.

Intermittent or Alternating Wet-Dry Irrigation: Once initial flood depth of ca. 7 to 15cm is achieved, irrigation is halted and flood is allowed to subside until the soil moisture reaches ca. 85% saturation. This is equal to ca. 43% volumetric soil water content (θ_V). At this time, irrigation is resumed and flood returned to its initial height.

Multiple-Inlet or Side-Inlet Irrigation: Multiple-inlet irrigation pumps water through flexible polyethylene pipe ("poly-pipe") having numerous floodgates along its length rather than adding water into a rice paddy at only a few irrigation riser locations as with conventional practices. This allows the irrigation water to be distributed more quickly and evenly across the field, reducing pumping time, pumping costs and water losses from field edges.

Water savings using intermittent rice irrigation compared to continuous flooding have also been observed in field studies. The increased water use efficiency is attributed to decreased water loss from percolation, field edge seepage, and floodwater runoff (Bouman and Tuong, 2001; Dong et al., 2001; Li, 2001). In small plot studies, no loss of weed control were observed, however rice yields declined significantly when water inputs dropped below threshold levels (Table 2).

Volumetric Soil Water Content (θ_V)	*Total H_2O Use* **(cm/ha)**	*Barnyardgrass Control (%)*	*Rough Rice Yield* **(kg/ha)**
20% [A]	48 ± 18	96	5130
27%	53 ± 17	97	7110
34%	55 ± 20	96	7920
41% [B]	59 ± 16	95	7880
48% [B]	62 ± 19	96	7830
51% [C]	70 ± 21	96	8400

Notes: (A) Basing irrigation timing on 20% θ_V allows soil to dry between irrigation cycles.
(B) Irrigation water begins to puddle prior to reestablishment of flood.
(C). Continuous flood maintained on plots.

Table 2. Three-year averages from small-plot research assessing the effect of intermittent irrigation on weed control and rice yield. (Adapted from Scherder et al., 2003).

Intermittent irrigation reduces methane emissions from rice

When soils containing labile carbon are flooded for extend periods, methane gas is produced under highly anaerobic conditions (<-150 mV) by methanogenic bacteria (Bronson et al., 1997). Given that methane (CH_4) absorbs ca. 20-times more infrared radiation than CO_2 and has an atmospheric residence time of 5 to 10 yrs, there is international interest in reducing CH_4 emissions from rice and other anthropogenic sources. Current estimates indicate that global flooded rice culture contributes ca. 8 percent of total methane production (IRRI, 2001; Ramanujan and Keeler, 2002). In China, intermittent flooding has greatly reduced methane emissions within transplanted rice culture (IRRI, 2002; Ramanujan and Keeler, 2002). Similar reductions in direct-seeded rice in the U.S. have not been previously reported.

Objectives

In 2002 a collaborative effort between researchers at Mississippi State University, the University of Arkansas and the USDA's Southern Weed Science Research Unit, was begun to investigate the agronomic and environmental benefits associated with intermittent rice irrigation. The objectives of this research were to:

1. Compare continuously flooded (conventional) rice production to intermittent irrigation in terms of season-long water use and rice yield at the field scale.

2. Compare methane emissions from conventional vs. intermittent rice irrigation systems.

3. Assess changes in soil microbial communities occurring in these two irrigation regimes.

Materials & Methods

The most promising irrigation levels observed in small plot research by Scherder et al. (41 and 48% θv) were combined and used in field-scale trials in 2002 at the University of Arkansas' Pine Tree Experiment Station. Season-long water use, rough rice yield and methane emissions from rice produced using either intermittent irrigation (44% θv) or conventional (continuous flood) irrigation (51% θv). Yield and water use, but not methane, were also measured in a multiple inlet irrigation system. Each field was about 8 ha in size and arranged in the manner shown in Figure 2. The fields were cropped with the rice cultivar 'Ahrent' and received identical pesticide and fertilizer inputs.

Season-long water use for each field was measured using a McCrometer odometer-type water meter. Irrigation timings were based on volumetric soil water content, θ_V. Basing timing of intermittent irrigation inputs upon θ_V instead of time since last irrigation will allow rice producers to manage irrigation inputs according to their prevailing soil and climatic conditions.

Methane emissions were determined using closed chamber techniques (Hutchinson and Moiser, 1981). Eight 18 cm x 25 cm PVC chambers were positioned along transects in the conventional and intermittent irrigation treatments. Gas samples were collected at 2 hr intervals from 10 am to 4 pm. Methane was quantified by gas chromatography and flame ionization detection with a limit of quantification of ca. 10 parts per million.

Soil samples were collected from the surface 2.5 cm of soil inside the PVC chambers and placed on ice until they could be stored at –80^{o}C. Fatty acids were extracted from 4 g subsamples and esterified in the method of Shutter and Dick (2000). Resulting fatty acid methyl esters (FAMEs) were separated by gas chromatography using the EUKARY method and the Sherlock Microbial Identification System (MIDI, Inc., Newark, DE). Comparisons in FAME profiles were made by Principle Component Analysis and used to assess changes in microbial community structure as impacted by irrigation regime.

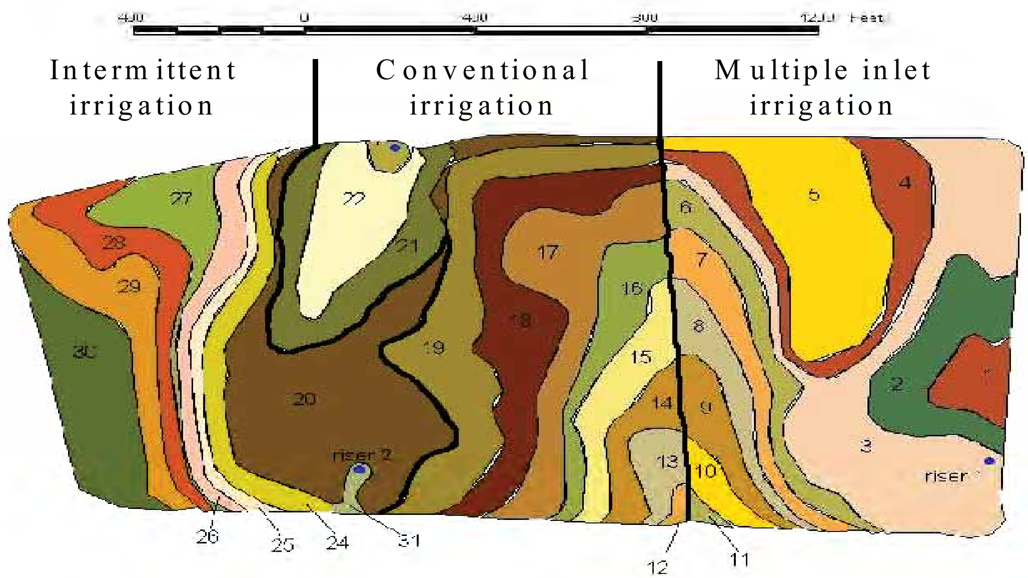

Figure 2. 2002 field layout at Pine Tree, Arkansas, used to compare three irrigation systems.

Results & Discussion

Preliminary results from the one-year production-scale fields are given in Table 3. A 51% water savings over conventional (continuous flood) rice irrigation was observed using intermittent irrigation. Rice yield was reduced by about 4% using intermittent irrigation. These results support previous reports that intermittent rice irrigation has the potential to significantly reduce water use and pumping costs while maintaining acceptable rice yields (Bouman and Tuong, 2001; Dong et al., 2001; Li, 2001). Maintaining economically acceptable yields is key to the success of any water-saving irrigation practice.

Irrigation Treatment	Water Use (cm/ha)	Water Savings (%)	Rough Rice Yield (t/ha)	Pumping Cost ($ /ha)
Conventional	95	---	9.7	133
Multiple Inlet	72	24	10.6	100
Intermittent	47	51	9.4	66

Table 3. Economic comparison of in-field water savings and rough rice yields for three irrigation systems.

In terms of methane emissions, our preliminary results agree with accounts published by IRRI (2002) and Ramanujan and Keeler (2002) that indicate that intermittent rice irrigation produces significantly less methane than continuously-flooded systems. Initial (zero-time) methane concentrations observed in chambers installed in continuously flooded rice soil were ca two-fold higher than those measured in intermittently irrigated soil (Figure 3). We observed little or no methane evolution under intermittent irrigation (< 25 □moles/ cm^2 / h) compared to an approximately six-fold greater methane flux under flooded soil at 65-d after initial flooding (Figure 3). Similar results were observed from small-plot studies we conducted at Stuttgart, AR in 2002 (data not shown). Results from FAME analysis suggest that the observed differences in methane production may be due to changes in microbial community structure resulting from water management and concomitant changes in redox potential (Figure 4).

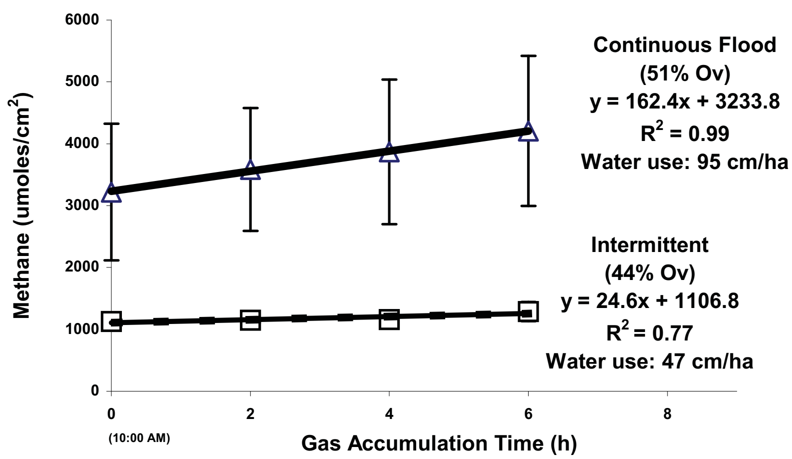

Figure 3. Comparison of methane flux from rice paddies under conventional (continuous flood) and intermittent irrigation at Pine Tree, AR (August, 2002).

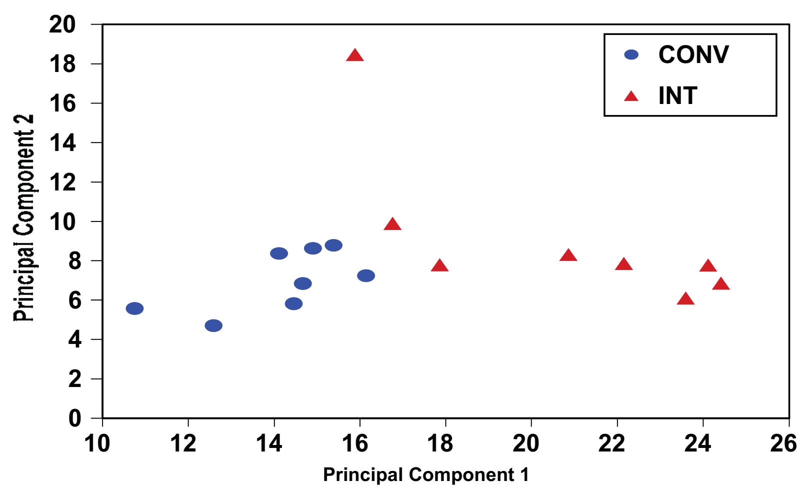

Figure 4. Principal component analysis of fatty acid methyl ester (FAME) composition reflects changes in microbial community structure under conventional (CONV) and intermittent (INT) irrigation regimes.

Conclusions

Our preliminary research indicates that direct-seeded rice grown using intermittent rice irrigation techniques may reduce season-long water use by up to 50% over conventional (continuous flood) methods with small reductions in yield. In addition, late-season methane flux may be significantly less than that of continuously flooded rice paddies. These findings agree with those reported from Asia involving transplanted rice. Given the potential agronomic and environmental benefits of intermittent rice irrigation, it should be further evaluated for use in rice growing areas of the Mississippi River Embayment region.

Future Research

A key concern surrounding intermittent irrigation is the potential for increased soil denitrification losses. This must be thoroughly investigated as it may have serious, negative agronomic and environmental implications. Additional research is needed to ascertain potential reductions in non-point source runoff of pesticides and nutrients, as well as altered pest infestations and control in rice resulting from intermittent irrigation practices. Future research should also investigate the potential for combining multiple inlet irrigation with intermittent rice irrigation techniques. This research should be conducted across a variety of soil and climatic settings and include thorough economic comparisons with conventional rice production practices.

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CYP1B MRNA EXPRESSION AND ESTROGEN METABOLISM IN CHANNEL CATFISH COLLECTED FROM MISSISSIPPI DELTA

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CYP1B1 is a P450 gene that in mammals is involved in the metabolism of polycyclic aromatic hydrocarbons (PAHs) and estradiol to potentially toxic intermediates. Certain environmental contaminants found in Mississippi sediments act by binding to the aryl hydrocarbon receptor (AhR) and inducing a gene battery that includes CYP1B and CYP1A. In mammals, CYP1B1 metabolizes estrogen to 4-hydroxyestradiol whereas CYP1A metabolizes it to 2-hydroxyestradiol. Quantitating induction of CYP1B mRNA or estrogen metabolism in catfish could potentially be a useful biomarker of exposure to AhR ligands. The objective of our study is to characterize in vivo and in vitro CYP1B mRNA expression and estrogen metabolism in laboratory raised and wild-caught channel catfish (*Ictalurus punctatus,* CC) from Lake Roebuck, Bee Lake and Sunflower River. Laboratory fish were exposed to corn oil or 20 mg/kg benzo(a)pyrene (BaP) for 4 days. Using quantitative real time RT-PCR, BaP exposure induced CYP1B mRNA in blood, liver and gonad, CYP1B mRNA in wild catfish was not statistically increased relative to control fish. The relative tissue levels of CYP1B mRNA from Lake Roebuck fish were gill >> blood > liver = gonad. CYP1B mRNA showed more induction in primary cultured gill cells compared to hepatocytes following BaP exposure ($5x10^{-9}$ to $5x10^{-5}$ M). Ongoing work is investigating if other AhR ligands also induce CYP1B mRNA in vitro. Liver microsomal ethoxyresorufin-O-deethylase (EROD) activities from wild fish were intermediate between control and BaP-exposed animals. Liver microsomes metabolized estradiol to predominately 2-hydroxyestradiol (compared to 4 hydroxyestradiol) and metabolism was induced by BaP. In gill microsomes, EROD activities and estrogen metabolism were much lower compared to liver. Also gill microsomes did not form any 4-hydroxyestradiol. These results will ultimately help characterize the utility of CYP1B as a marker of environmental contamination.

NOTES:

MONITORING THE QUALITY OF WATER IN THE UNSATURATED ZONE AT CAMP SHELBY AND CAMP MCCAIN, MISSISSIPPI

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During 2002 the U.S. Geological Survey, in partnership with the Mississippi Army National Guard, began a study to determine the quality of water in the unsaturated zone (soil zone above the water table) at Camp Shelby and Camp McCain, Mississippi. Eight soil-water samplers (lysimeters) were installed at shallow depths at selected locations at Camp Shelby (near Hattiesburg) and six were installed at shallow depths at Camp McCain (near Grenada). Two lysimeters installed for another study near Greenwood were used for quality control/quality assurance purposes (to determine reference/background conditions). The lysimeters were periodically purged to remove all water introduced during the installation. Specific conductance and/or other water-quality measurements were made to determine when the water being collected was representative of that in the unsaturated zone (and uninfluenced by the installation of the lysimeters). When conditions were satisfactory, soil-water samples were obtained from these lysimeters and analyzed for major anions, major cations, dissolved metals, nutrients, volatile organic compounds, semi-volatile organic compounds, and explosives.

NOTES:

ADAPTIVE HYDROLOGIC AND METEOROLOGIC INSTRUMENTATION FOR FLOOD WARNING IN THE LIMPOPO RIVER BASIN OF BOTSWANA

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Near real-time, low maintenance hydrological and meteorological instrumentation is needed in remote access areas subject to periodic flooding. In Botswana, there is limited coverage of hydrological and meteorological monitoring stations in the Limpopo River Basin, and only a few stations provide near real-time reporting capability. During 1999-2000, many parts of the Southern African Region experienced devastating floods, most of which occurred from December 1999 through March 2000. Rainfall accumulations during February 2000 in Botswana have been estimated in some areas to have been greater than 1,000 millimeters (39.4 inches) in one storm event, which is more than twice the annual average rainfall. Many lives were lost; tens of thousands of people were displaced from homes; and more than $285 million of damage was reported. The local water-related agencies were not adequately equipped to respond to these rapidly occurring major flood events. In addition, the local data-collection agencies currently operate antiquated river-gaging equipment that has no dynamic capacity to convert the raw data into the type of information needed by the Republic of Botswana National Disaster Management Office (NDMO). The information available to the decision makers during this flooding could have been significantly improved by the installation of additional, strategically placed, near real-time river and rainfall monitoring stations.

In coordination with a project entitled “Village Flood Watch: A program for the Improved Preparedness, Warning and Response in the Limpopo River Basin in Botswana,” personnel of the U.S. Geological Survey (USGS) designed and constructed eight hydrological and meteorological monitoring stations for the special environment in the Limpopo River Basin of Botswana. The project was made possible by a grant from the U.S. Agency for International Development / Regional Center for Southern Africa (USAID/RCSA) located in Gaborone, Botswana.

Three of the eight gages constructed record continuous river stage using a new non-contact sensor recently tested and approved for use by the USGS in river monitoring. This non-contact sensor, which measures river stage using micro-pulse radar technology, is currently being beta-tested at two streamgages in Mississippi. The unique adaptation of this technology for USGS application in Botswana provided the project with the ability to quickly and efficiently construct near real-time hydrological monitoring stations on three bridges. Other construction on the project included retrofitting three existing stilling wells used as river monitoring stations in the Limpopo River Basin and construction of two meteorological gages to record continuous rainfall, wind speed/direction, barometric pressure, relative humidity, and air temperature. The meteorological stations were designed for construction at selected secondary schools within the Limpopo River Basin for the dual purpose of providing additional meteorological data and adding to the school curriculum in the study of Earth sciences.

All the hydrological and meteorological stations transmit data via the Meteorological Satellite (METEOSAT) operated and maintained by the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) in Darmstadt, Germany.

This effort provides hydrological and meteorological parameters and a pilot hydrological run-off model that will assist the Botswanan government agencies in the propagation of hydrological run-off models in all the sub-basins of the Limpopo River Basin for use in the future flooding disasters.

NOTES:

SPATIAL TECHNOLOGIES ASSESSING RURAL SEPTIC SYSTEMS (STARSS)

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Over one third of Mississippi residents depend on septic systems to dispose of household waste water. Septic system failure is particularly a problem in fast growing rural areas. The Spatial Technologies Assessing Rural Septic Systems (STARSS) project plans to locate and map these problems using mobile computing, field mapping, remote sensing, and GIS technologies.

In many cases, the locations of rural septic systems are poorly mapped and only known to workers. The STARSS pilot project effort is directed at developing a GIS/GPS field application for septic system mapping, inspection, and fault reporting. The intended product is a simple, user friendly, portable application to standardize the locating and mapping of the septic system while providing attribute information of the location. The custom application being developed will leverage PDA, GIS, and GPS technologies. The application will integrate selected basemap information downloaded from a server in a seamless application for the user and will have custom menus and interfaces that meets the field mapping needs of the application.

The STARSS project is funded by the MSU GeoResources Institute (GRI) and Mississippi's Water Resources Research Institute's (WRRI) Southeastern Regional Small Drinking Water Systems Technical Assistance Center through a U.S. Environmental Protection Agency grant.

NOTES:

Hydrogeologic Significance of Pesticide and Nitrate Concentrations in the Water-Table Aquifer and Memphis Aquifer in the Memphis Area, Tennessee

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Introduction

The Memphis, Tennessee, area uses ground water pumped from the Memphis aquifer as a major source of drinking water. The Memphis aquifer was assumed to be protected from surface contamination by the overlying deposits of low hydraulic conductivity which separate the Memphis aquifer from the alluvial and fluvial deposits that make up the shallow water-table aquifers. Graham and Parks (1986), Parks (1990), and Kingsbury and Parks (1993) determined that the confining unit between the Memphis aquifer and water-table aquifers is heterogeneous and discontinuous in many areas, allowing for direct recharge to the Memphis aquifer from the water-table aquifer. Therefore, water in the Memphis aquifer in the Memphis area could be vulnerable to contamination by surface-applied chemicals, such as pesticides and fertilizers.

Purpose and scope

As part of the National Water-Quality Assessment (NAWQA) Program, the U.S. Geological Survey (USGS) began an assessment of water quality in the Mississippi Embayment (MISE) study unit. Ground-water samples from 32 wells installed (Gonthier, 2003) in urban and recently industrialized locations throughout the Memphis area (figure 1) were collected during spring 1997 and were analyzed for nutrients, major ions, volatile organic compounds (VOCs), trace elements, and pesticides. Pesticide and nutrient (nitrate plus nitrite) data collected as part of the study and reported by Gonthier (2003) were used in this study to assess the correlation between the anthropogenic compounds present in the ground water and the hydrogeology of the corresponding wells.

Hydrogeologic Setting

Memphis is located in Shelby County in southwestern Tennessee. Memphis lies in the northern part of the Mississippi Embayment, which is part of the East Gulf Coastal Plain physiographic province (Cushing and others, 1964). The Mississippi Embayment is characterized structurally as a large southward plunging syncline or valley-like feature with the axis running near the present-day Mississippi River. The syncline is filled with sediments derived from sea regressions and transgressions which shaped the geology of the Embayment (Arthur and Taylor, 1997). The deposition of sediments such as sand, silt, and clay are responsible for the many aquifer systems found throughout the Embayment and within the Memphis study area.

Stratigraphic units of interest in the study area are of Tertiary and Quaternary age (table 1). The Memphis Sand constitutes the Memphis aquifer, the primary aquifer from which ground water is withdrawn for drinking water in the Memphis area.

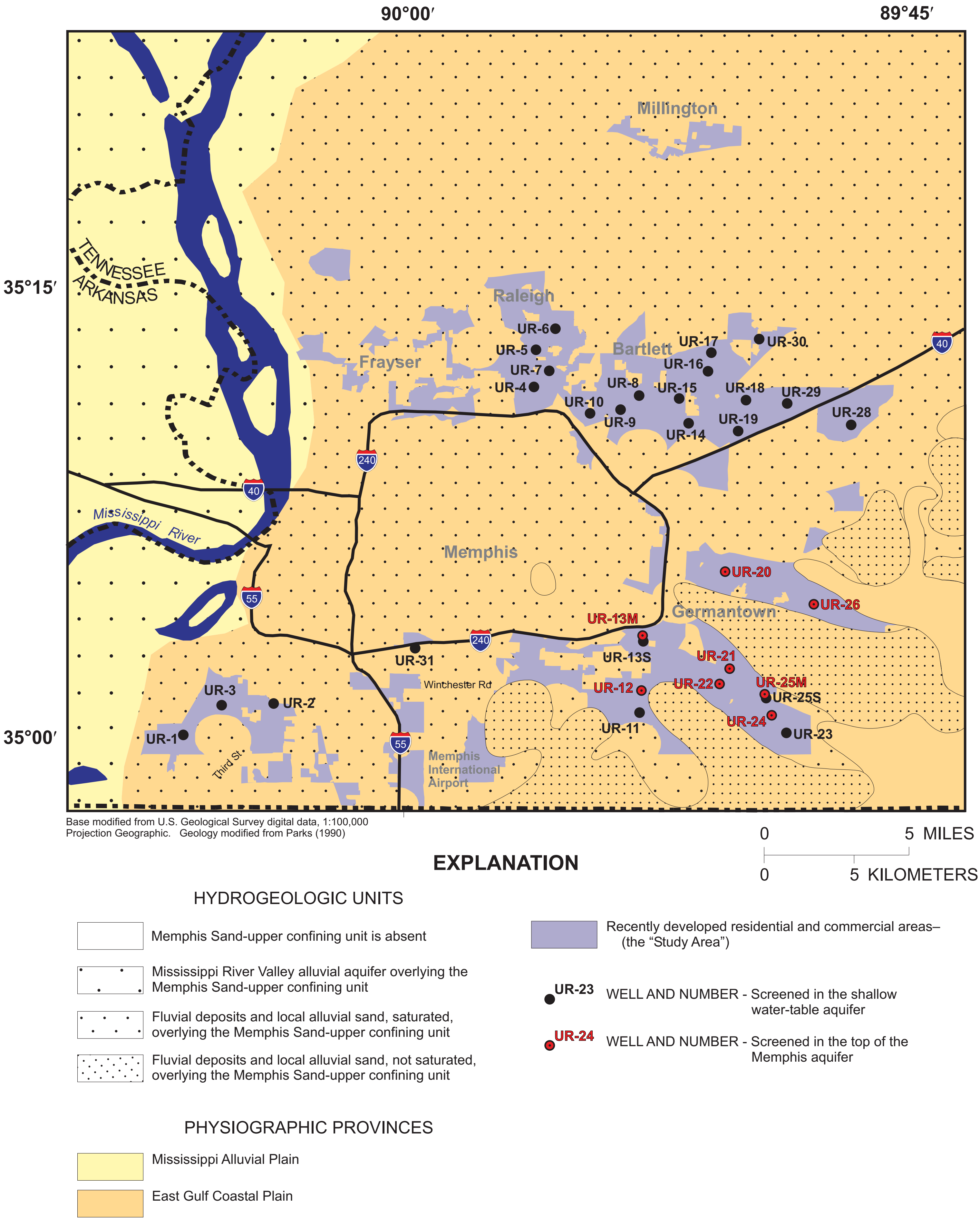

Figure 1. Hydrogeology and physiography in the Memphis vicinity, Tennessee, 1997.
(modified from Gonthier, 2003)

Table 1. Stratagraphic column with geologic units and their hydrogeologic characteristics within the Memphis area, Tennessee.

[Modified from Kingsbury and Parks (1993).]

Time unit			Statigraphic units		Hydrogeologic significance	
Era	Period	Epoch	Group	Formation	Hydrology	Lithology
Cenozoic	Quaternary	Holocene and Pleistocene		Alluvium	water-table aquifer	sand, gravel, silt and clay
		Pleistocene		Loess	low hydraulic conductivity, retards recharge to the water- table aquifer	silt, silty clay, and minor sand
	Quaternary and Tertiary (?)	Pleistocene and Pliocene (?)		Fluvial deposits	water-table aquifer	sand, gravel, minor clay, and ferruginous sandstone
	Tertiary	Eocene	Jackson	Jackson	Jackson-upper Claiborne confining unit*	fine clay, silt, and sand
			Claiborne	Cockfield		
				Cook Mountain		
				Memphis Sand	Memphis aquifer	sand, silt, with clay lenses throughout formation
		Eocene and Paleocene (?)	Wilcox	Flour Island	confining unit	clay and silt with some sand and lignite

* The groups and formations comprising the Jackson-upper Claiborne confining unit are currently being reevaluated by the Mississippi Office of Geology as to their existence up to the Mississippi-Tennessee border and are referred to in this paper as the upper confining unit.

The Memphis Sand, also known as the “500-foot” sand, is comprised mainly of fine to coarse-grained sand with some clay lenses. It overlies the Flour Island Formation, a clay and silt unit, which serves as the lower confining unit of the Memphis aquifer and upper confining unit of the underlying Fort Pillow aquifer. Deposits from the upper Claiborne Group and Jackson Formation overlie the Memphis Sand. These deposits are referred to by Parks (1990) as the Jackson-upper Claiborne confining unit. However, because current geologic investigations and mapping efforts are being conducted to better define the stratigraphy of these deposits, they will be referred to in this paper as the upper confining unit.

The upper confining unit is heterogeneous and laterally discontinuous (Parks, 1990), and its eastern limit is in the southeastern part of Shelby County (figure 1). Throughout the Memphis area, there are many places in which the confining unit is very thin or entirely absent. The overlying water-table aquifer is found within Quaternary aged alluvium and Tertiary to Quaternary aged fluvial deposits. Recharge to the fluvial deposits can be hindered by overlying loess deposits that are thickest on the bluffs near the alluvial plain of the Mississippi River. Direct recharge and surface-water contamination from the water-table aquifer into the Memphis aquifer can occur where the upper confining unit is very thin or absent. Kingsbury and Parks (1993) have also identified various fault zones that have displaced the Memphis Sand. If these displacements are greater than the upper confining unit thickness then the Memphis aquifer will come in direct contact with the water-table aquifer, allowing for direct recharge from the surface. Geophysical logs and S-wave reflection surveys have revealed channels within the confining unit in which recharge may also occur from the water-table aquifer to the Memphis Sand (Ground-Water Institute, 2001).

Data Collection and Analysis

The ground-water urban land-use study (Gonthier, 2003) followed the procedures outlined by NAWQA protocol. Standard procedures for the installation and documentation of the study wells are outlined by Lapham and others (1995). Thirty of the 32 sampled wells in the study were installed by the USGS during summer 1996, and 2 were existing wells belonging to Memphis, Light, Gas, and Water (table 2). Twenty-four of the wells were completed in the water-table aquifer, and 8 were completed in the upper part of the Memphis aquifer. All eight of the Memphis aquifer wells are located in the southeast part of Memphis, where the upper confining unit is known to often be thin or absent. Two pairs of wells (UR-13S, UR-13M, UR-25S, UR-25M) were nested with one well screened in the water-table aquifer and a deeper well screened in the Memphis aquifer. The upper confining unit for the Memphis aquifer was found to be absent in two of the wells (UR-22 and UR-24) screened in the Memphis aquifer.

During spring 1997, water was collected from all 32 wells and analyzed for major ions, nutrients, trace elements, pesticides, VOCs, and tritium. Collection of water samples and quality assurance was completed using guidelines described by Koterba and others (1995). Water samples were collected at each well after several casing volumes of water had been purged from the well, and field measurements remained stable.

Table 2. Description and number of the 32 wells sampled in the study area, April-May 1997.
[--, no data available]

Well number	Water-level below land surface (feet)	Well Depth (feet)	Water Column (feet)	Aquifer	Memphis upper-confining unit present?
UR-24	66.2	100	33.8	Memphis	no
UR-22	79.4	98	18.6	Memphis	no
UR-12	99.8	109	9.2	Memphis	yes
UR-20	53.7	76	22.3	Memphis	yes
UR-13M	64.9	98	33.1	Memphis	yes
UR-25M	73.2	94	20.8	Memphis	yes
UR-26	69.7	108	38.3	Memphis	yes
UR-21	74.9	88	13.1	Memphis	yes
UR-01	19.6	70	50.4	Water table	--
UR-02	25.4	68	42.6	Water table	--
UR-03	14.9	68	53.1	Water table	yes
UR-04	22.3	38	15.7	Water table	yes
UR-05	36.1	46	9.9	Water table	--
UR-06	28.0	40	12.0	Water table	--
UR-07	26.7	49	22.3	Water table	yes
UR-08	8.3	44	35.7	Water table	yes
UR-09	13.1	45	31.9	Water table	yes
UR-10	17.5	48	30.5	Water table	yes
UR-11	12.9	53	40.1	Water table	yes
UR-13S	13.5	33	19.5	Water table	yes
*UR-14	71.6	90	18.4	Water table	--
*UR-15	25.0	--	--	Water table	--
UR-16	63.6	88	24.4	Water table	yes
UR-17	18.5	48	29.5	Water table	yes
UR-18	62.0	68	6.0	Water table	--
UR-19	42.6	56	13.4	Water table	--
UR-23	34.2	43	8.8	Water table	yes
UR-25S	15.3	43	27.7	Water table	yes
UR-28	18.9	39	20.1	Water table	yes
UR-29	70.2	87	16.8	Water table	--
UR-30	73.1	80	6.9	Water table	--
UR-31	27.7	43	15.3	Water table	--

* Well installed and maintained by Memphis Light, Gas, and Water (MLGW).

After collection, VOCs and nutrient samples were sent overnight on ice to the National Water Quality Laboratory (NWQL) in Denver, Colorado.

Pesticide samples were first shipped overnight to a nearby USGS office for solid-phase extraction, and then the samples were sent to the NWQL.

Results

Pesticides

Of the 85 pesticides analyzed, 26 were detected in at least one of the 32 wells. Out of these 26, atrazine and simazine were detected most frequently, occurring in 12 wells. Seven of the 12 were from the water-table aquifer and 5 from the Memphis aquifer. Metalochlor was detected in 10 wells (5 water-table and 5 Memphis aquifer) and deethylatrazine was detected in 8 wells (6 water-table and 2 Memphis aquifer). Deethylatrazine is a degradation product of the triazine pesticides and especially atrazine.

At least one pesticide was detected in all 8 Memphis aquifer wells and in 62 percent (15 of 24) of the water-table wells (figure 2). The well in which the most pesticides were detected was UR-24, which is located in the Memphis aquifer where the upper confining unit is known to be absent. UR-24, located in the southeastern Memphis area, had 12 pesticide detections, which is twice as many as the highest number of detections found in any other water-table well.

Nitrate and Dissolved Oxygen

The highest concentrations of nitrate plus nitrite, here after referred to as nitrate, are found in water collected from the water-table wells (figure 3). Nitrate was present in 71 percent (17 of 24) of samples from the water-table wells and in 25 percent (2 of 8) of the Memphis aquifer wells. The highest concentration of nitrate reported from the water-table wells was 6.18 mg/L, found in UR-9; whereas UR-22 had the highest concentration, 1.1 mg/L, of the wells completed in the Memphis aquifer.

In the nested wells, nitrate was not found in water from UR-25S or UR-25M, whereas nitrate was found in water from UR-13M (Memphis aquifer well) but not in water from UR-13S (water-table well). Dissolved oxygen concentrations were higher (5.8 mg/L) in the Memphis aquifer well than in the water-table well (0.2 mg/L) at this location. However, some error may have been introduced into the dissolved oxygen concentrations because of different sampling methods used for each aquifer due to low water levels in the Memphis aquifer. Water from the water table aquifer (UR-13S) was sampled with a pump whereas water form the Memphis aquifer (UR-13M) was sampled using a bailer, which may have allowed oxygen to be introduced into the sample.

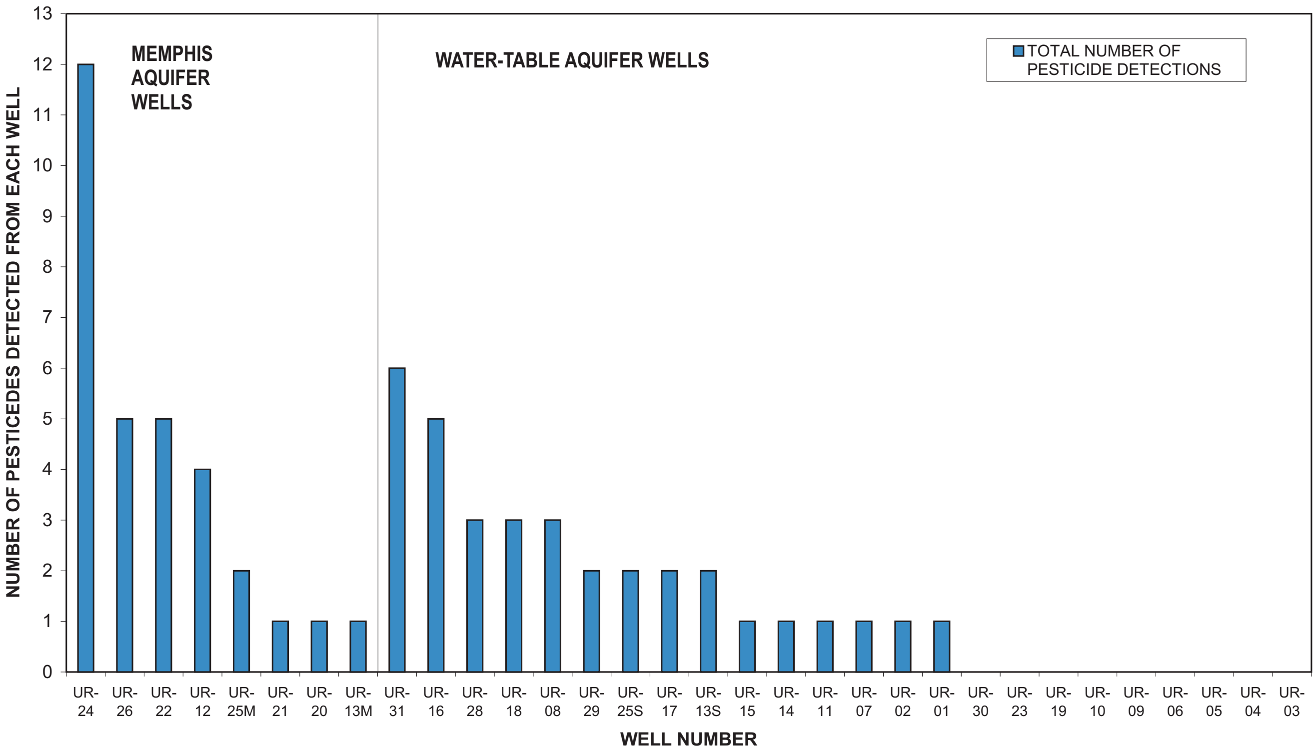

Figure 2. Total number of pesticides detected in water samples collected from each well in the study area.

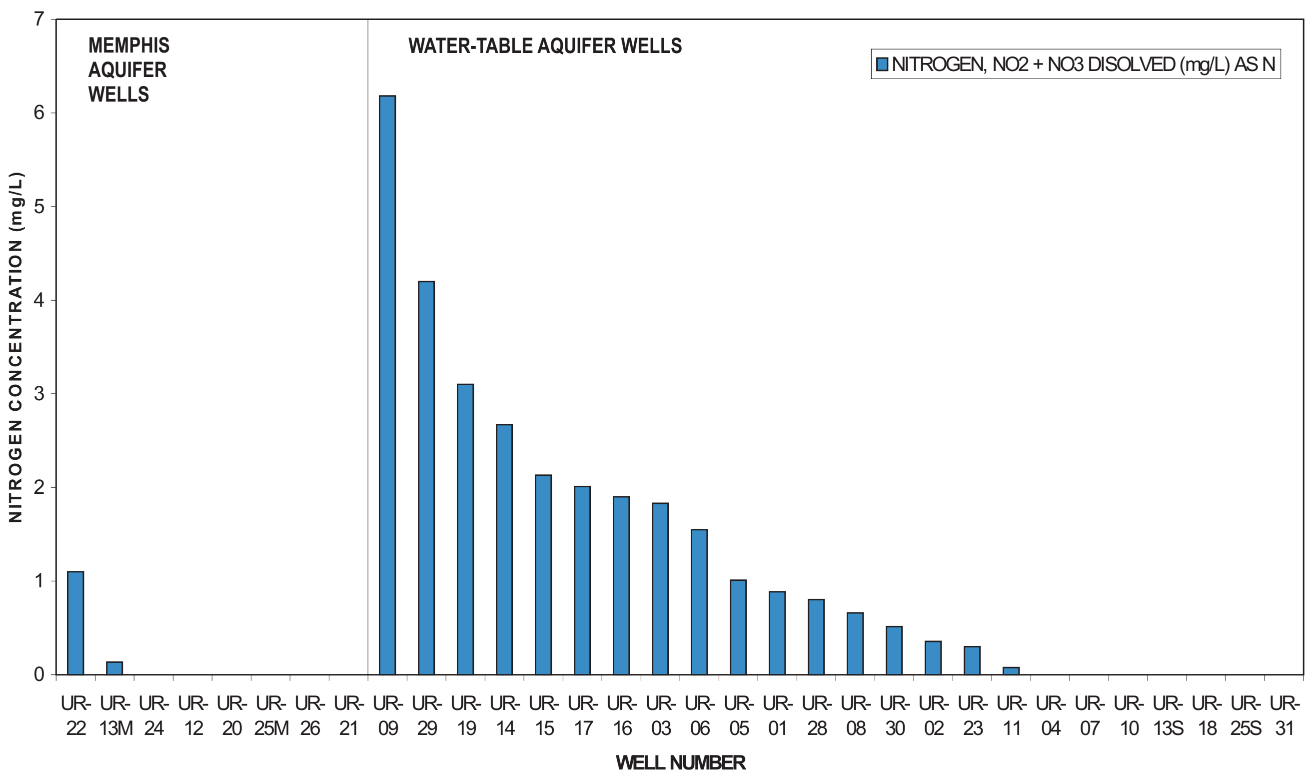

Figure 3. Nitrogen concentrations detected in water samples collected from each well in the study area.

Discussion

When interpreting the data from the water-table wells and the Memphis wells, it is important to keep in mind two limiting factors which make it difficult to compare the two types: 1.) Three times more water-table aquifer wells were sampled than Memphis aquifer wells. This skews the comparison of the two aquifers and also creates an unequal geographical distribution of the wells. 2.) The wells representing the Memphis aquifer are located in the upper 20 to 50 ft. (5 percent) of the Memphis Sand unit and may not represent the entire Memphis aquifer. However, because the hydrogeologic properties of the nested wells and wells located in areas where the upper confining unit is known to be absent are understood, the pesticide and nitrate data can be used to better understand the lateral discontinuity and heterogeneous nature of the upper confining unit.

The presence of pesticides, a strictly anthropogenic class of compounds, nitrate (which can have a natural and anthropogenic source), and dissolved oxygen in the Memphis Sand wells suggests recharge is occurring within the Memphis area probably due to a lack of homogeneity and continuity of sediments in the upper confining unit. Most of the pesticides investigated in this study are relatively water soluble and once introduced into the ground water, will generally stay in solution. Although the pesticides undergo microbial degradation, the process is slow. Therefore, these pesticides can be said to act as conservative tracers in the short term and once in the ground water, the concentrations should remain constant and move with ground water, subject to dilution and absorption phenomenon. Pesticide concentrations in ground water may not be uniformly distributed because of seasonal application. The variations in the pesticide concentrations throughout the water-table aquifer and Memphis aquifer are in part functions of the non-uniform distribution and the hydraulic conductivity of overlying units.

The two Memphis Sand wells in which the upper confining unit is known to be absent (UR-22 and UR-24) demonstrate a relation between direct recharge from the water-table aquifer and the number of pesticides and concentration of nitrate found in the water samples. Water analyzed from UR-24 had the highest number of pesticide detections and UR-22 tied for the second highest number of pesticide detections. The highest concentration of nitrate in the Memphis Sand wells was found in water collected from UR-22. Pesticides and nitrate both have surficial anthropogenic sources generally found in surface-water and shallow unconfined aquifers. The frequent occurrence of pesticides within the Memphis Sand wells, especially the two unconfined wells, may be an indication of a leaky upper confining unit.

Nitrate and dissolved oxygen concentrations in the nested UR-13S and UR-13M wells suggests that direct recharge occurs to the Memphis aquifer, even when the upper confining unit is locally present. Higher nitrogen concentrations and dissolved oxygen levels in UR-13M could be the result of surface recharge moving through horizontal paths in the upper confining unit created by faulting or channelization within the unit. Nitrate and dissolved oxygen are both used in reactions upon entering ground-water systems and are transformed. Therefore, it would be expected to find a decline in dissolved oxygen and nitrate concentration with deeper, older ground water.

Instead, in the case of UR-13S and UR-13M, the deeper aquifer contains higher concentrations of dissolved oxygen and nitrate. These higher concentrations at depth may indicate a discontinuity within the confining unit and recent infiltration or recharge from an indirect source unrelated to UR-13S.

Summary and Conclusions

The combination of pesticide and nutrient data from the NAWQA ground-water study along with earlier hydrogeologic investigations show that the Memphis aquifer can be subjected to localized surface-water contamination. A more specifically designed study with a greater number of wells is needed to more precisely quantify the discontinuity of the upper confining unit. Many studies and investigations are currently being conducted to gain a better hydrogeologic understanding of the aquifer system which supplies the Memphis, Tennessee, area.

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WATER MONITORING PROGRAM IN A RECHARGE AREA OF THE GUARANY AQUIFER IN SOUTH AMERICA

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The Guarany aquifer is the greatest groundwater reservoir of water in South America and its extension covers the central-south part of Brazil, northern Argentina and part of Uruguay and Paraguay. The region of Ribeirao Preto, Sao Paulo State, Brazil, is located on a recharge area of Guarany aquifer and has sugar cane as its main agricultural activity. Based on the use of a number of pesticides and fertilizers in the sugar cane crop management and the natural vulnerability of recharge area, the Brazilian Agricultural Research Agency (EMBRAPA-Environment) carried out a number of studies in this region to study the quality of the Guarany aquifer water from 1995 to 1999. Results of these studies are published in a number of papers and showed no evidence of contamination of Guarany aquifer water. Tebuthiuron, (N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N'-dimethylurea), is a phenylurea herbicide used in sugar cane for pre-emergence control of weeds and was one of the pesticides monitored in the area. During the years of 2000 and 2002, EMBRAPA-Environment and Dow AgroSciences established a partnership in order to continue monitoring tebuthiuron in wells used in this region to supply drinking water to the population of Ribeirao Preto city region. Nine different sampling points were selected in the region and their wells were sampled from November 2000 to November 2002, covering samplings in rainy and dry seasons during this period. An analytical method using HPLC and UV detection was established to perform residue analysis. The limit of quantification used was 0.1 µg/Kg (ppb, part per billion) for the first three sampling carried out and 0.03 µg/Kg for the following five samplings. The majority of samples showed no detectable residues of tebuthiuron and two samples showed residues below the 0.03 µg/Kg limit of quantification, well below EPA's Lifetime Healthy Advisory limit of 500 µg/L for tebuthiuron in drinking water. The results confirm no changes in the quality of water in this recharge area of Ribeirao Preto region for the specific compound monitored in the present study.

1. Introduction

The region of Ribeirão Preto city, located in Southeast of Brazil, São Paulo State, (Figure 1) is an important sugarcane producing area, with agrochemical utilization. This region is also an important recharge area for groundwater supply for the Guarany aquifer which comprises areas of eight Brazilian states plus parts of Argentina, Uruguay and Paraguay, with approximately 1,200,000 Km^2. Geological studies have identified a watershed (4000 ha) as very susceptible to groundwater contamination by agrochemicals, so it was chosen as research site to study the movement of different herbicides and other compounds, including tebuthiuron (1).

Figure 1. Map of South America showing the city of Ribeirao Preto, Brazil, where the watershed is located.

The intensive cultivation of sugar cane in that area has been demanding the constant use of pre-emergent herbicides. The behavior of those products in soil, normally reapplied annually, have been object of study "in loco" to analyze the risk of leaching to the groundwater. The high permeability of some soils present in the area, and products with high mobility, constitute factors that make important to study the movement of some compounds in the area. Also, 100% of water for urban consumption of cities close by is supplied by the aquifer. The purpose of this work was to monitor the herbicide tebuthiuron in municipal wells located at the edge of the watershed to make sure that the quality of the water will be preserved.

The herbicide tebuthiuron is regularly applied in the watershed (1). Tebuthiuron (N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N'-dimethylurea) is a phenylurea herbicide used in sugar cane culture for pre and post-emergence control of weeds (2). The herbicide is applied once or twice per crop cycle, which depend on crop variety but lasts about 5 to 6 years as an average. Application rate is about 1.0 Kg/ha (Kilogram per hectare) of active ingredient on the first treatment and reduced to about 50 to 70% of this rate in case of a second treatment during same crop cycle. Analysis of tebuthiuron and of other phenylurea herbicides in environmental samples can be performed by HPLC, or by gas chromatography using selective detectors such as nitrogen-phosphorus detector (NPD), electron-capture detector (ECD) or a mass spectrometer (MS), (3, 4, 5, 6).

2. Materials and Methods

The study area is located in Espraiado watershed, north of the São Paulo State, Brazil, in the municipal districts of Ribeirão Preto, Cravinhos and Serrana, in the geographical coordinates 21°05 ' and 21°20 ' of south latitude and 47°40'e 47°50' of west longitude. The climate of the area is tropical with dry winter savanna. The annual medium temperature is 22°C, with rain varying between 1300 and 1500 mm/year. The potential evapotranspiration reaches 1000 mm/year, based on the method of Thorntwaite. The area holds the Botucatu Aquifer where the recharge area and the watershed is located.

WATER SAMPLING. Water was collected from wells located at the edge of the watershed during the years of 2000 to 2002 using dark bottles. The water samples (1000 ml) were stored in amber flasks and kept at 4°C prior to extraction.

TEBUTHIURON DETERMINATION IN WATER. Tebuthiuron was analysed by HPLC using a Agilent model 1110 Series, Column Agilent Eclipse XDB-C8 5-Micron, 4,6 mm ID x 150 mm. Solid phase extraction was made with Octadecyl column C18, (SPE) J.T.Baker. Mobile phase was 40% acetonitrile + 60% water.

3. Results and Discussion

Efficiency of methodology was checked based on recoveries of fortified water samples performed on the range of 0.025 to 10 µg/Kg. Average from 39 recoveries performed during the 2 years is 90%. Overall standard deviation from same data points is 9%.

The statistical limits of detection and quantification (7), calculated as 3 and 10 times the standard deviation from the replicate analysis at quantification limit of analytical method (0.025 µg/Kg) resulted in 0.008 and 0.025 µg/Kg. The quantification limit of analytical method applied was 0.03 µg/Kg.

Typical calibration curve used in the study is presented in Figure 1.

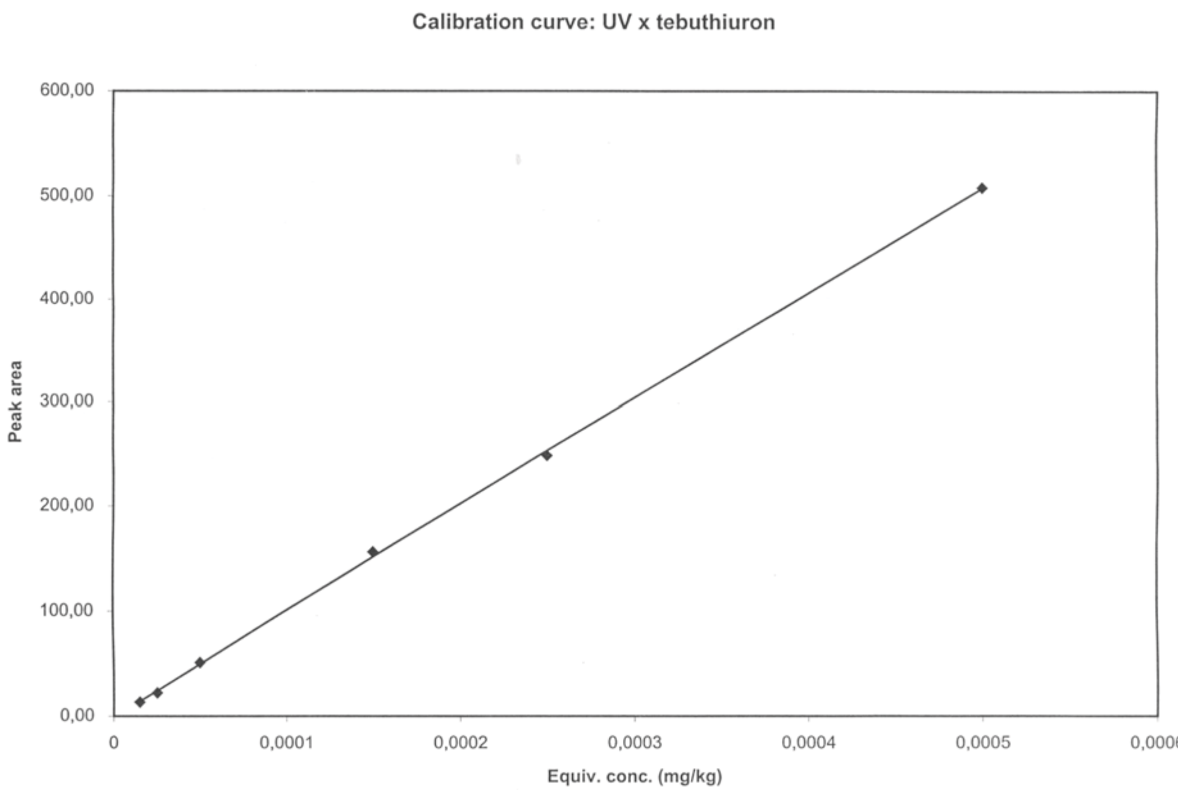

FIGURE 1. CALIBRATION CURVE FOR TEBUTHIURON ANALYSIS IN WATER ($Y = 1E+10^6X - 0.9847$).

Typical chromatograms of analytical standard solution at concentration of 0.05 ug/L and water sample collected in a Ribeirão Preto Municipal well are presented in Figures 2 and 3, respectively.

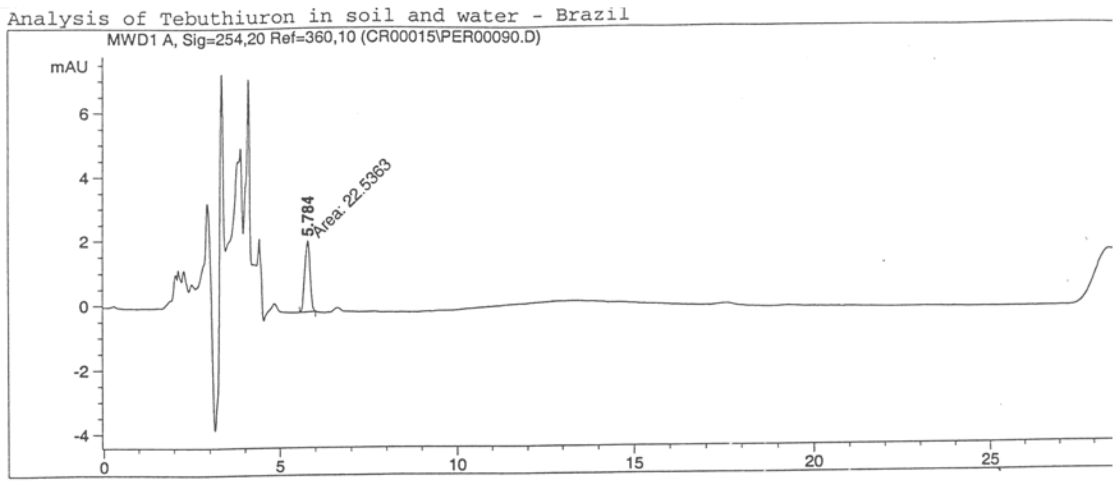

FIGURE 2- CHROMATOGRAM OBTAINED WITH THE HERBICIDE TEBUTHIURON IN WATER AS STANDARD (0.05 ug/L).

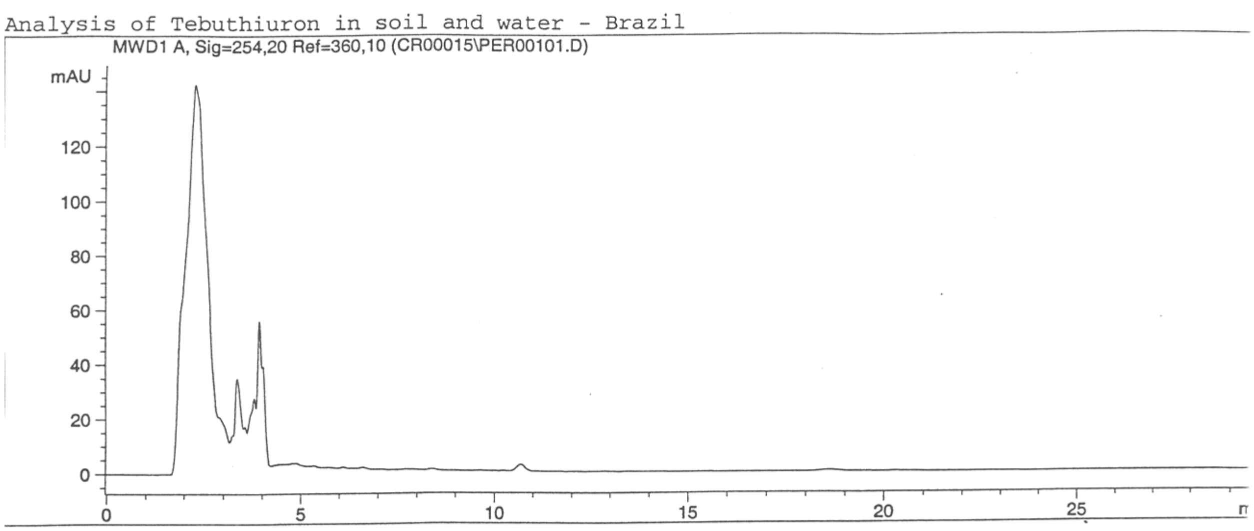

FIGURE 3- GENERAL CHROMATOGRAM OBTAINED FROM WATER COLLECTED FROM MUNICIPAL WELLS.

The majority of samples showed no detectable residues of tebuthiuron and two samples showed residues below the 0.03 μg/Kg limit of quantification, well below EPA's Lifetime Healthy Advisory limit of 500 μg/L for tebuthiuron in drinking water. Due to the difference between residues found in these two water samples and EPA´s limit no confirmatory study was made to certify if residues found were really related to tebuthiuron. Results are presented in Table 1.

	Date of Sampling								
WELLS	nov/00	apr/01	may/01	jul/01	nov/01	mar/02	apr/02	jun/02	nov/02
São Sebastião (Old)	ND	ND	ND		ND	ND	ND	ND	ND
Palmares	ND	ND	ND			ND	ND	ND	ND
JP Hotel	ND	ND	ND		ND	ND	ND	ND	ND
São José	ND	ND	ND		ND	ND	ND	ND	ND
Recreio Internacional	ND	ND	ND		<0,03	ND	ND	ND	ND
Higienopolis		ND	ND		ND	ND	ND		
DAERP Central		ND	ND		ND	ND		ND	ND
São Jose Farm				<0,03	ND				
Dow Cravinhos					ND				

TABLE 1. RESIDUES OF TEBUTHIURON (ppb) IN WATER FROM RIBEIRÃO PRETO MUNICIPAL WELLS . ND MEANS NOT DETECTABLE.

4. Conclusions

Results confirm no changes in the quality of water in this recharge area of Ribeirao Preto region for the specific compound monitored in the present study.

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FISH TISSUE CONTAMINANT CONCENTRATIONS IN REGIONS OF THE YALOBUSHA RIVER AND GRENADA RESERVOIR WATERSHED

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ABSTRACT

The Yalobusha River and its recipient, Grenada Reservoir, are frequently used by recreational and subsistence fishermen. The watershed is currently receiving major modifications designed to remedy widespread channel instability and flooding in the Calhoun City, MS, region caused by a large debris jam that has occluded the river channel. These remedial actions should decrease future fisheries contamination by decreasing contaminant inputs. To provide a base line of current contaminant concentrations in the system, we analyzed available data on metals, persistent pesticides, and PCB concentrations from 462 fish. Highest average arsenic (11.8 ppm), copper (2.26 ppm), and lead (0.318 ppm) tissue concentrations (viscera, flesh, and whole fish) were observed in the river downstream of the debris jam, while highest average concentrations of iron (137 ppm), chromium (0.308 ppm), cadmium (0.163 ppm) and zinc (18.46 ppm) occurred in Grenada Reservoir. Mercury was observed in similar concentration in fish from most watershed divisions (average 0.284 ppm) but was much lower in the Yalobusha River (0.065 ppm). DDT and metabolites (summed) were observed in highest average concentrations in fish tissues from the Yalobusha River upstream of the debris jam (327 ppb). Lowest average ΣDDT concentrations were observed from fish in tributaries, either upstream (14 ppb) or downstream (5 ppb) of the debris jam, and in the main body of Grenada Reservoir (20 ppb). PCBs were never detected in fish from Grenada Reservoir or watershed tributaries, and were only rarely detected from fish of the Yalobusha River. The persistent pesticide toxaphene was detected in only one fish, and chlordane, the third most common cause for advisories in the U.S., was never detected in fish during our study.

INTRODUCTION

Fish Contamination

Accumulation of pesticides and metals in fish is a topic of national (Research Triangle Institute 2001) and international concern (Costa et al. 1998, Bakre et al. 1990). World organizations such as the United Nations Food and Agricultural Organization (FAO) and World Health Organization (WHO) recognized the need for addressing possible hazards in food, and in 1962 established the Codex Alimentarius Commission (CAC) that is concerned with health of consumers. Since then, the CAC has studied contaminant levels in foods world-wide and provided draft maximum and guidance levels for some contaminants of edible fish (CAC 2003). The United States Environmental Protection Agency (USEPA) and U.S. Food & Drug Administration (USFDA) have ongoing programs of research concerning levels of contaminants in fish, and publish information and guidelines as well as concentrations of concern and tolerances for foods (Table 1). Estimates in the United States are that national consumption of prepared fish is approximately 5 grams/person/day (USEPA 2002a), yielding a total U.S. consumption rate of nearly 1.2 million kg / day. Within the State of Mississippi alone, over 430,000 residents go fishing each year (U.S. Department of the Interior and U.S. Department of Commerce 1998). Nationally, over 34.1 million U.S. residents engaged in fishing (U.S. Department of the Interior and U.S. Department of Commerce 2001) even while 28% of U.S. lake acres and almost 14% of U.S. river miles were under fish consumption advisories, mostly for the bio-accumulative pollutants mercury, PCB's, chlordane, dioxins and DDT (USEPA 2002b).

Some characteristics of water quality, biology and physical aspects of the Yalobusha River watershed and Grenada Reservoir have been investigated recently (Downs and Simon 2001, Shields et al. 2000, Jackson 2000, Cooper et al. 1998, Simon 1998) or in the past (Jackson 1993, Jackson and Jackson 1989, Fitzpatrick and Busack 1989, Cooper and Johnson 1980), but risk associated with contaminant levels in fish has been addressed only for mercury (Huggett et al. 2001) or superficially (Cooper et al. 1998). Contaminant levels in water and sediment throughout this watershed were recently published by Cooper et al. (2002). Extensive erosion of agricultural lands in this watershed has provided potential for fisheries contamination where large amounts of sediment and water carrying contaminants have been transported, deposited, and re-suspended during the past century. High concentrations of mercury in fish of this watershed recently caused the Mississippi Department of Environmental Quality (MDEQ) to issue a consumption advisory for the reservoir and river downstream of the dam (MDEQ 2001). The potential for decreased contamination of fish from current and future channel stabilization, flood control, and improved farming practices merits more detailed study, especially since the river and its downstream recipient, Grenada Reservoir, are frequently used by subsistence and recreational fishermen.

Table 1. United States Food & Drug Administration Environmental Contaminant Action Levels or Tolerances (USFDA 2001).

ANALYTE	LEVEL	FOOD
ARSENIC	76.0 mg kg^{-1}	Crustacea
ARSENIC	86.0 mg kg^{-1}	Molluscan bivalves
CADMIUM	3.0 mg kg^{-1}	Crustacea
CADMIUM	4.0 mg kg^{-1}	Molluscan bivalves
CHROMIUM	12.0 mg kg^{-1}	Crustacea
CHROMIUM	13.0 mg kg^{-1}	Molluscan bivalves
LEAD	1.5 mg kg^{-1}	Crustacea
LEAD	1.7 mg kg^{-1}	Molluscan bivalves
METHYL MERCURY	1.0 mg kg^{-1}	All fish
ALDRIN / DIELDRIN	300 µg kg^{-1}	All fish
BHC	300 µg kg^{-1}	Frog legs
ΣDDT, DDD, DDE	5000 µg kg^{-1}	All fish
HEPTACHLOR / HEPTACHLOR EPOXIDE	300 µg kg^{-1}	All fish
POLY-CHLORINATED BIPHENYLS (PCB's)	2000 µg kg^{-1}	All fish

Watershed and Reservoir

The U.S. Army Corps of Engineers (USACE) completed Grenada Reservoir, located in Grenada County, MS, in 1954. It is one of 555 reservoirs operated by the USACE out of approximately 2000 reservoirs controlled by the U.S. federal government (USACE 2000). Built primarily for flood control, the reservoir also serves for recreational activities, including swimming, fishing, and boating. It is one of over 3,300 reservoirs within the State of Mississippi referenced in the National Inventory of Dams (USACE 2000). Maximum storage capacity of Grenada Reservoir is approximately 3.33 trillion cubic meters (2.7 million acre-feet), about one tenth the capacity of the largest U.S. reservoir, Lake Mead, Nevada. Outlet gates control water level in Grenada Reservoir and normal elevation (National Geodetic Vertical Datum – NGVD) ranges from 59 m (193 ft) NGVD (40 km^2 or 9,800 acres of water) to a maximum flood control elevation of 70 m (231 ft) NGVD (261 km^2 or 64,600 acres of water). Water level is held at a recreational pool level of 65 m (215 ft) NGVD (145 km^2 or 35,820 acres of water) during the summer months. The reservoir's flood control purpose requires a summer/fall seasonal draw-down so that it will have maximum capacity for storing winter/spring rains (annual precipitation may exceed 140 cm). This practice causes annual exposure of large quantities of accumulated marginal lake sediments that are then subject to re-suspension mainly due to shallow wave action and rainfall.

Two rivers provide inflow into the reservoir, the Yalobusha to the south, and the Skuna to the north, creating a distinctive Y-shaped reservoir with two large lateral arms to the east and the main body westward. Flow within the watershed and the reservoir is from east to west, with controlled outflow from the reservoir into the Yalobusha River channel below the dam. Flow ultimately joins the Mississippi River along the western border of Mississippi via the Yazoo River that drains most of the northwestern region of the State. The contributing watersheds associated with the two river drainages differ in that the Yalobusha River watershed has a floodplain area of intensive agriculture, including large-scale production of sweet potatoes [Ipomoea batatus (L.) Lam.] rotated with cotton (Gossypium hirsutum L.), soybeans [Glycine max (L.) Merr.] and corn (Zea mays L.) centered around the towns of Calhoun City and Vardaman, while the Skuna River watershed is currently less agricultural and more silvicultural. Total watershed drainage area entering Grenada Reservoir from the two rivers and direct tributaries is approximately 3,419 square kilometers.

The entire Grenada Reservoir watershed has been impacted by channelization projects and additional channel incision that began in the early 1900s. With the exception of approximately 21 km (13 miles) in the Yalobusha River upstream of Grenada Reservoir, all of the river and major tributaries of the watershed have been channelized. Original channelization projects were conducted during the 1910s and 1920s. Repeated additional works were conducted in the late 1930s to 1950s when the Yalobusha River and Topashaw Creek, the major river tributary, became plugged with debris and sediment. Late in the 1960s the U.S. Department of Agriculture Soil Conservation Service began the last major series of watershed modifications above the reservoir, including extensive clearing and dredging of many channels and installation of numerous gully erosion control structures. Also during the 1960's some dredging was done in the upper reservoir, but the extent is unknown. A major cycle of channel incision, a current response to previous channelization efforts, is currently migrating up watershed streams (Simon and Thomas 2002).

Over the past decade, an occlusive debris jam has formed in the Yalobusha River upstream of the non-channelized portion of the river east of the reservoir. This debris jam, in excess of 2 km long and formed from eroded upstream materials, is forcing river flow into adjacent riparian floodplain bottomland forest and, occasionally, agricultural fields and homes. The USACE, under direction from Congress, is currently addressing this and other problems in the watershed through a system-wide approach. Tributary stabilization projects have already been enacted, and downstream (river stabilization and debris jam clearing) actions are underway. Since 1998, the USACE, Vicksburg District, has awarded nearly $10,000,000.00 in construction contracts associated with this watershed, with advance notice of additional contracts still pending. Construction efforts by contractors in the Yalobusha River watershed may increase short-term potential for runoff-related (often associated with suspended and dissolved solids) contamination in a region where intense agricultural production and actively eroding stream channels already produce high inherent risk. Although channel, bank and infrastructure work in the watershed including the debris jam in the main river channel has begun, data available through end of year 2002 indicated that concentrations of suspended or dissolved solids downstream of the work area had not increased (unpublished data, USDA-ARS-NSL-WQEPRU).

As the Yalobusha River watershed becomes more stable following completion of work, movement of contaminants from field soil, urban areas, and streambeds should be minimized and exposure to fish of the system should decrease. Bio-available contaminants in the streams, Yalobusha River and Grenada Reservoir should decrease, allowing current concentrations of these contaminants in fish to also decline. In order to provide for future comparison of fish contaminant levels, we herein present metal, pesticide and PCB concentrations from fish collected in the various regions of this watershed.

METHODS

We analyzed available data on metals, persistent pesticides, and PCB concentrations from over 450 fish taken from the Yalobusha River watershed and Grenada Reservoir between years 1996 and 2003. Fish were collected using backpack electroshockers in wadeable streams. Boat-mounted electroshocker or hoop or gill nets were used in non-wadeable river sites and Grenada Reservoir. Fish were identified, measured to the nearest 1 mm, weighed to the nearest 1 g (except large fish > 4 kg weighed to the nearest 0.1 kg), and placed on ice for transport. In some cases, fish of the same species or trophic and size class were composited, resulting in 118 total chemical analyses for up to 46 analytes from 462 individual fish.

For comparison, the Yalobusha River watershed and Grenada Reservoir were divided into several geomorphologic regions of interest, including tributary and river sites upstream and downstream of the debris jam, a new natural channel bypassing the debris jam, the main body and Skuna and Yalobusha river arms of Grenada Reservoir, and the spillway channel below the reservoir. All species and age / size classes of fish were not collected at all locations, and thus direct comparisons of data were not always possible. Sources of pesticide and metal contaminants addressed in this study included both recent releases of agricultural, industrial and urban compounds, as well as unwanted legacy compounds from watershed sources or sinks, the most common source being sediment in runoff from agricultural fields and the most common sink being deposited sediments.

Table 2. Methods used and method detection limits (MDL) for quantifying metal concentrations during this study. Information for pesticides is given in the text.

ANALYTE	METHOD	MDL µg kg^{-1} [ppb]
ARSENIC	EPA 206.2	1
CADMIUM	EPA 200.7	1
CHROMIUM	EPA 200.7	2
COPPER	EPA 200.7	3
IRON	EPA 200.7	2
LEAD	EPA 200.7	15
MERCURY	EPA 245.1	0.1
ZINC	EPA 200.7	3

Tissues analyzed included skinless flesh (muscle fillets), viscera (all contents of the abdominal cavity), and whole-fish (usually for small-sized species such as minnows, shiners, and some Centrarchidae or smaller age / size classes of other species that would typically be eaten whole by predators). Large and predatory fish were skinned and the body muscle was filleted to obtain flesh samples. Viscera samples from large and predatory fish were a composite of all contents of the abdominal cavity exposed by cutting from between the pectoral fins to the anal opening. For obtaining tissue samples, we used cleaned stainless steel knives. Samples were sealed in aluminum foil (dull-side-in), labeled, and placed in sealed plastic bags, then frozen until prepared for contaminant analyses.

Analytes were quantified at the University of Louisiana Monroe Soil-Plant Analysis Laboratory using ASTM and USEPA approved methods. Priority pollutant pesticides and polychlorinated biphenyls (PCBs) were tested according to EPA method SW 846:8140 with a detection limit of 1 µg kg^{-1}. Methods and detection limits for analyses of metals were as indicated in Table 2. Number of samples of each tissue type of each fish species analyzed is given in Table 3.

RESULTS

Metal Concentrations

Overall average concentration of metals (mean of all locations and sample types) is presented in Table 4. Highest watershed location average arsenic (11.8 ppm), copper (2.26 ppm) and lead (0.318 ppm) fish tissue concentrations (combined data from viscera, flesh, and whole fish tissue sample types) from the different geomorphic areas studied were observed in the Yalobusha River downstream of the debris jam, while highest average concentrations of iron (137 ppm), chromium (0.308 ppm), cadmium (0.163 ppm) and zinc (18.46 ppm) occurred in Grenada Reservoir. Mercury was observed in similar concentration in fish tissues (all sample types combined) from most watershed divisions (average 0.284 ppm) but was considerably lower in fish from the tributaries upstream of the debris jam (0.146 ppm), the new bypass channel (0.122 ppm) and in the Yalobusha River (0.065 ppm). Highest observed overall mean mercury concentration (all sample types combined) for a location was at the spillway region of the Yalobusha River downstream of Grenada Reservoir (0.423 ppm). Mean mercury concentration in fish of Grenada Reservoir was 0.351 ppm.

Flesh (fillet)

Largest observed average metal concentrations for the flesh of a single fish species were for iron (28.543 ppm) and zinc (12.725 ppm) in Largemouth Bass. The highest observed mean flesh concentration of arsenic was 7.050 ppm for channel catfish. Cadmium was detected in flesh only of Largemouth Bass (0.020 ppm). Highest observed chromium was seen in white bass (0.335 ppm) and Blue Catfish (0.195 ppm), while copper was highest in flesh of Largemouth Bass (0.676 ppm) followed by Common Carp (0.573 ppm). Greatest mean concentration of mercury

Table 3. Common name and scientific name of fish from which tissue samples were analyzed during this study. Trophic groups were: 1 omnivores; 3 general invertivores; 4 benthic invertivores; 5 piscivores and large invertivores; 6 planktivores (group 2, herbivores, were not encountered during sampling efforts). Habitat orientations were: A surface; B littoral; C benthic; D general; E pelagic.

Species	Scientific Name	FLESH	VISCERA	WHOLE	Number of Fish	Trophic Group	Habitat Orientation
Bigmouth Buffalo	Ictiobus cyprinellus	1	1	0	1	4	C
Black Buffalo	Ictiobus niger	2	2	0	2	4	C
Blackspotted topminnow	Fundulus olivaceus	0	0	45	45	3	A
Blue Catfish	Ictalurus furcatus	2	1	0	2	1	C
Bluegill	Lepomis macrochirus	0	0	33	33	3	D
Channel Catfish	Ictalurus punctatus	2	2	6	8	1	C
Common Carp	Cyprinus carpio	6	3	0	6	1	C
Creek Chubsucker	Erimyzon oblongus	0	0	9	9	1	C
Flathead Catfish	Pylodictis olivaris	2	1	6	8	5	C
Gizzard Shad	Dorosoma cepedianum	1	1	52	53	6	E
Golden Shiner	Notemigonus crysoleucas	0	0	9	9	6	A
Green Sunfish	Lepomis cyanellus	5	0	161	166	4	D
Largemouth Bass	Micropterus salmoides	15	4	1	16	5	B
mixed Cyprinids	Cyprinidae genus spp.	0	0	50	50	3	D
mixed Lepomis	Lepomis spp.	0	0	13	13	3	D
Smallmouth Buffalo	Ictiobus bubalus	17	10	0	17	3	C
Spotted Gar	Lepisosteus oculatus	2	2	0	2	5	B
Spotted Sucker	Minytrema melanops	1	1	0	1	4	C
Warmouth	Lepomis gulosus	1	0	5	6	3	C
White Bass	Morone chrysops	3	0	0	3	5	E
White Crappie	Pomoxis annularis	7	2	5	12	5	D
Grand Total	-	67	30	395	462	-	-

in flesh was observed for Bigmouth Buffalo (0.649 ppm) and Largemouth Bass (0.563 ppm). Lead was never detected in fish flesh.

Viscera

Greatest average viscera concentrations of arsenic occurred in Gizzard Shad (58.350 ppm), while Cadmium was observed only in viscera of Common Carp (0.045 ppm) and Largemouth Bass (0.035 ppm). Chromium was most concentrated in viscera of Largemouth Bass (0.815 ppm) and Bigmouth Buffalo (0.270 ppm). Greatest observed copper concentrations in viscera were in Bigmouth Buffalo (7.68 ppm) and Common Carp (6.603 ppm). Iron was most concentrated in viscera of Common Carp (378.3 ppm) and Largemouth Bass (306.475 ppm). Highest observed concentration of lead in viscera was in Smallmouth Buffalo (2.065 ppm), followed by Bigmouth Buffalo (0.255 ppm) and Largemouth Bass (0.180 ppm). Mercury in viscera of a large (> 12 kg) Blue Catfish exceeded 1.4 ppm (its flesh contained 0.329 ppm), followed by that of Spotted Gar (0.443 ppm). Zinc concentrations were similar in several species encountered (Common Carp 13.665 ppm, Largemouth Bass 13.165 ppm, Blue Catfish 10.95 ppm, Flathead Catfish 10.53 ppm) but were considerably higher in Bigmouth Buffalo (28.74 ppm) and lower in White Crappie (3.6 ppm).

Whole-fish

Highest mean observed concentrations of arsenic in whole fish analyses were for Blackspotted Topminnows (3.895 ppm) and Green Sunfish (3.32 ppm). Chromium and copper were highest in mixed *Lepomis* spp. (0.453 and 1.628 ppb respectively). Iron concentrations in Gizzard shad (202.746 ppm) were more than 4 times greater than the next lower observed concentration (mixed *Lepomis* spp., 49.988 ppm). Lead in whole fish samples was only observed in Gizzard Shad (0.004 ppm). Mercury concentrations were very similar in Blackspotted Topminnows (0.391 ppm), small Flathead Catfish (0.361 ppm), Green Sunfish (0.337 ppm), and small Channel Catfish (0.334 ppm). Zinc was more than twice as concentrated in mixed Cyprinidae (41.235 ppm) than in any other tested species.

Table 4. Overall mean concentrations of metals found in fish tissue from the Yalobusha River watershed and Grenada Reservoir.

ANALYTE	Mean Concentration mg kg^{-1} [ppm]
ARSENIC	2.248
CADMIUM	0.028
CHROMIUM	0.200
COPPER	1.011
IRON	54.017
LEAD	0.049
MERCURY	0.284
ZINC	10.148

Pesticide Concentrations

Overall average concentrations of pesticides and PCBs from the study region are presented in Table 5. Location comparisons revealed that DDT and metabolites (summed, SDDT) were observed in greatest observed average concentrations in fish tissues from the Yalobusha River upstream of the debris jam (327 ppb), in the new channel bypassing the debris jam (251 ppb), the river downstream of the debris jam (243 ppb) and in the spillway channel below the reservoir (224 ppb). Lowest average SDDT concentrations were observed from fish in tributaries, either upstream (14 ppb) or downstream (5 ppb) of the debris jam, and in the main body of Grenada Reservoir (20 ppb).

SDDT invariably had the highest pesticide contamination levels that we observed, regardless of tissue type or fish species. The mean concentration of SDDT for flesh (fillet) samples was highest in Spotted Gar (378.25 ppb), followed closely by flesh of Common Carp (368.94 ppb). Viscera concentrations of SDDT were greatest for Largemouth Bass (745.758 ppb), White Crappie (564.81 ppb), Spotted Gar (532.15 ppb), and Flathead Catfish (530.1 ppb). Of the whole-fish samples tested, small Channel Catfish (167.9 ppb), Bluegill (149.83 ppb), and small Largemouth Bass (90.0 ppb) had much greater concentrations of SDDT than other tested species.

Other (non-DDT) notable pesticide compounds found in flesh samples at mean concentrations greater than 25 ppb included Endosulfan Sulfate (Spotted Gar, 47.54 ppb), SBHC (Gizzard Shad, 41.2 ppb), Cyhalothrin (Gizzard Shad, 41.2 ppb), and Atrazine (Black Buffalo, 27.91 ppb). Non-DDT compounds found in viscera samples at concentrations greater than 50 ppb included SBHC (Gizzard Shad, 152.7 ppb), Endrin (Channel Catfish, 100.05 ppb), Endosulfan II (Spotted Gar, 90.7 ppb), and Endosulfan Sulfate (Common Carp, 79.1 ppb; Spotted Gar, 51.95 ppb).

Of whole-fish samples analyzed, non-DDT compounds encountered at concentrations above 5.0 ppb included only Endosulfan Sulfate (Bluegill, 12.237 ppb), Dieldrin (mixed *Lepomis* spp., 10.07 ppb), Heptachlor (Bluegill, 8.685 ppb; Channel Catfish, 5.989; Gizzard Shad, 5.24 ppb), Endrin (Bluegill, 7.055 ppb), and SBHC (Bluegill, 6.777 ppb; Green Sunfish, 5.725).

PCB Concentrations

PCBs were never detected in fish from Grenada Reservoir or watershed tributaries, and were rarely detected from fish of the Yalobusha River. Only four detections of PCBs occurred in our analyses, and all four were in flesh (fillet) samples taken from fish in the Yalobusha River main channel upstream of the debris jam. One occurrence was in a Common Carp weighing 2.37 kg (Aroclor 1260, 1.6 ppb), and the other three were from Smallmouth Buffalo weighing 1.97, 2.44, and 2.54 kg individually. Aroclor 1242 was detected (2.0 and 1.7 ppb) in the two largest Buffalo, and Aroclor 1260 was detected (2.3, 3.5, and 3.9 ppb) in all three Buffalo. All of these fish found to contain PCBs were approximately 0.5 m in body length.

DISCUSSION

Contaminant flow in surface water runoff or aerial deposition to receiving surface waterbodies results in rapid exposure of contaminants to humans. This is especially true where the receiving waterbodies are lakes or reservoirs where recreational activities involve direct physical contact with contaminated waters and subsistence and recreational fishing leads to consumption of fish that have bio-accumulated contaminants (pesticides and metals).

Table 5. Overall mean concentrations of pesticides and PCBs found in fish tissue from the Yalobusha River watershed and Grenada Reservoir.

ANALYTE	Mean Concentration $\mu g\ kg^{-1}$ [ppb]
DDE 4,4'	117.372
DDD 4,4'	36.589
DDT 4,4'	12.792
ENDOSULFAN SULFATE	5.156
ENDRIN	4.380
HEPTACHLOR	3.404
BHC-GAMMA	3.158
ENDOSULFAN II	1.917
ATRAZINE	1.269
DIELDRIN	0.989
ENDOSULFAN I	0.769
CYHALOTHRIN (KARATE)	0.747
BHC-BETA	0.746
BHC-DELTA	0.521
BHC-ALPHA	0.456
HEPTACHLOR EPOXIDE	0.433
ALDRIN	0.406
ENDRIN ALDEHYDE	0.374
TOXAPHENE	0.169
FLUOMETURON	0.116
PCB (AROCLOR 1260)	0.096
PCB (AROCLOR 1242)	0.031
CHLORDANE	0.000
PCB (AROCLOR 1016)	0.000
PCB (AROCLOR 1221)	0.000
PCB (AROCLOR 1232)	0.000
PCB (AROCLOR 1248)	0.000
PCB (AROCLOR 1254)	0.000
PENDIMETHALIN (PROWL)	0.000
ALDICARB (TEMIK)	0.000
METHYL PARATHION	0.000

North Mississippi has a combination of the world's most erosive soil and high annual rainfall, much of which is associated with high-intensity storm events. Because of these factors and past landscape–scale farming and drainage practices, a landscape scale erosion control and stream stabilization project on the Yalobusha River watershed is being executed by the USACE [Demonstration Erosion Control Project in the Yazoo Basin (DEC)]. Predictions of increased annual precipitation associated with higher-intensity rainfall events point to even greater risk of contaminant runoff and related environmental and ecological damages in upcoming years (SWCS 2003). Increased precipitation, occurring in the already high-average-precipitation region of the southeastern United States, also means more risk of precipitated atmospheric metals, especially mercury (Raloff 2003).

Huggett et al. (2001) reported mercury levels in flesh of fish from Enid Lake, a nearby north Mississippi reservoir, finding highest mean concentrations in Gar (*Lepisosteus* spp.) (1.890 ppm), Black Crappie (1.690 ppm) and Largemouth Bass (1.40 ppm), and lower concentrations in catfish (0.820 ppm) and carp (0.634 ppm). Their analyses, however, included only three samples (fish fillets) each of carp, gar, and crappie, four of catfish, and five of bass. A more comprehensive sampling of fish is needed to adequately characterize tissue mercury concentrations for the entire reservoir. Also, no fish tissue was sampled or analyzed from the contributing streams and rivers during that study. Their finding of high mercury levels in fish of that reservoir may support inference of atmospheric deposition as the source, as atmospheric concentration of mercury has been estimated to have increased 200% to 600% since the industrial revolution (circa 1880 to present; Keating et al. 1997, Mason et al. 1995a). Deposition from the atmosphere has been shown to have increased 20-fold over the same period (Schuster et al. 2002), accumulating in various components of the environment (ocean water, Mason et al. 1995b; freshwater wetlands, Zillioux et al. 1993; lake sediments, Lindqvist et al. 1991). Conversely, of all fish sampled during our study of Grenada Reservoir only one large Largemouth Bass (460 mm length, weight 1.53 kg) had a flesh concentration of mercury above the USFDA action level of 1 ppm, and that single fish (of fifteen sampled) was only slightly (1.032 ppm) above the level.

In a large natural water body in the State of Washington, Mueller and Serdar (2002) found highest flesh levels of mercury in predaceous Smallmouth Bass (0.49 ppm), followed by the omnivorous yellow perch (0.20 ppm) and Brown Bullhead (0.16 ppm), then zooplanktivorous Kokanee (0.12 ppm), benthivorous Pumpkinseed (0.10 ppm), and herbi-detritivorous Signal Crayfish (0.10 ppm). Most bass from our study contained similar concentrations of mercury regardless of size. A Bigmouth Buffalo captured in our study had more concentrated flesh mercury levels than bass (mean for species), and it was a large, older fish (> 6.25 kg weight, 68 cm length). Overall, however, significant relationships between fish size and mercury concentration could not be developed.

An examination of the contaminant data by trophic groups and habitat preferences provided some insight into the distribution of the contaminants within the ecosystem. Trophic groups of omnivores, bottom feeders and piscivores contained the greatest concentrations of arsenic and mercury in both flesh and viscera, highlighting the widespread ecosystem contamination. Bottom feeders ingest sediment and benthic invertebrates that are known accumulators of sediment-bound contaminants (Steingraeber and Wiener 1995). Piscivores commonly exhibit notable pesticide concentrations since they are at the top of the aquatic food chain. Cooper and Knight (1987) in a study of Lake Chicot, Arkansas, reported that bottom feeders and piscivorous fishes had higher concentrations of pesticides than did other groups of fishes.

Of the legacy pesticides, SDDT had the greatest concentration in flesh or viscera samples at all locations except Grenada Lake proper and the tributaries of the Yalobusha River. While tributaries harbored notable concentrations of SDDT (Cooper et al. 2002), many had little moveable fine sediment (mainly sand or hard clay bottoms). River dwelling fish have been exposed to contaminated sediments eroded from the tributaries in past years, as evidenced by accumulations in the debris jam, river downstream of the jam, and in the reservoir. However, no DDT was detected in stream water. Cooper et al. (2002) detected only 8 of 25 residual pollutants in reservoir sediment samples, while twice that number, 16, were detected in stream sediments. As with metals, omnivores, piscivores and bottom feeders had the greatest pesticide concentrations per species. Other legacy pesticides were also found in gizzard shad, suggesting transfer of pesticides by plankton. In samples of whole fish, sunfish and shad were important concentrators of legacy pesticides.

The highest number of detections and highest average concentrations of persistent pesticides were observed from the Yalobusha River and new bypass channel around the debris jam where sediments are actively accumulating. Metals and SDDT were associated with bottom feeders and piscivores, but concentrations varied more with individuals than with location or some dominant species. Overall, DDT and metabolites were the most pervasive and concentrated pesticide compounds observed.

PCBs were rarely detected from fish of the Yalobusha River and never detected from other watershed regions or from Grenada Reservoir. Chlordane, the third highest cause of fish advisories nationally in the U.S., was never detected in our study, and we detected toxaphene, still a concern in the nearby Mississippi Delta region, in only one fish.

Annual reservoir draw-down, with associated re-suspension and export of sediments, may contribute to the observances of highest levels of mercury and moderate levels of DDT in fish of the Yalobusha River downstream of the reservoir spillway. Previous observations of mercury and DDT in sediments were greater in Grenada Reservoir than in river sites (Cooper et al. 2002). Since a major metal and pesticide source is farmed watershed soils, erosion control by the DEC project should lessen continuing contamination associated with runoff and sediment transport that is flowing through the Yalobusha River and entering Grenada Reservoir. In so much as levels of legacy pesticides have reached non-detectable concentrations in stream and lake water, contamination in fishes should be expected to decline in future years.

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USDA NONDISCRIMINATION STATEMENT

SPATIAL TECHNOLOGIES ASSESSING RURAL SEPTIC SYSTEMS (STARSS)

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Over one third of Mississippi residents depend on septic systems to dispose of household waste water. Septic system failure is particularly a problem in fast growing rural areas. The Spatial Technologies Assessing Rural Septic Systems (STARSS) project plans to locate and map these problems using mobile computing, field mapping, remote sensing, and GIS technologies.

In many cases, the locations of rural septic systems are poorly mapped and only known to workers. The STARSS pilot project effort is directed at developing a GIS/GPS field application for septic system mapping, inspection, and fault reporting. The intended product is a simple, user friendly, portable application to standardize the locating and mapping of the septic system while providing attribute information of the location. The custom application being developed will leverage PDA, GIS, and GPS technologies. The application will integrate selected basemap information downloaded from a server in a seamless application for the user and will have custom menus and interfaces that meets the field mapping needs of the application.

The STARSS project is funded by the MSU GeoResources Institute (GRI) and Mississippi's Water Resources Research Institute's (WRRI) Southeastern Regional Small Drinking Water Systems Technical Assistance Center through a U.S. Environmental Protection Agency grant.

NOTES:

Conserving Mississippi's Freshwater Biodiversity

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Abstract

The southeastern United States harbors a rich diversity of freshwater species and ecosystems. In particular, Mississippi contains a spectacular diversity of aquatic plants and animals throughout its many watersheds, from coastal black water systems to lower Appalachian Tennessee River systems. Certain incompatible human uses of Mississippi's natural resources pose potential threats to this natural heritage, and many entities, including non-profit organizations, governmental agencies, local community groups and private sector companies are increasing their efforts to protect water quality, quantity and biodiversity within the State. Limited resources, however, require their efforts be carefully planned and focused to increase the probability of successful conservation and thus have a positive impact on aquatic natural resources. The Nature Conservancy (TNC) has been active in biological conservation of Mississippi's natural resources for many decades. In recent years, the Mississippi (MS) Chapter of TNC has focused resources and efforts on protecting and restoring the biodiversity of Mississippi's freshwater ecosystems. Through a process called Conservation by Design, freshwater conservation areas of biodiversity significance have been identified and prioritized and the development of plans to conserve and or protect these areas is underway. The next steps for the MS chapter of TNC will be to implement these conservation plans, measure the success of our conservation efforts and continue to revise the conservation plans as data and information become available. A major factor in the success of our conservation efforts will rely upon how well the community is engaged in the process, partnering with local, state and federal government agencies, using scientific data as the foundation of the process and obtaining adequate funding for the planning and implementation of the conservation strategies.

Key Words

freshwater conservation, freshwater biodiversity, conservation planning

Introduction

The Nature Conservancy (TNC) is a non-profit organization whose mission is to preserve the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive. The conservation goal of TNC is the long-term survival of all representative types of viable native biological species and communities. The Mississippi Chapter of the Nature Conservancy was established in 1989, however the Nature Conservancy has been actively engaged in conservation in Mississippi since the 1970's, mainly through land acquisition. The Nature Conservancy also helped to establish the Mississippi Natural Heritage Program in 1976, which identifies the state's most significant natural areas through a comprehensive inventory of rare plant and animal species, exemplary natural communities, special geological features, and significant natural areas.

The importance of preserving biodiversity has been documented extensively (Wilson 1992, Norton 1988, McNeely et al. 1990, Ehrlich and Ehrlich 1981, Myers 1992 and Plotkin 1988) and includes major benefits such as: maintaining ecosystem integrity, water recycling and purification, aiding plant pollination, generating and maintaining productive soils, production of foods and medicines, providing biological pest control, offering recreation, assisting in the bioremediation of chemical pollutants and advancing biotechnology. Annual U.S. economic benefits of biodiversity are estimated at 300 billion dollars (Pimental et al. 1997). This does not take into account the many benefits that have not yet been discovered.

Historically, much of TNC's focus has been on the conservation and protection of terrestrial biodiversity. In recent years, however, TNC has committed to focusing resources and efforts to the preservation and conservation of aquatic ecosystems, both freshwater and marine.

Freshwater biodiversity in the United States is known to be rich and diverse and a large portion of the world's freshwater species occur in the U.S. (Master et al. 1998) (Table 1). Further, the southeastern United States is remarkably rich in aquatic species (Table 2).

Table 1. Global Significance of U.S. Freshwater Species

Taxonomic Group	Percentage of Known Species Worldwide Found in U.S.
Fishes	10
Crayfishes	61
Freshwater Mussels	30
Freshwater Snails	15
Stoneflies	40
Mayflies	30
Caddisflies	13
Dragonflies and Damselflies	8

Table 2. Significance of Southeastern U.S. Freshwater Species

Taxonomic Group	Percentage of U.S. Species Found in Southeast	Percentage of North American Species Found in Southeast
Fishes	62	
Crayfishes	90	
Freshwater Mussels	91	
Freshwater Snails	61	
Stoneflies		32
Mayflies		39
Caddisflies		40
Dragonflies and Damselflies		48

It has the richest fish diversity (686 species) and highest number of endemic fishes in North America north of Mexico (Warren et. al. 2000). Ninety-one percent (269 of 297) of all mussels in the United States occur in the southeast (Neves et. al. 1997). There are 313 species of freshwater snails in this region, 61% of the U.S. total. Estimates show that freshwater crustaceans, including both cave and surface dwellers, are the most diverse in the U.S. (Hobbs 1992).

This diverse assemblage of species, occurring in freshwater ecosystems of the southeastern U.S. is highly imperiled. Almost 50% of the most imperiled freshwater regions in the U. S. occur in the southeast (Master et. al. 1998). Sixty percent of mussels and 28% of fishes are in jeopardy. In the southeast, the aquatic fauna has experienced one of the highest rates of extinction in the continental U.S. (Warren et. al. 2000). This is especially true for the freshwater snails and mussels, with 38 and 36 species known to be extinct.

There are many stresses and sources of stress, together called "threats", affecting aquatic communities and species in the southeast. In most freshwater ecosystems, there are several stresses acting on the community simultaneously, resulting in degradation of the ecological integrity and ultimately the extinction of species. Of the many stresses that exist, TNC has identified three major stresses:

- In-stream habitat and hydrologic alteration
- Water quality pollutants (mainly sedimentation, organic enrichment and nutrification)
- Predation and competition from invasive species

In light of these circumstances, the MS Chapter of TNC has developed and initiated a freshwater conservation program focused on meeting the mission and conservation goal of TNC.

The Nature Conservancy's Conservation Approach

In order to meet its ambitious mission, TNC has developed a strategic, science-based planning process, called *Conservation by Design* (CBD), which helps identify the highest-priority places that, if conserved, promise to ensure biodiversity over the long term. In other words, CBD provides a framework for achieving meaningful, lasting conservation results. The MS Chapter f TNC utilizes the process of CBD in its conservation efforts, including freshwater conservation. Conservation by Design involves four main steps (Figure 1):

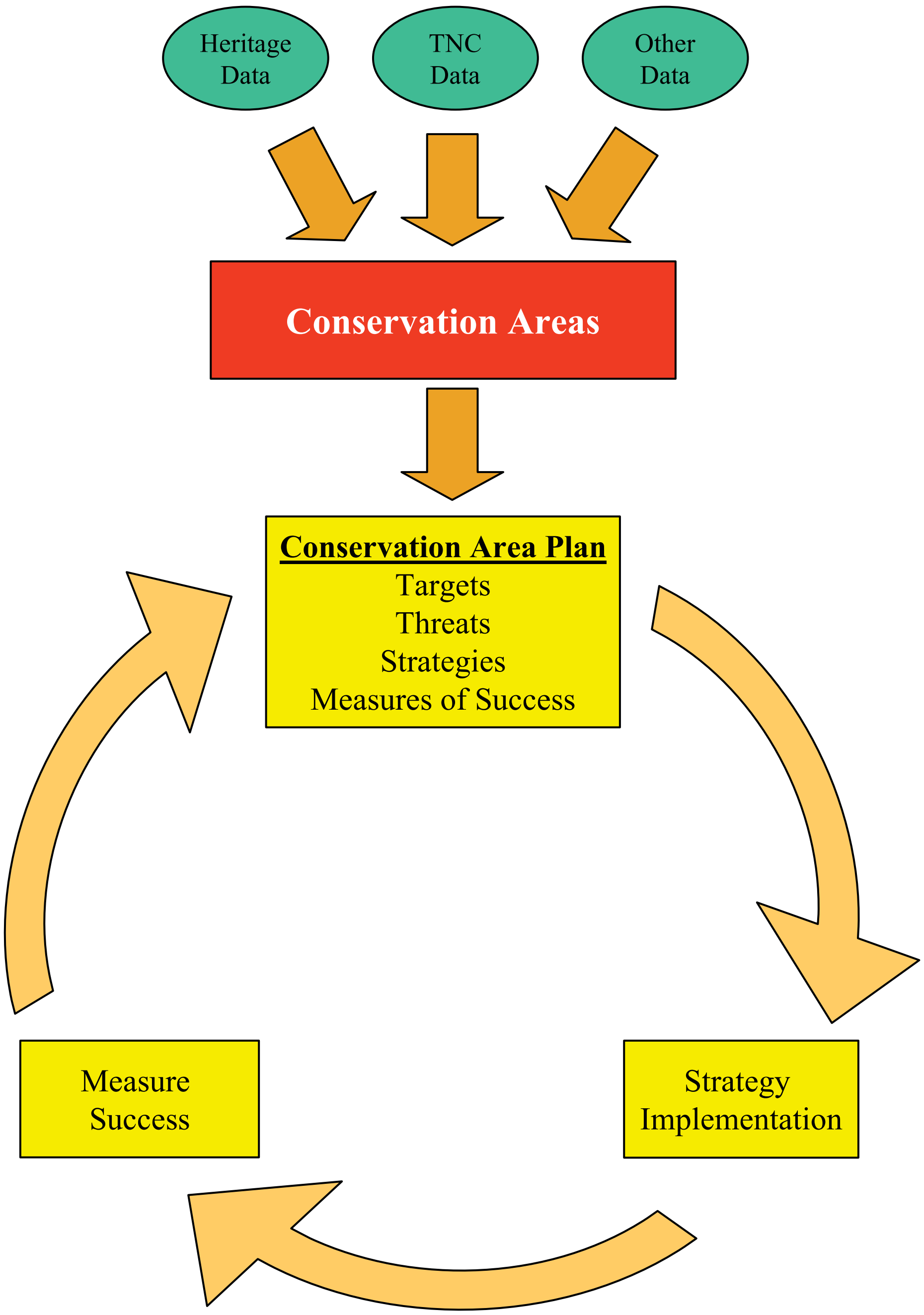

Figure 1. Conservation by Design

- Step 1. Identify and Prioritize Conservation Areas
- Step 2. Develop a Conservation Area Plan for each Conservation Area
- Step 3. Implement the Conservation Area Plan
- Step 4. Perform Measures of Success to evaluate the progress of implementation

Step 1. Identify and Prioritize Conservation Areas

The first step in CBD involves the identification and prioritization of areas of biodiversity significance. Areas of biodiversity significance are those that if protected or restored the mission and conservation goals of TNC will be met. Specifically, these biodiversity significant areas contain rare, endemic or imperiled species, represent a wide range of natural and unique biological communities, and/or are good examples of ecologically significant ecosystems.

The identification process involves gathering data and information, identifying potential conservation target species, communities and systems, assessing the viability of the targets, and developing portfolios of conservation areas using these data. Sources of data and information for identifying portfolio conservation areas include TNC Ecoregional Planning Process, Natural Heritage Programs, TNC's Freshwater Initiative Program, government agencies, remote sensing data warehouses, and regional expert workshops.

The prioritization process involves consideration of several priority factors, scoring these factors for each portfolio area and ranking the areas according to their scores. The factors used to prioritize portfolio areas are:

- Conservation value
- Viability of targets
- Severity and scope of threats
- Feasibility of implementation of strategies

The Mississippi Chapter of TNC has completed the identification of freshwater conservation areas to be included in the MS Chapter's portfolio of all conservation areas, both terrestrial and aquatic (Table 3, Figure 2). In addition, these sites have been prioritized and the highest priority areas for immediate focus are shown in Figure 3. It is important to note that the list of portfolio sites is iterative and new sites may be added, current sites may be dropped and/or the priority of sites may change as new data and information become available.

Step 2. Develop a Conservation Area Plan for each High Priority Conservation Area

Once conservation areas have been identified and prioritized, a plan for how to conserve or protect the highest priority areas is developed. This plan is called a Conservation Area Plan (CAP). The CAP is developed in partnership with other technical experts with knowledge of the conservation area. The utilization of other experts in the development of the CAP is critical to developing a sound and meaningful plan. The first step in developing a CAP for areas of high priority is to gather and compile existing information and data specific to the area. Much of these data will have been gathered during the identification of conservation areas, however, this process will involve a much more comprehensive and detailed data search. Data to be gathered include but are not limited to physical, chemical, biological, remotely sensed, location of point and non-point sources of pollution, land use characteristics, and landowner information.

Table 3. Freshwater Conservation Areas Identified for Mississippi

Conservation Area Name	Conservation Program	Priority
Amite River	Central Mississippi	High
Bayou Pierre	Central Mississippi	High
Rodney Lake	Central Mississippi	High
Strong River	Central Mississippi	High
St. Catherine Creek	Central Mississippi	Medium
Bayou Sara	Central Mississippi	Low
Big Black River	Central Mississippi	Low
Clark Creek	Central Mississippi	Low
Lower Buffalo River	Central Mississippi	Low
Tallahaga/Noxapater Creeks	Central Mississippi	Low
Tangipohoa River	Central Mississippi	Low
Thompson Creek	Central Mississippi	Low
Upper Yockanookany	Central Mississippi	Low
Buttahatchee River	Northeast Mississippi	High
Hatchie River	Northeast Mississippi	High
Luxapalila/Yellow Creeks	Northeast Mississippi	High
Bull Mountain Creek	Northeast Mississippi	Medium
Noxubee River	Northeast Mississippi	Medium
Sucarnoochee River	Northeast Mississippi	Medium
Upper Wolf River	Northeast Mississippi	Medium
East Fork Tombigbee River	Northeast Mississippi	Low
Pickwick Lake	Northeast Mississippi	Low
Bay St. Louis	South Mississippi	High
Lower Pearl River	South Mississippi	High
Pascagoula River	South Mississippi	High
Tchoutacabouffa River	South Mississippi	Medium
Big Sunflower River	Yazoo Basin	High
Lower Yazoo River	Yazoo Basin	High
Indian Bayou	Yazoo Basin	Medium
Chewalla Creek	Yazoo Basin	Low
Hurricane Creek	Yazoo Basin	Low
Jenkin's Lake	Yazoo Basin	Low
Little Tallahatchie River	Yazoo Basin	Low
Otoucalofa Creek	Yazoo Basin	Low
Piney Creek	Yazoo Basin	Low
Puskus Creek	Yazoo Basin	Low
Taylor Creek	Yazoo Basin	Low
Toby Tubby Creek	Yazoo Basin	Low
Upper Yalobusha River/Shutispear	Yazoo Basin	Low

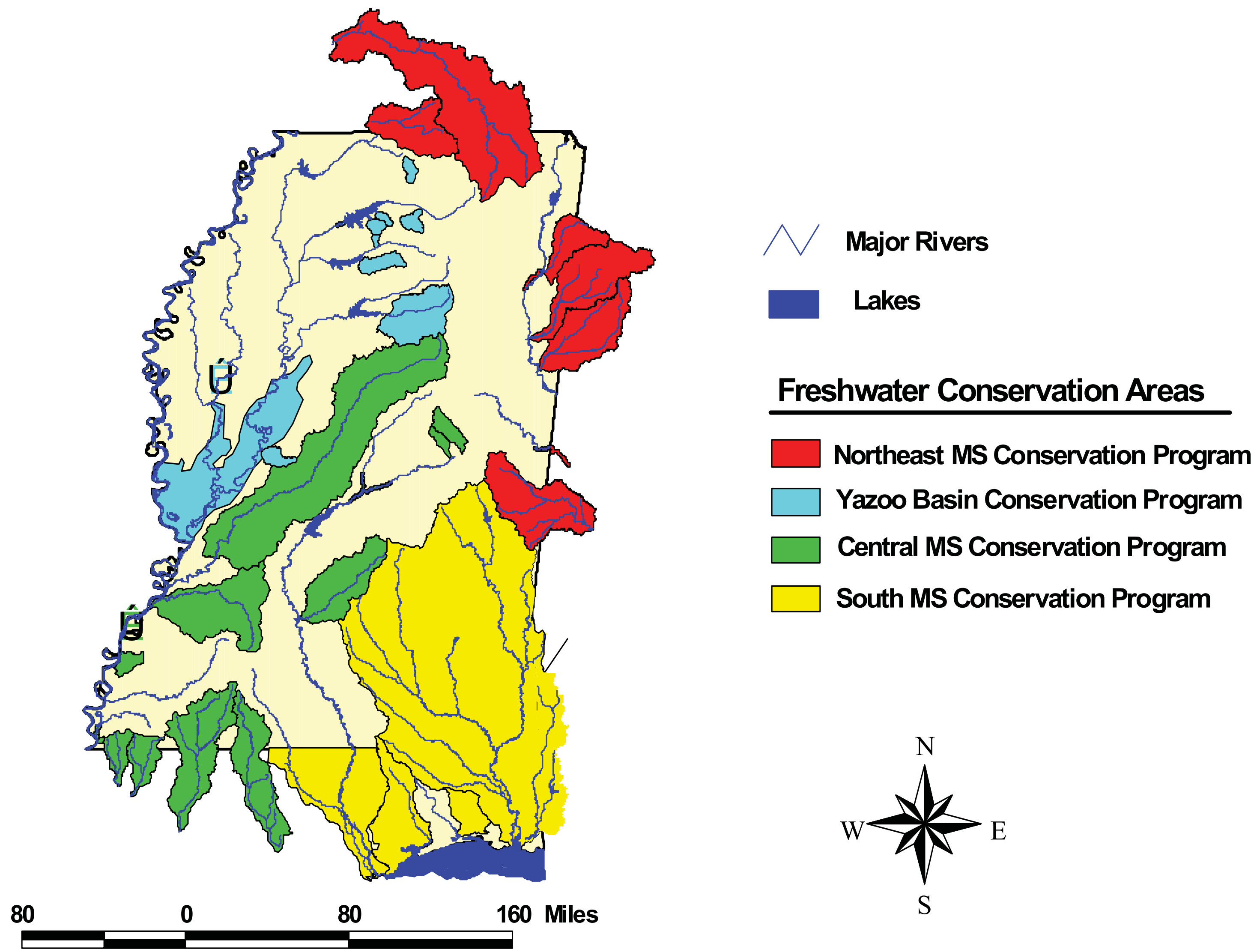

Figure 2. Map of Freshwater Conservation Areas Identified for Mississippi

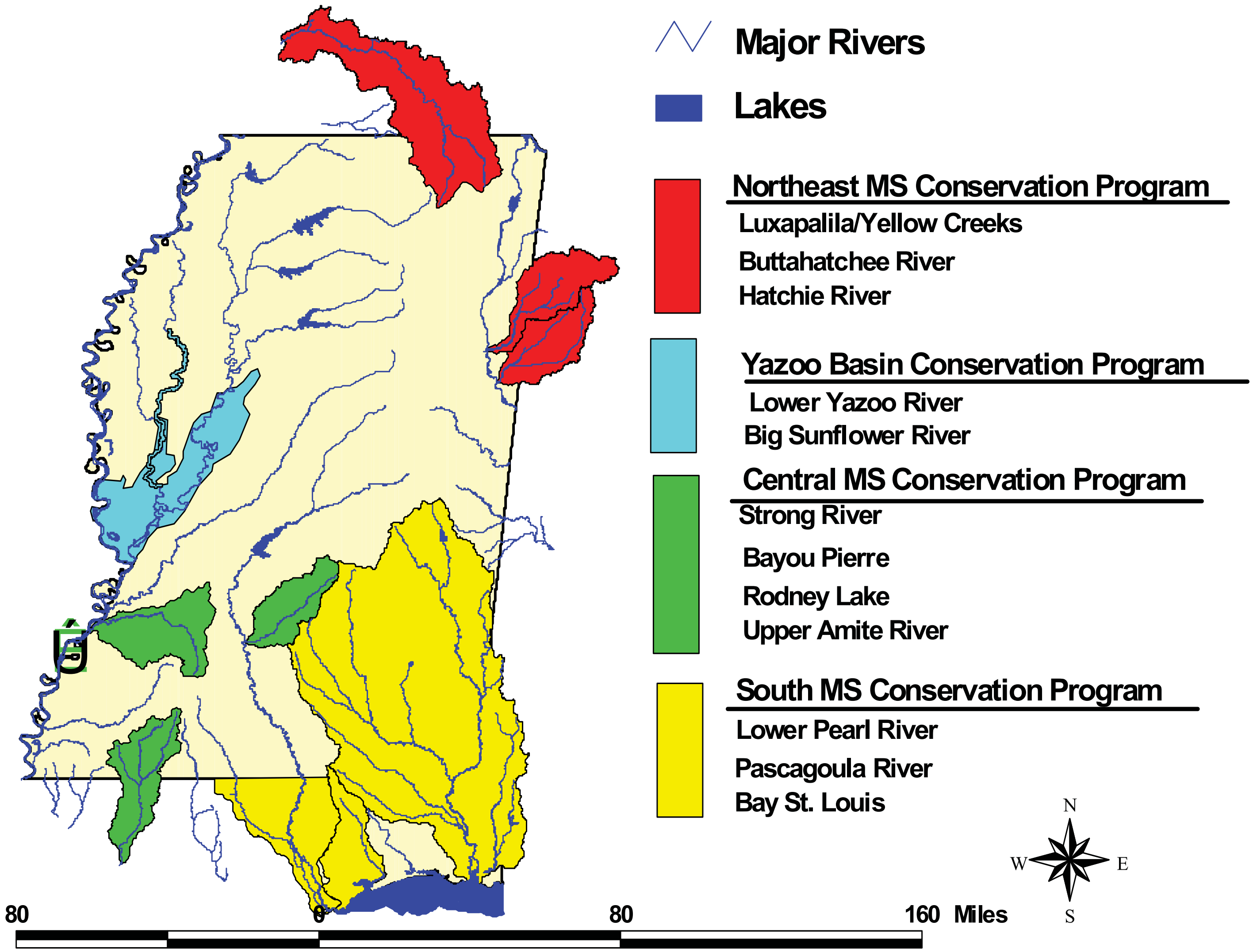

Figure 3. Map of High Priority Freshwater Conservation Areas Identified for Mississippi

The second step in the CAP process is to evaluate the compiled data and information to identify *conservation targets,* and *threats* to those targets, with *threats* being defined as *stresses* and *sources of stress* to the targets. *Conservation targets* include species that are imperiled, endangered or of special concern, biological communities that are groupings of co-occurring significant species, and ecological systems that are assemblages of communities occurring together on the landscape and are linked by common environmental processes, regimes, or gradients. *Stresses* are factors that may potentially degrade or negatively impact the targets within the next ten years. Stresses may be those factors that directly impact the target or those that indirectly impact the target by affecting important ecological processes that influence the target. Examples of stresses include habitat disturbance, sedimentation, reduction of connectivity, organic enrichment and nutrient enrichment. *Sources of stress* are anthropogenic practices that are incompatible and result in the stress to the targets. Sources of stress include active sources as well as historical sources. Examples of sources of stress include: incompatible urban development, incompatible grazing practices, incompatible forestry practices, alteration of channel morphology and/or hydrologic regime, and point source pollution discharges.

The third step in the CAP process is to develop strategies to abate the threats to the conservation targets and to develop measures to evaluate the success of the conservation strategies. Strategies that are identified are also ranked according to their benefits, feasibility and cost of implementation. Following are some examples of strategies that have been used by TNC:

- Land Acquisition
- Conservation Easements
- Develop/Promote Watershed Management Plans
- Provide Land Management Assistance
- Influence Public Policy/Planning
- Establish Water Management Agreements
- Support/Promote Compatible Development
- Support/Promote Sustainable Forestry
- Provide Wetland/Stream Mitigation
- Develop Regional Conservation Alliances
- Support/Promote and Implement Best Management Practices

The fourth step in the CAP process is to identify measures of success. Measuring the success of conservation strategies can be difficult and expensive, and may involve establishing monitoring programs. Ultimate success may take many years; therefore, surrogate measures of intermediate success or milestones are also used. To evaluate the success of conservation strategies, one may measure the condition of the conservation target, the persistence of the threats, or the progress of the strategy. In addition, one may employ the use of surrogate measures of overall ecological integrity of the system of which the target is a part. Following are examples of measures of success that have been used by TNC:

- <u>Target specific measures</u>: population status and trends, species surveys
- <u>Ecological System measures</u>: using Indices of Biological Integrity as indicators of community health, geomorphic status indicators, and habitat quality indicators
- <u>Threat abatement measures</u>: BMPs, miles of riparian buffer, sediment loads

Step 3. Implement the Conservation Area Plan

This is the natural next step upon completion of the CAP. Strategy implementation occurs based on the ranking of strategies, as outlined in the CAP, and available funding and resources. Strategy implementation is enhanced by the use of partnerships with other agencies and groups committed to the same mission and goals. In addition, TNC's experience indicates that long-term ecosystem conservation will succeed only with strong support from the people who live and work in these places. Therefore, TNC strives to build strong community support during the implementation phase of the process.

Step 4. Perform Measures of Success to evaluate the progress of implementation

The Nature Conservancy has defined conservation success as making substantial progress towards the long-term abatement of critical threats and the sustained maintenance or enhancement of biodiversity health at conservation areas. The two core measures of success involve measuring biodiversity health and threat status and abatement. There is often a lag-time between implementation of threat abatement strategies and abatement of the threat, and an even longer lag-time between strategy implementation and showing changes in biodiversity health. Therefore, TNC has developed a set of short-term indicators that reflect our capacity to implement effective strategies and enhance or maintain the conservation targets.

Status of Conservation Efforts at Mississippi's Highest Priority Freshwater Conservation Areas

The MS Chapter of TNC has been actively engaged in conservation efforts in the Pascagoula watershed long before a state chapter even existed. Subsequently, we have been most successful through Conservation by Design in this conservation area. To date we have completed the first iteration of the CAP for the Pascagoula watershed and are actively engaged in strategy implementation. We are also continuing to refine the conservation targets, threats and strategies.

With the recent addition of a Program Director for the Northeast Mississippi Conservation Program, we have initiated freshwater conservation efforts in the Luxapalila and Buttahatchee River conservation areas. For these areas and the other high priority conservation areas, we are in the beginning stages of data and information gathering, CAP development and strategy implementation.

Example of Conservation Efforts in the Pascagoula Watershed

The Pascagoula River is the largest river with an unimpeded main stem channel in the lower 48 states and represents one of the finest natural areas remaining in Mississippi (Figure 4). It contains a long, mostly contiguous block of bottomland hardwood forest and coastal marsh. The Pascagoula River and the Ward Bayou Wildlife Management Areas (over 50,000 acres of conservation land) include about fifty miles of frontage along the Pascagoula River that consists

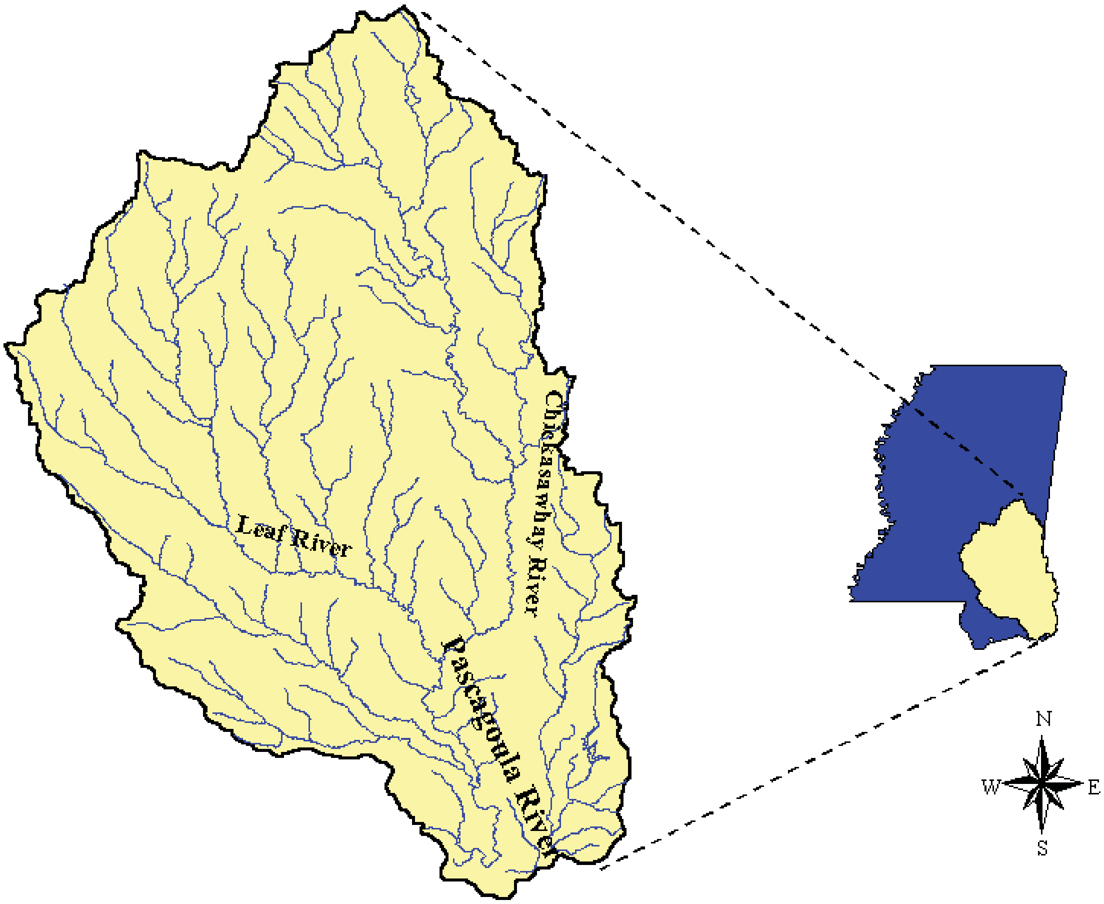

Figure 4. Pascagoula River Watershed

of sandbars, low ridges, high flats, low flats and over fifty oxbow lakes. The Coastal Preserve System includes over 11,000 acres in the Pascagoula and Escatawpa marshes, of which TNC has bought or protected 4,500 acres. The Nature Conservancy has been actively engaged with conservation on the Pascagoula beginning with the original state acquisitions in the early 1970s. In 1999 a 3300-acre preserve at the confluence of the Leaf and Chickasawhay Rivers was purchased and dedicated in honor of Charles Deaton. In 2002, a 1700-acre preserve adjacent to the Deaton preserve was purchased and dedicated in honor of Herman Murrah.

Through the development of the first iteration of a CAP for the Pascagoula River the following conservation targets have been identified:

- Resident Riverine Aquatic Alliance
- Anadromous Fish
- Emergent Marsh Complex
- Seagrass Beds
- Bottomland Hardwood Forest Complex
- Swallow tailed Kite
- Longleaf Sandhill Matrix

While about fifty miles of the river corridor is already protected by the State or by The Nature

Conservancy, several high threats to conservation targets exist and require immediate action. The following threats have been identified for the Pascagoula River during the development of the CAP:

- Sedimentation
- Alteration to Hydrologic Regime
- Land Conversion and Forest Fragmentation
- Point Source Pollution
- Exotic Invasive Species
- Alteration of Fire Regimes

The MS Chapter of TNC has identified and engaged in several strategies to abate critical threats facing the Pascagoula River Watershed. Some of the higher priority strategies include:

- Collaborate with MDEQ's Basin Management Approach
- Establish and Support a Pascagoula River Basin Alliance
- Acquire Lands Along the Pascagoula River and its Major Tributaries
- Form a South MS Prescribed Fire Council
- Further the Scientific Knowledge and Understanding of the Pascagoula Watershed

Water withdrawal projects and proposed reservoirs require The Nature Conservancy to engage with community-based strategies and to acquire hydrologic expertise in order to abate these threats. In addition, there is a need to work with industry, particularly the shipbuilding industry, to diminish toxins in the river. Education and compatible economic development are community-based strategies that can affect best practices by industry.

One issue of important concern, that will require a creative strategy is the increase in the amount of sediment entering streams and rivers in the Pascagoula, as well as the issue of in-stream sedimentation caused by scouring of the bed and bank erosion. The building of roads at an unprecedented rate creates sedimentation concerns as well as interrupting hydrologic flow. Incompatible silviculture practices are also a major source of sedimentation. Gravel mining, sedimentation and alterations to hydrologic regime are major threats to the migration and spawning habits of Gulf Sturgeon, Pearl Darter and Alabama Shad.

By following through with implementation of identified strategies, the MS Chapter of TNC is involved in several projects in the Pascagoula Watershed.

A Coastal Impact Assistance Program (CIAP) funded collaboration between TNC, MDEQ, Jackson County and George County has led to the Upper Pascagoula Connector Project. In addition, the MS Chapter of TNC has initiated a Lower Pascagoula Connector Project. The goal of these projects is to connect the eastern riverfront side of the Upper Pascagoula with the Deaton Preserve, to connect the western side of the Upper Pascagoula protected lands with the Desoto National Forest and to connect the lower portion of the Pascagoula Protected Lands with the Coastal Preserves (Figure 5).

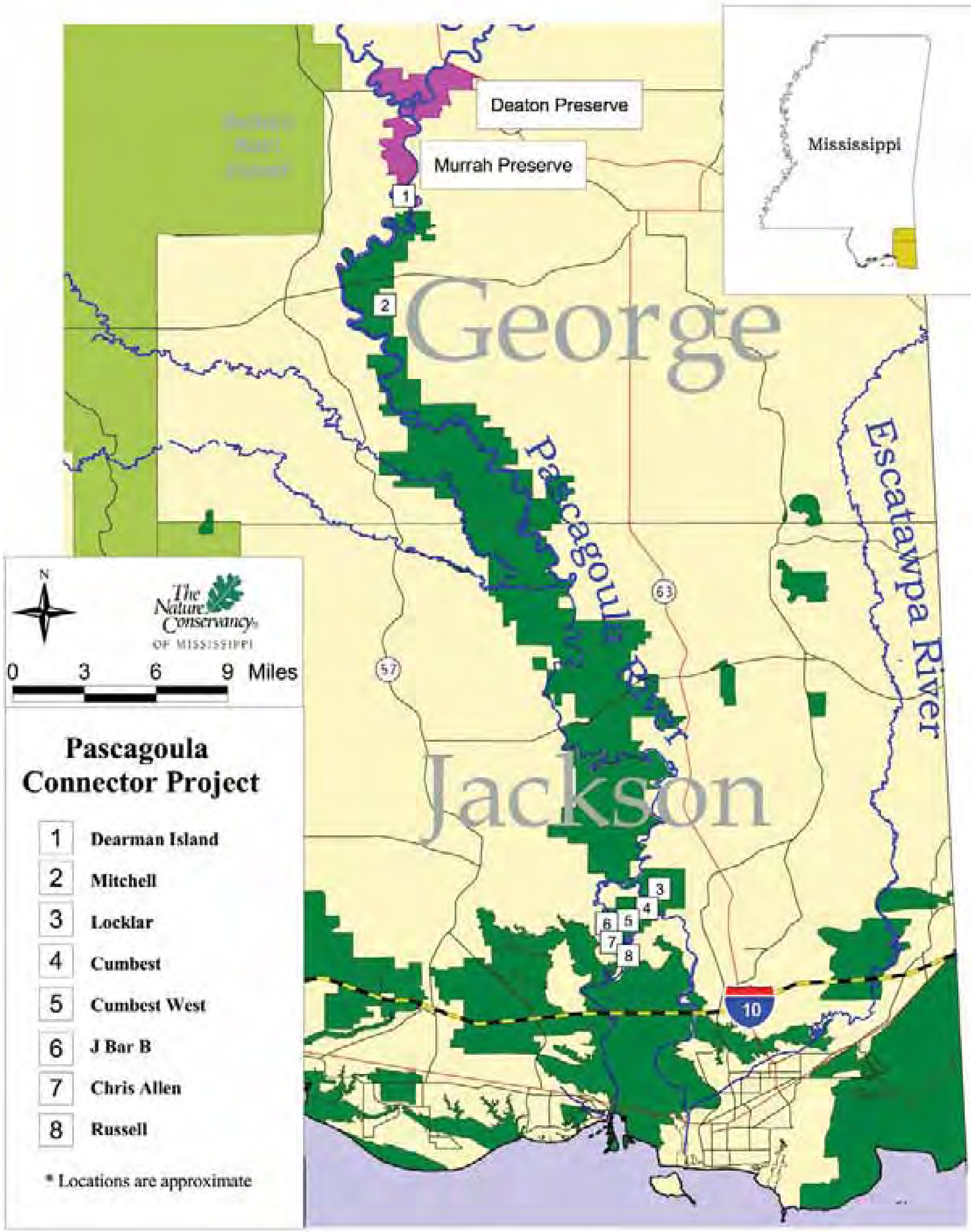

Figure 5. The Upper and Lower Pascagoula Connector Projects

Another CIAP funded collaboration between TNC, MDEQ, Jackson and George Counties, the

Coastal Preserves and Audubon MS has led to the Pascagoula River Ecotourism Study. This study will hopefully provide sound data and information to foster the utilization of ecotourism as a successful strategy that will promote environmental protection and restoration, while at the same time, provide a boost to the economy of the area.

Collaboration between TNC, George County Economic Development Foundation, the Lucedale Garden Club and Audubon MS has led to the holding of an annual Migration Discovery Day in George County, MS. This is another example of where TNC and its partners hope to build positive awareness of the ecological significance of this area by engaging the public in positive interaction with the ecosystem.

A Nature Trail and Observatory are being developed along the Escatawpa River in Jackson County, MS. The nature trail and observatory will be located in the Grand Bay Wildlife Refuge, at the Mississippi Welcome Center on Interstate 10. The objective of this project is to capitalize on the heavy traffic along this major interstate to attract visitors to view the beautiful and pristine ecosystem of this area to hopefully promote awareness of the significance of the Escatawpa River and its surrounding landscape.

Finally, TNC is partnered with the Pat Harrison Waterway District, U.S. Army Corps of Engineers and the U.S. Geological Survey to conduct a geomorphic assessment of the Pascagoula River System. Dr. Joann Mossa, from the Department of Geology at the University of Florida is conducting the study for the purposes of gaining an understanding of the current geomorphic state of the Pascagoula River and to understand the causes and effects of accelerated erosion within the watershed. The results of this study will facilitate a better understanding of the physical and hydrological characteristics of the Pascagoula River so that better and more sound assessments can be made regarding the threats to the system and appropriate strategies can be developed. In addition, these results will provide sound scientific data for decision and policy makers and will hopefully help guide decisions regarding the future uses of the resources and the management of the Pascagoula River Watershed.

Summary

The southeastern United States contains a rich diversity of freshwater species, communities and ecosystems. In particular, Mississippi contains a rich diversity of aquatic plants and animals throughout its many watersheds. Certain incompatible human uses of Mississippi's natural resources pose threats to this natural heritage, resulting in an increasing need for efforts to protect water quality, quantity and biodiversity within the State. Limited resources, however, require these efforts be carefully planned and focused to increase the probability of successful conservation and thus have a positive impact on aquatic natural resources. Through a process called Conservation by Design, freshwater conservation areas of biodiversity significance have been identified and prioritized and the development of plans to conserve and or protect these areas is underway. The next steps for MS TNC will be to implement these conservation plans, measure the success of conservation efforts and continue to revise the conservation plans as data and information become available. Key factors in the success of the conservation of Mississippi’s freshwaters are to engage the community in conservation planning and the implementation of conservation strategies, to educate the citizens and policy makers of the State as to the importance and significance of freshwater biodiversity and conservation, to form partnerships with private, public and non-profit organizations to complement and enable resources to achieve common objectives, to use scientific data as the foundation of conservation planning and to identify and secure adequate funding for conservation activities.

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TURBIDITY ESTIMATED SEDIMENT LOADS AT DEER CREEK EAST OF LELAND, MISSISSIPPI

By Michael S. Runner
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INTRODUCTION

The Mississippi District of the U. S. Geological Survey (USGS), in cooperation with the Mississippi Department of Environmental Quality-Office of Land and Water Resources (MDEQ-OLWR), the U.S. Fish and Wildlife Service (USF&WS), and the Yazoo Mississippi Delta Joint Water Management District (YMD), began collecting stream stage, discharge, turbidity and other water-quality data, and suspended-sediment concentration data at Deer Creek East of Leland, Mississippi, in December 2001. The purpose of this study is to collect data for the evaluation of the aquatic health of Deer Creek as part of the Deer Creek Restoration Project.

This paper presents the results of an analysis to test the use of continuous-turbidity data as a surrogate for suspended-sediment concentrations. Sensors that measure the bulk optical properties of water, such as turbidity, have been used to provide a continuous time series estimate of suspended-sediment concentrations with a quantifiable certainty (Schoellhamer, 2001). Christensen, and others (2000) used simple linear regression to develop a site-specific model using turbidity to continuously estimate suspended-sediment concentrations. The generated regression equation explained about 93 percent of the variance in suspended-sediment concentrations.

SITE DESCRIPTION

Deer Creek is in the northwestern part of Mississippi in the Mississippi Alluvial Plain, an area known locally as the Delta (fig. 1). The headwaters of Deer Creek are Lake Bolivar at Scott, Mississippi. The stream flows south through the Delta into the Yazoo River near Vicksburg, Mississippi. The drainage area of Deer Creek for the monitoring site (gage) is 80 mi^2; a significant part of the land adjacent to the stream drains away from the stream and contributes little or no surface-water runoff.

Streamflow at the monitoring site is controlled by a weir 200 feet downstream of the gage. Water is pooled behind the weir at low discharge. Stream velocities at the site are low, even during periods of high discharge [0.69 ft/s (feet per second) at 622 ft^3/s (cubic feet per second)]. The low stream velocity limits the ability of the stream to transport large sediment particles. Most of the suspended sediment in transport is fine grain material (<0.062 mm) and little-to-no sand is in transport at the site. A relation between turbidity and suspended-sediment concentration was possible because of the predominance of fine sediments in transport at Deer Creek.

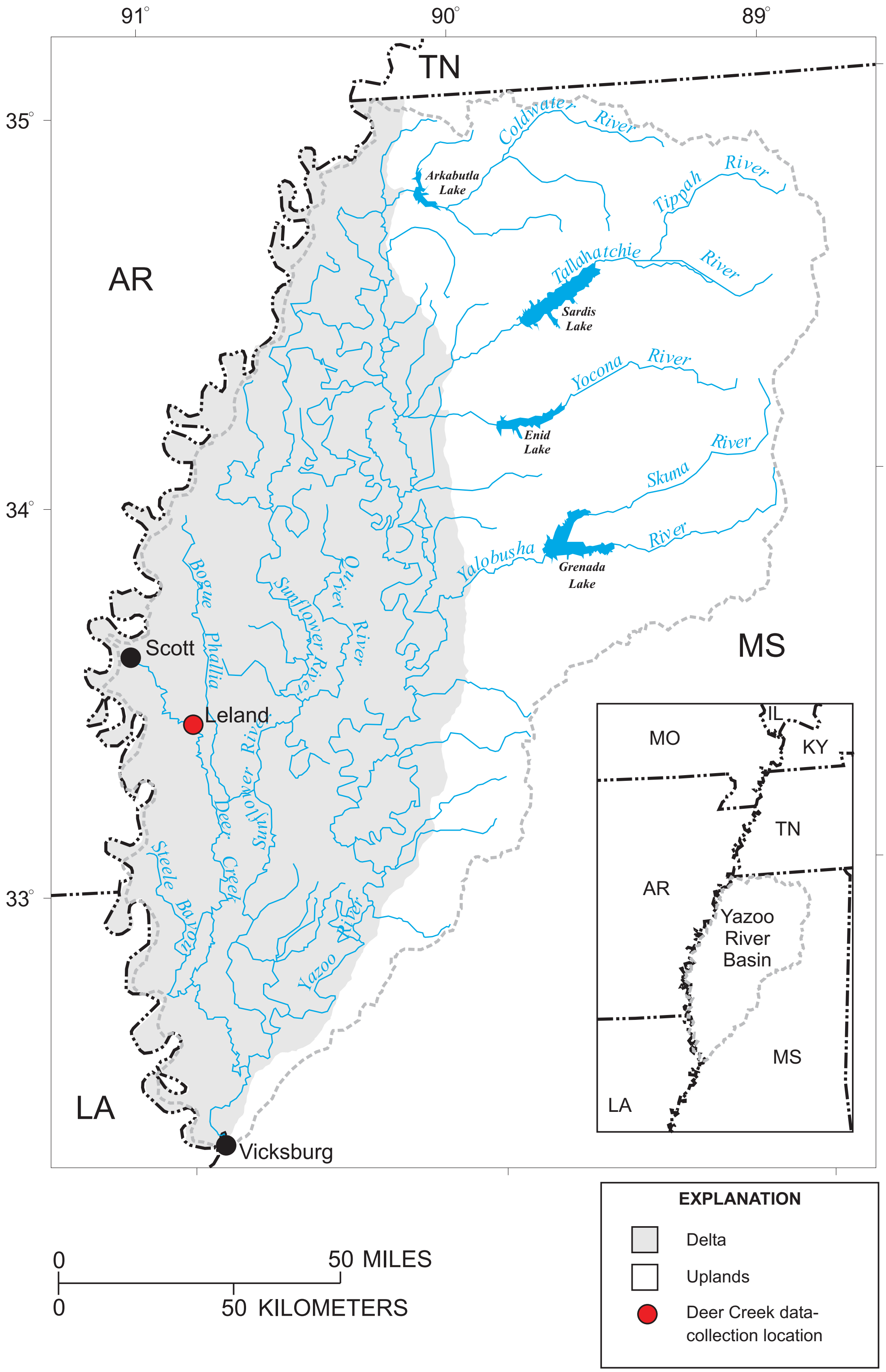

Figure 1. Location of Deer Creek East of Leland, Mississippi, data collection site.

DATA COLLECTION

Stream stage and turbidity and the other water-quality properties are measured and recorded every 30 minutes and transmitted via satellite to the USGS Mississippi District office every 4 hours. The data are made available through the Mississippi District real-time data web page. Suspended-sediment samples are collected every 2 weeks, along with cross-section measurements of the water-quality properties.

Stream stage is measured and recorded by using a non-submersible pressure transducer. Discharge measurements have been made by using Price AA velocity meters and an acoustic Doppler current profiler (ADCP) over a range in stream stage to define the stage/discharge relation (Rantz and others, 1982). A YSI-6820 water-quality monitor with a model 6026 turbidity probe is installed in a pipe secured to the downstream side of the right pile group and measures temperature, pH, dissolved oxygen, specific conductance, and turbidity.

The site is visited every 2 weeks to check the calibration of the water-quality monitor by using techniques described in the USGS publications "National Field Manual for the Collection of Water-Quality Data" (Wilde and others, 1998) and "Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting" (Wagner and others, 2000). Several measurements are made within the cross section to determine a cross-sectional average for each of the five water-quality properties. Also during each site visit, a depth-integrated, equal-width-increment suspended-sediment sample is collected by using techniques described in "Field Methods for Measurement of Fluvial Sediment" (Edwards and Glysson, 1999), to determine the average suspended-sediment concentration for the stream. Sediment samples are sent to the USGS sediment laboratory in Baton Rouge, Louisiana, for analysis.

DATA ANALYSIS

The standard method for collecting and publishing daily sediment values requires frequent manual and/or automatic sampling, laboratory analysis of the samples, and analysis of large data sets and is described in the USGS publications "Computation of Fluvial-Sediment Discharge" (Porterfield, 1972), and "Fluvial Sediment Concepts" (Guy, 1970). The computations rely heavily on the hydrographer's judgment and experience in estimating data when sediment-concentration data are not available. The method described in this paper is less subjective than the standard method.

The analyses of water-quality data are done according to the guidelines found in USGS publications (Wagner and others, 2000). Originally, the instantaneous turbidity data were planned to be adjusted to the cross-section average by using coefficients computed from the cross-sectional turbidity measurements. However the relation between the instantaneous turbidity data and suspended-sediment concentrations, and the relation between the EWI turbidity measurements and suspended-sediment concentrations was found to be almost statistically identical. Therefore, values of instantaneous turbidity were used for the correlation. The model developed for this study for estimating suspended-sediment concentrations is site and instrument specific and can be only be used with turbidity data from the same model turbidity probe.

RESULTS

Twenty-one suspended-sediment samples with concurrent cross-sectional turbidity measurements were made from December 2001 through September 2002. Suspended-sediment concentrations ranged from 53 to 569 mg/L (milligrams per liter). Measured turbidity ranged from 22 to 721 NTU (nephelometric turbidity units). Instantaneous turbidity measured by the continuous monitor at the times the sediment samples were collected ranged from 21 to 730 NTU. Stream discharges at the times of sample collection ranged from 0 to 745 ft^3/s. The computed stream discharge ranged from 0 to 800 ft^3/s. Stream discharge, turbidity, and suspended-sediment concentration data at the time of sample collection are summarized in table 1.

Continuous stream discharge and turbidity hydrographs for Deer Creek show that there is a lag between the time of peak discharge and the time of the peak turbidity, with the peak turbidity occurring during the falling limb of the discharge hydrograph (fig. 2). A comparison of the suspended-sediment concentration and instantaneous discharge illustrates the poor relation between the two (fig. 3). However, a plot of the suspended-sediment concentration and the instantaneous turbidity of the stream indicates a good relation (fig. 4). Two equations describing the relation between the suspended-sediment concentration and turbidity were developed. The models which gave the best fit to the data and their respective levels of significance are (1) a second-order polynomial ($R^2 = 0.97$), and (2) a linear equation ($R^2 = 0.94$):

$$Y = 0.0005X^2 + 0.3123X + 63.994 \tag{1}$$

$$Y = 0.6244X + 40.72 \tag{2}$$

Where Y = suspended-sediment concentration (mg/L), and X = turbidity (NTU). Both models were used to compute the sediment loads for Deer Creek by using the following equation:

$$S= Q*C*0.0027$$

Where S is the sediment load, in tons; Q is the mean-daily discharge (ft^3/s); C is the mean sediment concentration (mg/L) as estimated by the models; and 0.0027 is a conversion factor.

The model based on the polynomial equation computed a total load of 18,300 tons for the study period. The model based on the linear equation computed a total load of 19,400 tons. Neither of these totals considers the load transported during the 26 days of missing or bad turbidity data that occurred during the study period. Loads for these days would

Table 1. Discharge, cross section turbidity, unit value turbidity, and suspended sediment concentrations for data collected at Deer Creek East of Leland, Mississippi, December 2001 through September 2002 (ft^3/s, cubic feet per second; ntu, nephelometric turbidity units; mg/L, milligrams per liter; --, no unit value data available)

Sample date and time	Discharge (ft^3/s)	Cross-section turbidity (ntu)	Continuous turbidity (ntu)	Suspended-sediment concentration (mg/L)
12/11/01 13:15	446	174	155	131
12/18/01 18:30	745	249	250	164
1/16/02 11:30	59	181	--	142
1/31/02 12:15	592	424	420	249
2/13/02 11:30	172	305	240	187
2/26/02 15:00	142	330	290	217
3/13/02 11:15	63	289	240	195
3/26/02 12:30	251	355	336	221
4/10/02 11:30	240	514	505	334
4/25/02 11:15	40	49	62	61
5/7/02 11:45	140	721	730	566
5/24/02 11:15	8.7	106	130	111
6/5/02 12:00	2.9	63	78	92
6/20/02 11:15	0	32	35	54
7/2/02 13:45	9.8	30	53	62
7/16/02 13:15	14	22	33	53
7/31/02 12:00	12	27	22	65
8/15/02 11:30	5.8	50	44	124
8/28/02 10:30	0.78	35	31	73
9/11/02 11:15	0	55	51	93
9/24/02 12:30	1	34	21	86

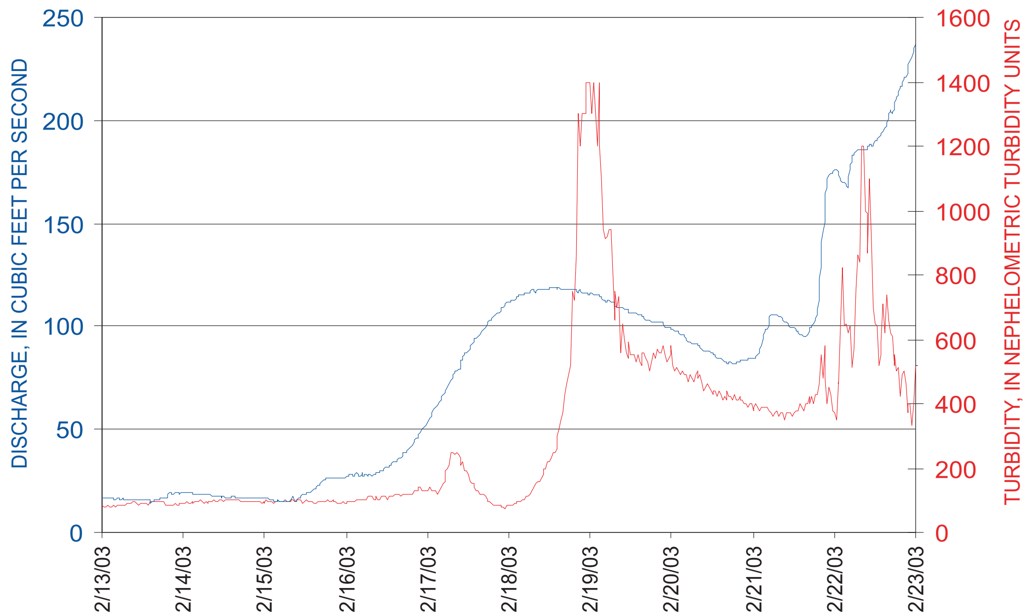

Figure 2.- Stream discharge and turbidity data for Deer Creek East of Leland, Mississippi, February 13 through February 23, 2003.

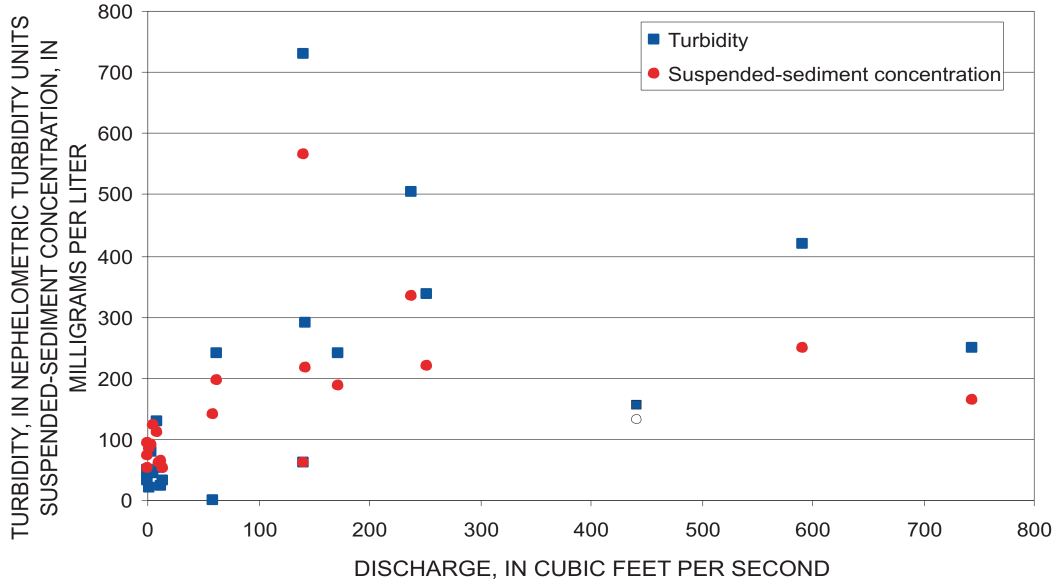

Figure 3.- Instantaneous turbidity and suspended-sediment concentration relation with stream discharge for Deer Creek East of Leland, Mississippi, December 2001 through September 2002.

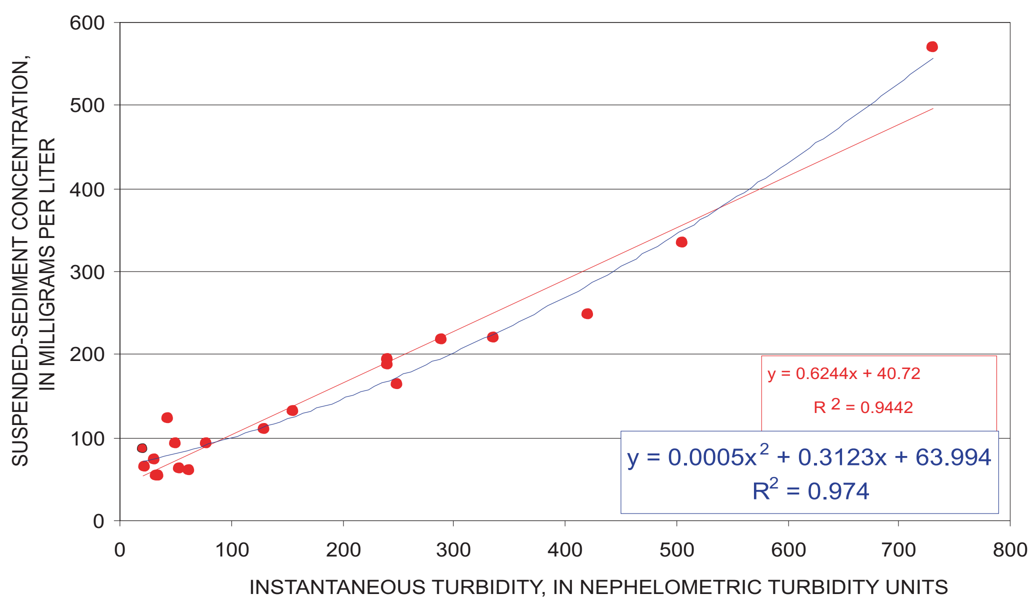

Figure 4.- Suspended-sediment concentrations and instantaneous turbidity relation for Deer Creek East of Leland, Mississippi, December 2001 through September 2002.

have to be estimated. The 1100-ton difference between the two models represents 6 percent of the total load for the study period.

These models are preliminary to a final model that will be developed after more samples are collected and may more accurately represent suspended-sediment concentrations in the stream. These models explain at least 94 percent of the variability of the suspended-sediment concentrations.

SUMMARY

The Mississippi District of the USGS has been collecting stream stage, turbidity, and suspended-sediment data on Deer Creek East of Leland, Mississippi, since December 2001. Stage and turbidity data are recorded every 30 minutes. Suspended-sediment samples are collected every 2 weeks. Data collected from December 2001, through September 2002, were used to compute suspended-sediment loads for Deer Creek based on the stream discharge and turbidity data, and the suspended-sediment concentrations. A model based on a polynomial equation and a model based on a linear equation were developed to describe the relation between the instantaneous-turbidity data and suspended-sediment concentrations at the site. Concentrations estimated by the models were then used, along with the computed discharges, to compute suspended-sediment loads. The model based on a polynomial equation computed a total of 18,300 tons of sediment were transported in Deer Creek for the days where a daily mean turbidity value was computed. The model based on a linear relation between instantaneous turbidity and suspended-sediment computed a total load of 19,400 tons for the days where a daily mean turbidity was computed.

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Sampling Strategy and Selected Water-Quality and Bottom-Material Data for the Deer Creek, Mississippi, Synoptic Study

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INTRODUCTION

The Deer Creek Basin, in northwestern Mississippi, is located in the Mississippi River Alluvial Plain, an area locally referred to as the Mississippi Delta. Deer Creek begins at Lake Bolivar at Scott, north of Greenville, and empties into the Yazoo River north of Vicksburg (fig. 1). The channel meanders from north to south and is 164 miles long. The drainage area at the mouth is about 110 square miles. The basin drains a largely rural, agricultural landscape, but includes small communities such as Scott, Leland, Hollandale, Rolling Fork, Cary, and Valley Park. Flow in the upper part of the basin is semi-regulated by several small weirs. Much of the Deer Creek channel below Greenville is "perched" or elevated formed by natural levees such that overland runoff drains away from the main channel, and only local runoff drains into the main channel. Flow is diverted into Rolling Fork Creek at Rolling Fork, which is located near the center of the basin. The Deer Creek channel below Rolling Fork is actually a series of small "lakes" or cutoffs created by earthen crossings underlain with culverts. Many of the culverts are partially filled with sediment or have inadequate cross-sectional area to convey flow from Rolling Fork to the mouth of the creek at the Yazoo River. Illegal trash dumping, failing septic systems, and agricultural runoff are well documented in the basin, especially in the lower part.

The U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, the Mississippi Department of Environmental Quality (MDEQ), the Yazoo-Mississippi Delta Joint Water Management District, and the U.S. Geological Survey (USGS) have initiated a restoration effort for the Deer Creek Basin. Before restoration efforts began in the basin, the USGS conducted a synoptic study in September 2002 to collect baseline water-quality, bottom-material, habitat-assessment, and macroinvertebrate data in Deer Creek. This report describes the sampling strategy for the Deer Creek synoptic study, including site selection, sampling methods, quality-assurance and quality-control methods, and listing of analytes and laboratories. This report also includes selected water-quality and bottom-material data collected during the Deer Creek synoptic study.

Site Selection

Water-quality data were collected at 47 sites during the 2002 Deer Creek synoptic study (table 1, figure 1). Physical properties (turbidity, dissolved oxygen, pH, specific conductance, and temperature) were collected at all sites. Water-quality, bottom-material, habitat-assessment, and macroinvertebrate data were collected at 6 sites (shaded gray in table 1, numbered in figure1). These six sites (hereafter referred to as primary sites) were selected at key locations in the Deer Creek Basin based on the following information:

- Deer Creek at Scott, MS (site 1, figure 1) – This site is at the second channel crossing (local road) downstream from Lake Bolivar and was sampled to characterize the water quality of Deer Creek flowing out of the lake.
- Deer Creek East of Leland, MS (site 2, figure 1) – This site is within the city limits of Leland, MS, where a USGS real-time flow and water-quality-monitoring gage is currently installed (U.S. Geological Survey, 2003a).
- Deer Creek near Hollandale, MS (site 3, figure 1) – This site is at a former U.S. Army Corp of Engineers gaging station. Thus, historical stage, flow, and water quality data are available for the site (U.S. Army Corps of Engineers, 1995).
- Deer Creek at Rolling Fork, MS (site 4, figure 1) – This site is slightly upstream of the diversion of Deer Creek into Rolling Fork Creek.
- Deer Creek at Cary and at Valley Park, MS (sites 5 and 6, figure 1) – These sites were selected based on the availability of historical flow and water-quality data.

Sampling Methods

A multi-probe was used to measure physical properties such as turbidity, dissolved oxygen, pH, specific conductance, and water temperature. For sites with culverts or with minimal accessibility, physical properties were measured near the center of the channel. For sites with bridge crossings, the stream width was sub-divided into equal-width sections (at least 5 sections), and physical properties were measured near the water surface at each section. Where applicable, a bottom reading was also included for each equal-width section. Calibration of the multi-probe followed guidelines outlined in Wilde and Radtke (1998). The instruments were calibrated each morning and at the end of each sampling day. The final calibration for each constituent was required to meet measurement-performance criteria shown in Table 2.

At the six primary sites, water and bottom-material samples were collected from bridges, boats, or by wading using appropriate sampling equipment and established depth- and width-integrating techniques (Shelton, 1994). Sample collection, processing, and preservation followed protocols outlined in the National Field Manual for the Collection of Water-Quality Data (Wilde and Radtke, 1998). For each water sample, approximately 6 liters of water was collected and composited into a Teflon churn splitter. The composite sample was churned about 10 times before sub-sampling into analyses bottles, which were then packed in ice and shipped in coolers to laboratories for the various chemical analyses. For each bottom-material sample, approximately 500 milligrams (mg) of sample was collected and shipped to the laboratory for analysis.

Habitat assessment procedures were modified by MDEQ from an earlier assessment for streams in mountainous regions to fit the low-gradient glide/pool streams in the Mississippi Alluvial Plain (Barbour and Stribling, 1994; Florida Department of Environmental Protection, 1996). The biological field team selected a representative stream section and measured 100- to 500-meter (m) reaches depending on channel size at each site. The upstream (US) and downstream (DS) limits of the reach were marked with flagging labeled with the stream name, US or DS end, date, and samplers' initials. The actual assessment included visual inspection of 50 m on either side of the marked reach with the biological team documenting general characteristics and scored assessments (Barbour and Stribling, 1994; Florida Department of Environmental Protection, 1996). Macroinvertebrate samples were collected according to two different methods – natural habitat (woody debris, cut-banks, and bottom material) and artificial habitat (Hester-Dendy artificial substrate). Macroinvertebrate samples were analyzed by Tetra Tech, Inc. Presentation of habitat assessment and macroinvertebrate data are beyond the scope of this report.

Quality-Assurance and Quality-Control Methods

The Mississippi USGS office participates in the National Field Quality Assurance Program (NFQA) once each year. The USGS Ocala Water Quality and Research Laboratory in Ocala, FL, prepares water samples with known values of pH, alkalinity, and specific conductance. Field personnel perform a blind analysis on the samples for comparison to known values (Crawford, 1999). All Mississippi field personnel participating in the Deer Creek study successfully completed the NFQA for 2002.

Prior to sample collection, all equipment that came into contact with the sample water and bottom material was cleaned with a 0.2 percent non-phosphate detergent, rinsed with deionized water, air dried, wrapped in aluminum foil, and stored in a dust-free environment. All equipment (churn splitter, tubing, and bottles) was placed in plastic bags to prevent contamination. Teflon bottles were covered with nitrile gloves to keep the sampling chamber free of foreign materials. At the end of each sampling day, the churn splitters and tubing were cleaned thoroughly by using the non-phosphate solution, followed by a series of washes alternating tap water and deionized water.

Quality-control samples were collected to assess bias and variability for the set of environmental samples. Field equipment blank samples were collected to assess bias in the data set that could be caused by contamination of field equipment. One set of equipment blanks were run for the Deer Creek synoptic study. Replicate samples were collected to assess variability in the environmental data set due to random errors. One duplicate water sample was collected at the Deer Creek at Scott, MS, site. Habitat assessment duplicates were run at the Deer Creek at Scott, MS, and at the Deer Creek at Valley Park, MS, sites.

Lists of Analytes and Laboratories

A complete list of all analytes that were performed on the water-quality and bottom-material samples collected at the six primary sites is presented in Table 3. Four different USGS laboratories were used for the Deer Creek synoptic study (analytical methods and detection limits for each analyte are available online, and web pages for each laboratory are listed in the references section):

1. National Water Quality Laboratory in Denver, CO (U.S. Geological Survey, 2003b) – Water samples were analyzed for pesticides (herbicides, insecticides, and degradation products) dissolved organic carbon, and total particulate carbon.

Bottom-material samples were analyzed for historically-used organochlorine pesticides.

2. Ocala Water Quality and Research Laboratory in Ocala, FL (U.S. Geological Survey, 2003c) – Water samples were analyzed for nutrients (dissolved and total), major ions, trace elements, and total organic carbon.
3. Louisiana District Sediment Laboratory in Baton Rouge, LA (U.S. Geological Survey, 2003d) – Water samples were analyzed for suspended sediment.
4. Organic Geochemistry Research Laboratory in Lawrence, KS (U.S. Geological Survey 2003e) – Water samples were analyzed for the herbicide glyphosate and two degradation products.

WATER QUALITY AND BOTTOM MATERIAL DATA

Physical properties for all sites are presented in Table 4, selected nutrient values collected at the six primary sites are presented in Table 5, and organochlorine values for bottom-material samples collected at the six primary sites are presented in Table 6. The remaining water-quality data are available online within the USGS databases (U.S. Geological Survey, 2003f).

DISCLAIMER

The use of brand names in this paper is for identification purposes only and does not constitute endorsement by the U.S. Government.

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Table 1.—Map number, station number and name, locations, and constituents for sites sampled as part of the Deer Creek, synoptic study, September 2002

[USGS, U.S. Geological Survey; SR1, State Road 1; SE, southeast; SW; southwest; NE, northeast; NR, near; NW, northwest; AB, above; all sites located in Mississippi; latitude and longitude values presented as XXXXXX are XX° XX' XX"]

Map number (fig. 1)	USGS station number	Station name	Latitude	Longitude	Physical properties	Water sample, bottom-material sample, and habitat assessment
	333554091045000	DEER CREEK AT SR1 AT SCOTT	333554	910450	x	
1	7288730	DEER CREEK AT SCOTT	333546	910441	x	x
	333534091042000	DEER CREEK AT WEIR AT SCOTT	333534	910420	x	
	333447091023600	DEER CREEK SE OF SCOTT	333447	910236	x	
	333353091013600	DEER CREEK NORTH OF FORKLAND	333353	910136	x	
	333141091005500	DEER CREEK AT FORKLAND	333141	910055	x	
	333058090590400	DEER CREEK AT PRISCILLA,	333058	905904	x	
	333008090594500	DEER CREEK SW OF PRISCILLA	333008	905945	x	
	332733091001600	DEER CREEK AT METCALFE	332733	910016	x	
	332638090585900	DEER CREEK SE OF METCALFE	332638	905859	x	
	332541090552100	DEER CREEK NE OF STONEVILLE	332541	905521	x	
	332515090543400	DEER CREEK AT STONEVILLE	332515	905434	x	
	332440090543600	DEER CREEK SOUTH OF STONEVILLE	332440	905436	x	
2	728875070	DEER CREEK EAST OF LELAND	332404	905331	x	x
	332249090542600	DEER CREEK SOUTH OF LELAND	332249	905426	x	
	332008090533200	DEER CREEK NR BURDETTE	332008	905332	x	
	331611090523600	DEER CREEK AT ARCOLA	331611	905236	x	
	331304090521800	DEER CREEK AT ESTILL	331304	905218	x	
	331127090512600	DEER CREEK NORTH OF HOLLANDALE	331127	905126	x	
	7288768	DEER CREEK AT HOLLANDALE	331010	905102	x	
3	7288770	DEER CREEK NR HOLLANDALE	330859	905047	x	x
	330632090523900	DEER CREEK AT PERCY	330632	905239	x	
	330414090514400	DEER CREEK AT PANTHER BURN	330414	905144	x	
	330238090500200	DEER CREEK AT VICKLAND	330238	905002	x	
	330028090511000	DEER CREEK NR NITTA YUMA	330028	905110	x	
	325821090502300	DEER CREEK AT ANGUILLA	325821	905023	x	
	325754090511100	DEER CREEK NR ANGUIL	325754	905111	x	
	325554090525000	DEER CREEK NORTH OF ROLLING FORK	325554	905250	x	
4	325427090524500	DEER CREEK AT ROLLING FORK	325427	905245	x	x
	325251090531900	DEER CREEK SOUTH OF ROLLING FORK	325251	905319	x	
	325218090532500	DEER CREEK NORTH OF EGREMONT	325218	905325	x	
	325200090533700	DEER CREEK NR EGREMONT	325200	905337	x	
	325034090542100	DEER CREEK SOUTH OF EGREMONT	325034	905421	x	
	324951090544900	DEER CREEK NORTH OF CARY	324951	905449	x	
5	7288740	DEER CREEK AT CARY	324903	905517	x	x
	324728090570600	DEER CREEK SW OF CARY	324728	905706	x	
	324552090573000	DEER CREEK NW OF BLANTON	324552	905730	x	
	324509090554700	DEER CREEK AT BLANTON	324509	905547	x	
	324159090555000	DEER CREEK NR ONWARD	324159	905550	x	

Table 1.—Map number, station number and name, locations, and constituents for sites sampled as part of the Deer Creek, synoptic study, September 2002

Map number (fig. 1)	USGS station number	Station name	Latitude	Longitude	Physical properties	Water sample, bottom-material sample, and habitat assessment
	324202090562700	DEER CREEK SOUTH OF ONWARD	324202	905627	x	
	7288790	DEER CREEK NR VALLEY PARK	324016	905413	x	
	323915090513900	DEER CREEK NORTH OF VALLEY PARK	323915	905139	x	
	323821090513900	DEER CREEK AB VALLEY PARK	323821	905139	x	
6	323805090514700	DEER CREEK AT VALLEY PARK	323805	905147	x	x
	323437090502100	DEER CREEK NR HARDEE	323437	905021	x	
	323223090491400	DEER CREEK EAST OF FLOWEREE	323223	904914	x	
	323244090492300	DEER CREEK NR FLOWEREE	323244	904923	x	

Table 2. Day-end calibration measurement criteria

[GPS, global positioning system; m, meters; %, percent, mg/L, milligrams per liter; C, Celsius; µS/cm, microsiemens per centimeter; all criteria are dependent upon range of measurement for a specific multi-probe]

Measurement Property	Accuracy
GPS	± 15 m
Dissolved oxygen	The greater value of ± 2% of reading or ± 0.2 mg/L for 0-20 mg/L
pH	± 0.2 standard units
Temperature	± 0.15°C or ± 0.10°C
Specific conductance	± 0.5% + 1 µS/cm or the greater value of ± 1% of reading or + 1µS/cm
Turbidity	±2%

Table 3.—Listing of all analytes determined at USGS laboratories for water-quality and bottom-material samples collected at six primary sites of the Deer Creek synoptic study, September 2002

[OWQRL, Ocala Water Quality and Research Laboratory; NTU, nephlometric turbidity units; µS/cm, microsiemens per centimeter; C, Celsius; mg/L, milligrams per liter; NWQL, National Water Quality Laboratory; mL, milliliters; µg/L, micrograms per liter; LDSL, Louisiana District Sediment Laboratory; OGRL, Organic Geochemistry Research Laboratory; µg/kg, micrograms per kilogram]

Additional Field or Laboratory Constituents (Water)
Color (platinum-cobalt) - OWQRL
Turbidity (NTU) - OWQRL
pH, laboratory, standard units- OWQRL
Specific conductance, laboratory, µS/cm at 25º C - OWQRL
Alkalinity, water, unfiltered, laboratory, mg/L as $CaCO_3$- OWQRL
Carbon, organic, total, mg/L as C - OWQRL
Carbon, organic, dissolved, mg/L as C - NWQL
Carbon, inorganic + organic, particulate, total, mg/L as C - NWQL
Biochemical oxygen demand, 5-day, mg/L, at 20º C – Mississippi District
Chemical oxygen demand, high level, mg/L - OWQRL
Fecal coliform, colonies per 100 mL – Mississippi District
Chlorophyll-a, phytoplankton, µg/L - OWQRL
Sediment, suspended, mg/L - LDSL
Residue, total, non filterable, mg/L - OWQRL
Solids, residue on evaporation at 180º C, dissolved, mg/L - OWQRL

Major Ions (Dissolved in Water, mg/L) - OWQRL
Calcium (as Ca)
Magnesium (as Mg)
Potassium (as K)
Sodium (as Na)
Chloride (as Cl)
Fluoride (as F)
Sulfate (as SO_4)

Nutrients (Water, mg/L) - OWQRL, except where noted
Nitrogen, ammonia, dissolved (as N)
Nitrogen, ammonia, total (as N)
Nitrogen, ammonia plus organic, dissolved (as N)
Nitrogen, ammonia plus organic, total (as N)
Nitrogen, nitrite plus nitrate, dissolved (as N)
Nitrogen, nitrite plus nitrate, total (as N)
Nitrogen, nitrite, dissolved (as N)
Nitrogen, nitrite, total (as N)
Nitrogen, particulate, water, filtered, suspended, (NWQL)
Phosphorus, orthophosphate, dissolved (as P)
Phosphorus, orthophosphate, total (as P)
Phosphorus, dissolved (as P)
Phosphorus, total (as P)

Trace metals (Dissolved in Water, µg/L) - OWQRL
Aluminum (as Al)
Antimony (as Sb)
Arsenic (as As)
Beryllium (as Be)
Boron (as B)
Cadmium (as Cd)
Chromium (as Cr)
Cobalt (as Co)
Copper (as Cu)
Iron (as Fe)
Lead (as Pb)
Manganese (as Mn)
Mercury (as Hg)
Molybdenum (as Mo)
Nickel (as Ni)
Selenium (as Se)
Silver (as Ag)
Strontium (as Sr)
Thallium (as Tl)
Vanadium (as V)
Zinc (as Zn)

Table 3.—Listing of all analytes determined at USGS laboratories for water-quality and bottom-material samples collected at six primary sites of the Deer Creek synoptic study, September 2002 … *continued*

Pesticides and Degradates (Dissolved in water, µg/L) – NWQL, except where noted

2,4-d methyl ester	chlorothalonil	glyphosate (OGRL)	pebulate
2,4-d	chlorpyrifos	hdroxyatrazine	pendimethalin
2,4-db	clopyralid	imazaquin	permethrin, cis
2,6-diethylaniline	cyanazine	imazethapyr	phorate
3-hydroxy-carbofuran	cycloate	imidacloprid	picloram
3-ketocarbofuran	dacthal	lindane	prometon
acetochlor	DCPA	linuron	pronamide
acifluorfen	deethylatrazine	malathion	propachlor
alachlor	deethyldeisopropyl atrazine	MCPA	propanil
aldicarb sulfone	deisopropyl atrazine	MCPB	propargite
aldicarb sulfoxide	diazinon	metalaxyl	propham
amino methyl-phosphonic acid (OGRL)	dicamba	methiocarb	propiconazole
atrazine	dichlorprop	methomyl	propoxur
bendiocarb	dieldrin	methyl azinphos	siduron
benfluralin	dinoseb	methyl parathion	simazine
benomyl	diphenamid	metolachlor	sulfometruron methyl
bensulfuron-methyl	disulfoton	metribuzinl	tebuthiuron
bentazon	diuron	metsulfuron-methyl	terbacil
bromacil	EPTC	molinate	terbufos
bromoxynil	ethalfluralin	napropamide	thiobencarb
butylate	ethopropl	neburon	triallate
carbaryl	fenuron	nicosulfuron	tribenuron
carbofuran	flumetsulam	norflurazon	triclopyr
chloramben	fluometuron	oryzalin	trifluralin
chlorimuron	fonofos	oxamyl	urea, 3(4-chlorophenyl) methyl
	glufosinate (OGRL)	p,p' DDE	
		parathion	

Organochlorines in Bottom Material (µg/kg, dry weight) - NWQL

Aldrin	Heptachlor	o,p'-DDT
Chlordane, technical	Lindane	p,p'-DDD
Dieldrin	Methoxychlor	p,p'-DDE
Endosulfane I	Mirex	p,p'-DDT
Endrin	o,p'-DDD	Gross PCB's
Heptachlor epoxide	o,p'-DDE	Toxaphene

Table 4.—Measurements of physical properties for the Deer Creek synoptic study, September 2002

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; C, Celsius; all sites located in Mississippi; SR1, State Road 1; SE, southeast; SW; southwest; NE, northeast; nr, near; NW, northwest; AB, above; values in bold are means (medians for pH) for field measurements collected with depth and width at sites with bridge crossings]

Station name	Turbidity, nephelo-metric turbidity units	Dissolved oxygen (mg/L)	pH, Standard units	Specific conductance (µS/cm at 25 degrees C)	Temperature, water (degrees C)
Deer Creek at SR1 at Scott	**19**	**6.1**	**8.0**	**160**	**30.0**
Deer Creek at Scott	17	4.4	7.2	167	29.5
Deer Creek at Weir at Scott	**4.2**	**3.8**	**7.0**	**181**	**27.5**
Deer Creek SE of Scott	N/A	4.4	7.2	290	29.5
Deer Creek North of Forkland	15	5.6	7.6	463	29.0
Deer Creek at Forkland	**31**	**7.2**	**8.3**	**432**	**31.5**
Deer Creek at Priscilla	**92**	**10.4**	**8.5**	**389**	**32.0**
Deer Creek SW of Priscilla	**22**	**6.1**	**7.9**	**370**	**28.5**
Deer Creek at Metcalfe	17	7.7	7.9	435	29.0
Deer Creek SE of Metcalfe	**8.7**	**5.2**	**7.7**	**425**	**27.0**
Deer Creek NE of Stoneville	**25**	**6.3**	**7.8**	**425**	**28.0**
Deer Creek at Stoneville	**30**	**8.2**	**8.2**	**571**	**31.0**
Deer Creek South of Stoneville	**20**	**7.6**	**8.0**	**479**	**31.5**
Deer Creek East of Leland	28	6.9	7.7	500	29.5
Deer Creek South of Leland	**24**	**5.4**	**7.7**	**431**	**27.5**
Deer Creek nr Burdette	**16**	**5.2**	**7.8**	**454**	**28.5**
Deer Creek at Arcola	**18**	**4.8**	**7.5**	**328**	**29.0**
Deer Creek at Estill	**15**	**5.7**	**7.5**	**270**	**30.0**
Deer Creek North of Hollandale	**12**	**6.5**	**7.6**	**192**	**30.5**
Deer Creek at Hollandale	20	7.4	7.5	190	31.0
Deer Creek nr Hollandale	31	4.9	7.2	163	28.0
Deer Creek at Percy	**32**	**4.4**	**7.0**	**155**	**29.5**
Deer Creek at Panther Burn	**11**	**5**	**7.1**	**144**	**29.0**
Deer Creek at Vickland	**12**	**6.7**	**7.2**	**128**	**30.0**
Deer Creek nr Nitta Yuma	**18**	**8.1**	**7.8**	**211**	**31.0**
Deer Creek at Anguilla	18	6.4	7.6	384	29.5
Deer Creek nr Anguilla	**13**	**7**	**7.6**	**250**	**29.5**
Deer Creek North of Rolling Fork	N/A	N/A	N/A	N/A	N/A
Deer Creek at Rolling Fork	92	5.3	7.3	235	26.0
Deer Creek South of Rolling Fork	N/A	N/A	N/A	N/A	N/A
Deer Creek North of Egremont	140	5.5	7.2	109	31.0
Deer Creek nr Egremont	N/A	1.9	6.6	106	32.0
Deer Creek South of Egremont	34	5.3	7.1	210	29.0

Table 4.—Measurements of physical properties for the Deer Creek synoptic study, September 2002

Station name	Turbidity, nephelo-metric turbidity units	Dissolved oxygen (mg/L)	pH, Standard units	Specific conductance (µS/cm at 25 degrees C)	Temperature, water (degrees C)
Deer Creek North of Cary	55	3.1	6.8	121	28.5
Deer Creek at Cary	50	7.9	7.0	176	28.0
Deer Creek SW of Cary	38	5.3	7.4	N/A	29.5
Deer Creek NW of Blanton	**16**	**4**	**7.0**	**124**	**30.0**
Deer Creek at Blanton	**23**	**3.9**	**6.8**	**144**	**27.0**
Deer Creek nr Onward	**29**	**6.6**	**7.2**	**92**	**30.5**
Deer Creek South of Onward	N/A	N/A	N/A	N/A	N/A
Deer Creek nr Valley Park	**56**	**7.7**	**7.8**	**85**	**32.0**
Deer Creek North of Valley Park	N/A	10.3	7.5	113	32.0
Deer Creek AB Valley Park	46	8.1	7.6	102	31.0
Deer Creek at Valley Park	16	1.4	6.5	102	26.5
Deer Creek nr Hardee	**63**	**2.2**	**7.0**	**200**	**26.0**
Deer Creek East of Floweree	N/A	N/A	N/A	N/A	N/A
Deer Creek nr Floweree	16	3.1	6.4	126	28.5

Table 5.—Selected nutrient values for the six primary sites of the Deer Creek synoptic study, September 2002

[N, nitrogen; P, phosphorus; all sites are in Mississippi; values are in milligrams per liter; <, less than]

Station Name	Dissolved ammonia (as N)	Total ammonia plus organic nitrogen (as N)	Dissolved nitrite plus nitrate (as N)	Dissolved ortho-phosphorus (as P)	Total phosphorus (as P)
Deer Creek at Scott	0.08	1.6	0.04	0.10	0.24
Deer Creek East Of Leland	0.02	0.9	<0.02	0.07	0.12
Deer Creek Nr Hollandale	0.01	1.0	<0.02	0.07	0.22
Deer Creek At Rolling Fork	0.02	1.3	<0.02	0.24	0.42
Deer Creek At Cary	0.02	1.1	<0.02	0.03	0.18
Deer Creek At Valley Park	0.01	3.9	<0.02	<0.01	0.34

Table 6.—Organochlorine data for bottom-material samples collected at the six primary sites of the Deer Creek synoptic study, September 2002

[All sites are in Mississippi; <, less than; values listed are in micrograms per kilogram dry weight; all values above detection limits are in bold; E, estimated*]

Station Name	Lindane	Heptachlor	Aldrin	Heptachlor Epoxide	Technical Chlordane	Endosulfan I
Deer Creek at Scott	<0.2	<0.2	<0.30	**<1.00**	<3.0	<0.2
Deer Creek East of Leland	<0.2	<0.2	<0.2	<0.2	<3.0	<0.2
Deer Creek at Holland	<0.2	<0.2	<0.2	<0.2	<3.0	<0.2
Deer Creek at Rolling Fork	<0.2	<0.2	**<0.55**	<0.2	<3.0	<0.2
Deer Creek at Cary	<0.2	<0.2	<0.2	<0.2	<3.0	<0.2
Deer Creek at Valley Park	<0.4	<0.4	<0.4	<0.4	<6.0	<0.4

Station Name	Dieldrin	Endrin	p,p-DDE	p,p-DDD	p,p-DDT	p,p-Methoxychlor
Deer Creek at Scott	**4.67**	**<5.30**	**209**	**137**	**<3.65**	<2.5
Deer Creek East of Leland	<0.2	**6.09**	**617**	**260**	**28.2**	<2.5
Deer Creek at Holland	<0.2	**6.68**	**567**	**70.8**	**E4.55**	<2.5
Deer Creek at Rolling Fork	<0.2	**5.42**	**199**	**81.7**	**24.8**	<2.5
Deer Creek at Cary	<0.2	<0.2	**11.7**	**6.06**	**1.23**	<2.5
Deer Creek at Valley Park	<0.4	**2.11**	**132**	**35.0**	**11.7**	<5.0

Station Name	Mirex	Toxaphene	Gross PCB's	o,p-DDE	o,p-DDD	o,p-DDT
Deer Creek at Scott	<0.2	<50	**E15.1**	<0.2	**32.2**	**<4.55**
Deer Creek East of Leland	<0.2	<50	**25.4**	**22.2**	**43.5**	**8.99**
Deer Creek at Holland	<0.2	<50	**E22.2**	**13.7**	**14.0**	**5.98**
Deer Creek at Rolling Fork	<0.2	<50	**E7.25**	**3.47**	**E9.95**	**6.24**
Deer Creek at Cary	<0.2	<50	<5.0	<0.2	**0.55**	<0.5
Deer Creek at Valley Park	<0.4	<100	<10.0	**4.76**	**6.25**	**2.78**

* Some of the results listed were reported with an "E," or estimated, qualifier. Typical reasons the E qualifier is used include matrix interference or breakdown, analyte confirmed but below reporting limit, or analyte confirmed above standards based on a dilution of the sample. All of the estimated data are considered valid.

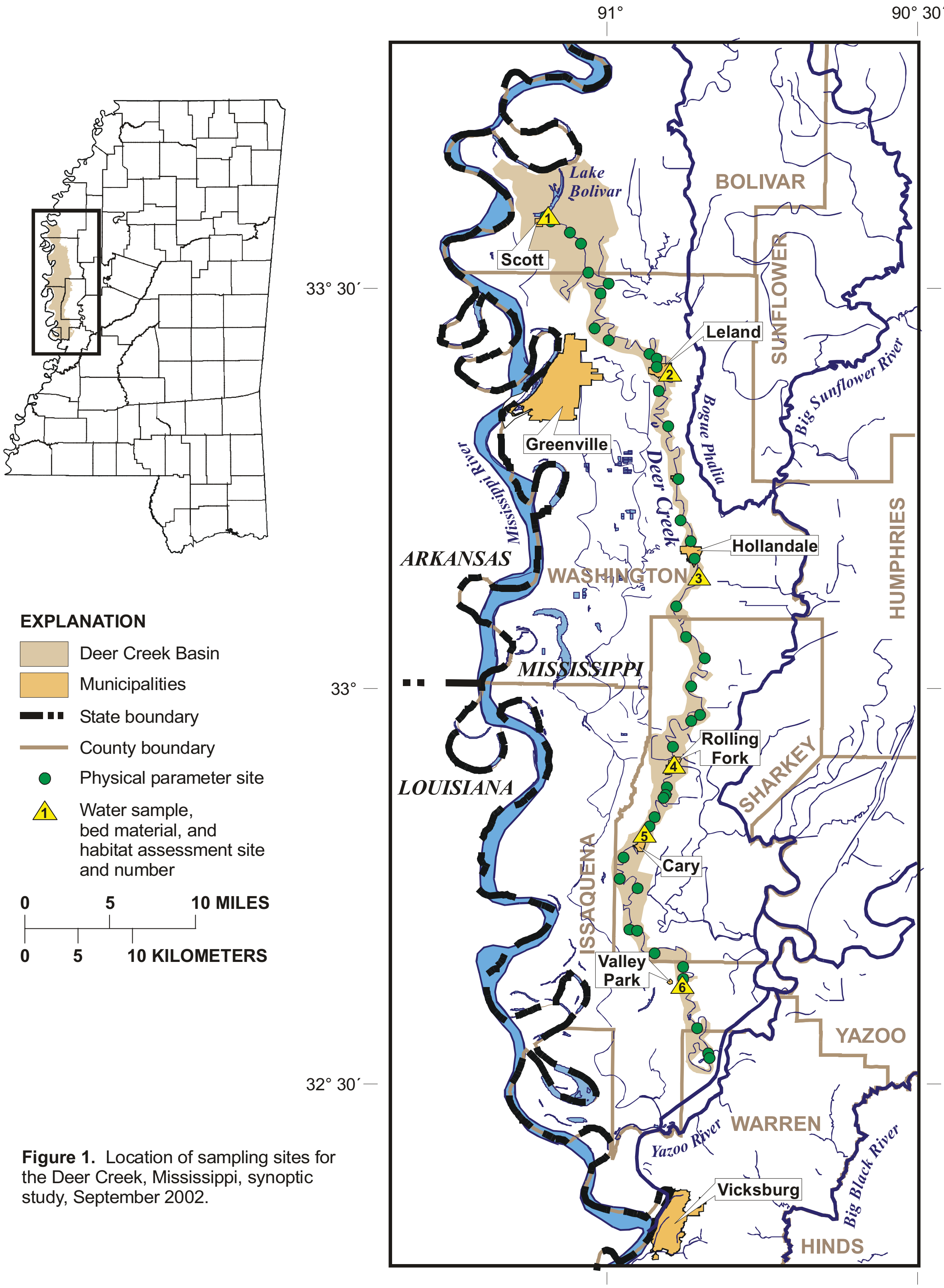

Figure 1. Location of sampling sites for the Deer Creek, Mississippi, synoptic study, September 2002.

Surface Water Sampling and Analysis for Comparisons with the USDA's AGNPS Model Predictions for the Upper Pearl River Watershed.

Mary Love Tagert, Joseph H. Massey, David R. Shaw, Michele B. Kroll, M. Cade Smith, Charles G. O'Hara, and Ronald L. Bingner[*].
Mississippi State University, [*]USDA-ARS National Sedimentation Lab.

As a result of recent legislation, the nonpoint source component of the 1972 Clean Water Act is now being implemented by the Environmental Protection Agency (EPA). Each state must submit a list of impaired waters to the EPA, and a Total Maximum Daily Load (TMDL) must eventually be established for each waterbody listed as impaired. Mississippi currently has 732 waters listed as impaired, with 25 of those impairments occurring in the Upper Pearl River Watershed. Contamination by pesticides is often listed as the reason for impairment in these and other Mississippi surface waters. In addition, the Upper Pearl River ultimately feeds into the Ross Barnett Reservoir, which is the drinking water supply for Jackson, MS. However, due to changes in land use/land cover in the Upper Pearl River Watershed, waters that were once impaired by pesticides may not currently be impaired. To assess the current level of impairment by pesticides in this watershed, a sampling regime was implemented to collect grab samples at seven gauged locations within the watershed. Samples were collected weekly from May through August 2002, and monthly thereafter. Samples were extracted via Solid Phase Extraction (SPE). Each extracted sample set includes two-liter samples from the seven selected sites, two lab spikes in deionized (DI) water, a field spike, a DI water blank, and a glassware wash. A multi-residue method was then used to analyze the surface water samples for fifteen pesticides: triclopyr, 2,4-D, tebuthiuron, simazine, atrazine, metribuzin, alachlor, metolachlor, cyanazine, norflurazon, hexazinone, pendimethalin, DDT insecticide degradation product, - p, p'-DDE -, diuron, and fluometuron.

Mean percent recoveries for spiked samples ranged from 39% for metribuzin to 120% for norflurazon. However, most average spike recoveries fell within an acceptable range (i.e., 85 to 95% recovery). Tebuthiuron, 2,4-D, metolachlor, and hexazinone were detected in ten or more samples out of a possible 36 samples. Fluometuron was the only compound that was not detected at any of the seven sites, while pendimethalin and metribuzin were only detected at one site to date. See Table 1 for ranges of concentrations detected in samples and the corresponding Health Advisory Levels (HAL) for each compound, if applicable.

Table 1. Concentration ranges detected with corresponding lifetime HAL.

Compound	**Concentration Range Detected (ng/mL)**	**Lifetime Health Advisory Level (mg/L)**
2,4-D	0.10 – 201.58	0.07
triclopyr	0.11 – 172.79	N/A
fluometuron	N/A	0.09
diuron	0.24 – 2526.46	0.01
tebuthiuron	0.21 – 0.43	0.5
simazine	0.15 – 0.18	0.004
atrazine	0.10 – 251.22	Under Review
metribuzin	0 – 423.54	0.2
alachlor	0.13 – 0.20	N/A
metolachlor	0.14 – 279.45	0.1
cyanazine	0.20 – 0.32	0.001
pendimethalin	0 – 129.27	N/A
p,p’ - DDE	0.10 – 144.78	N/A
norflurazon	0.21 – 0.23	N/A
hexazinone	0.12 – 650.85	0.4

DEVELOPMENT OF WATERSHED AND SUBWATERSHED BOUNDARIES FOR MISSISSIPPI

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INTRODUCTION

Successful implementation of federal regulatory programs such as the Clean Water Act and the Safe Drinking Water Act mandates that federal, state, and local agencies, as well as scientists and consultants in the private sector, have appropriate hydrologic data to make informed decisions, do analyses, and address water-quality issues on a watershed basis. These hydrologic data are required to accomplish such tasks as establishing and implementing Total Maximum Daily Loads (TMDLs) and source-water protection. Drainage-area data, at the watershed scale, are not currently available in many states. Engineers need drainage-area data to design various hydraulic structures such as bridges, culverts, storm-sewer systems, and intake and effluent discharges for various industrial, manufacturing, and processing plants. Accurate drainage-area data is needed by regulators and managers to assess the effects of proposed water use, design and develop flood-control structures, measure and mitigate water quality, and develop surface-water models to assist in appropriate water-resource management decisions.

In 2003 the U.S. Geological Survey (USGS), in cooperation with the U.S. Department of Agriculture/Natural Resources Conservation Service (NRCS), the U.S. Department of Agriculture/Forest Service (USFS), the Mississippi Department of Environmental Quality/Office of Pollution Control (MSDEQ-OPC), and the Mississippi Automated Resources Information System (MARIS), will complete development of a watershed and subwatershed map of Mississippi attributed with 10- and 12-digit hydrologic unit codes (HUC). The base data for this map are 1:24,000-scale, 7.5-minute topographic quadrangle sheets. These data will be made available as hardcopy, CD-ROM, or direct view and download through the USGS Internet portal at:

http://ms.water.usgs.gov/

These watershed and subwatershed boundaries provide a standardized dataset for the state of Mississippi for use by water-resource managers, engineers and planners in locating, storing, retrieving, and exchanging hydrologic data. Also, these data, in a digital form, can be used in surface-water steady- and unsteady-flow modeling, runoff modeling, cataloging water-data acquisition, the computation and estimation of flood frequency, and low-flow duration, as well as many other water-quality and water-use projects. This report presents information on methodology and development of drainage and hydrography in the form of USGS hydrologic boundaries of water-resources regions, subregions, basins (formerly called accounting units), subbasins (formerly called cataloging units), watersheds, and subwatersheds.

BACKGROUND

The USGS Office of Water Data Coordination, the U.S. Water Resources Council, and the USGS Resources and Land Information Program initiated the original production of the standard map series called “hydrologic unit maps,” which present codes, names, and boundaries of hydrologic units in the United States and U.S. territories in the Caribbean area (Seaber et al., 1975). In this national map series the United States is divided into 21 major regions. Mississippi is contained within three of these regions (the Mississippi regions are represented by 2-digit numbers: 03, 06, and 08). These 21 regions (each of these sub-divisions also being represented by 2-digit numbers) were then subdivided into 222 subregions, 352 accounting units, and 2,150 cataloging units (2 digits each) to establish the original 8-digit hydrologic unit code (HUC) region (ww), subregion (xx), accounting unit (yy), and cataloguing unit (zz) for the United States and U.S. territories in the Caribbean area (U.S. Geological Survey, 1977).

In the 1970s, the NRCS (formerly named the U.S. Department of Agriculture Soil Conservation Service) adopted the use of HUCs for all NRCS investigations and surveys. Subsequently, the NRCS initiated a national program to further subdivide HUCs into watersheds for use in water-resource planning. A 3-digit extension was added to the 8-digit HUCs by the NRCS during this time period to designate watersheds as 11-digit HUCs. The trailing digit was later dropped and the HUC designation was changed from 11 digits to 10 digits. A 10-digit watershed encompasses from approximately 40,000 to 250,000 acres (62.5 to 391 square miles (mi^2)). The NRCS successfully completed this program in the 1980s for Mississippi. During this period, the Mississippi District of the USGS delineated the drainage areas of many of the state’s smaller streams using 1:24,000- and 1:62,500-scale topographic quadrangle sheets as base maps. These drainage areas are less than 1 mi^2 in many parts of the state.

In 2001, the USGS, in cooperation with the NRCS, the USFS, MSDEQ-OPC, and the MARIS, began development of a statewide dataset of watershed and subwatershed boundaries showing the hydrologic units for the 10- and 12-digit hydrologic unit codes (5^{th} and 6^{th} order basins). This project followed guidelines published by the Federal Geographic Data Committee (FGDC) Proposal, Version 1.0 entitled: *Federal Standards for Delineation of Hydrologic Units Boundaries* (U.S. Department of Agriculture, 2001). The 12-digit subwatersheds for Mississippi generally range in size from approximately 7,000 to 40,000 acres (10.9 to 62.5 mi^2) and serve as a reference for drainage-area information. The dataset developed from this project will present information on drainage and hydrography in the form of USGS hydrologic boundaries of water-resource regions, sub-regions, basins, sub-basins, watersheds, and subwatersheds. The base maps used for these delineations are USGS 1:24,000-scale 7.5-minute topographic quadrangle sheets.

OBJECTIVES

This report describes the methods used in the development of watershed and subwatershed boundaries for Mississippi and presents examples of provisional results of this project. The report also discusses the development of the geographic information system (GIS) database for the basin, sub-basin, watershed and subwatersheds (6-, 8-, 10-, and 12-digit units). The data presented in this report are provisional and subject to change upon further review by personnel of the USGS.

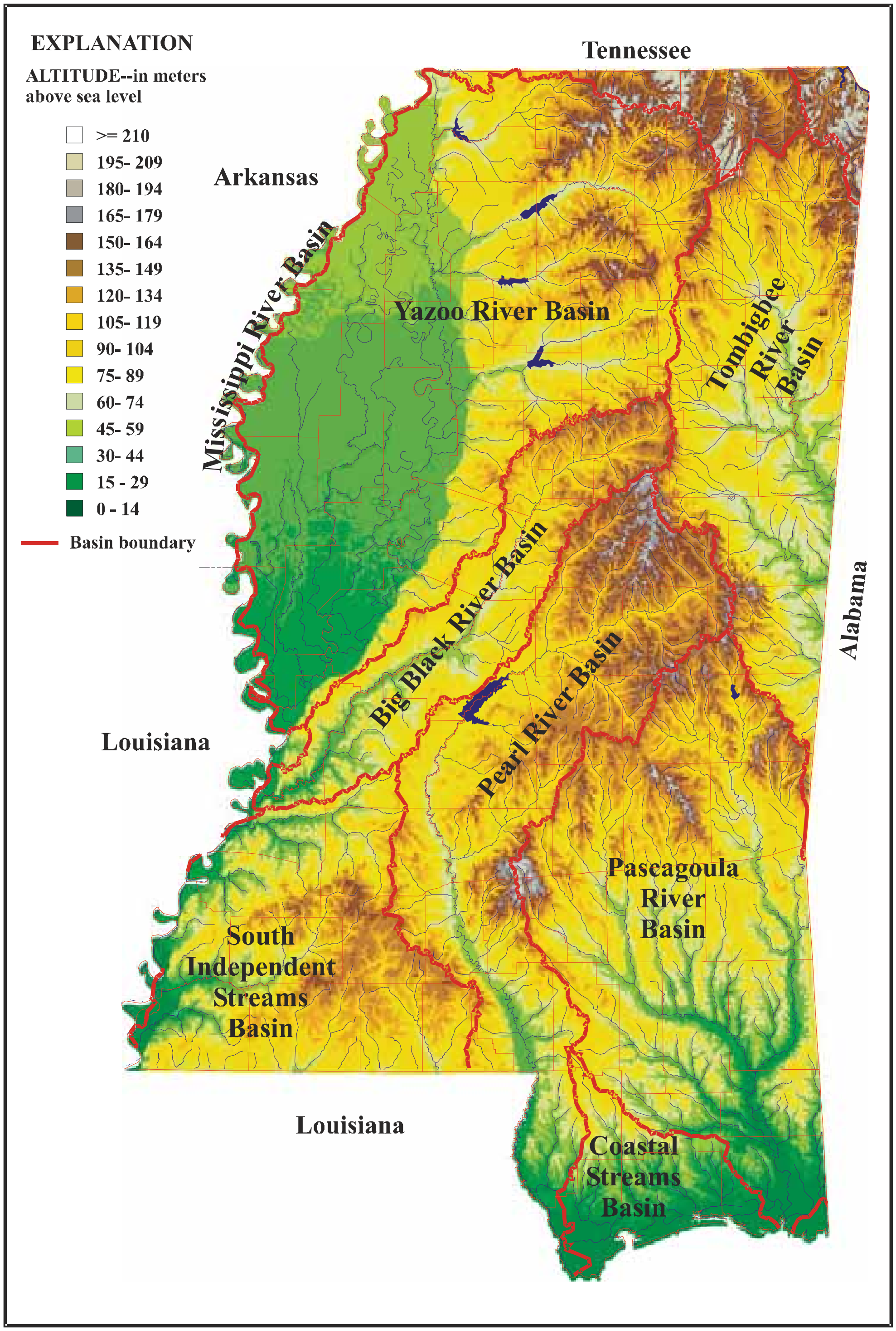

Figure 1. —Generalized land-surface elevation map of Mississippi showing the eight principal drainage basins in the state as designated by the MSDEQ (Strom, 1998).

STUDY AREA DESCRIPTION

Mississippi is located within the East Gulf Coastal Plain physiographic province and generally can be divided into two physiographic districts, the coastal plain uplands and the lower Mississippi River Alluvial Plain (known locally as the "Delta"). The state covers 47,716 mi^2 and is contained within the 30- and 35- degree north latitudes and the 88- and 92- degree west longitudes. The Coastal Plain Uplands District encompasses more than 40,000 mi^2 (about 85 percent of the state) and is predominantly rolling forested hills with undulating prairies that vary in natural species composition from predominantly pine in the lower third of the state, to pine-hardwood in other parts. The Delta contains approximately 7,000 mi^2 (about 15 percent of the state), is ellipsoidal in shape, extends 200 miles (mi) north-south, and is more than 60 mi at its widest point east-west. It extends from Vicksburg north to the state boundary south of Memphis, Tennessee. The Delta is an area of very low relief (less than 100 feet (ft) of rise in land-surface elevation from Vicksburg to Memphis) characterized by sloughs and old runs of the Mississippi River. A thick veneer of loess overlies the bedrock of the valley walls and forms an abrupt steep border between the Delta and the Coastal Plain Uplands (Thornbury, 1965). Land-surface elevations in the state range from sea level near the coast to more than 800 ft above sea level in the northeastern corner of the state. Mississippi's climate varies from humid to sub-tropical. Average annual rainfall ranges from approximately 50 inches (in.) in the northern part of the state to almost 70 in. near the coast (Wax, 1990).

The eight principal river basins in the State of Mississippi, as designated by the MSDEQ are the Big Black, Coastal Streams, Mississippi, Pascagoula, Pearl, South Independent Streams, Tombigbee, and the Yazoo (fig. 1). In the Coastal Plain Uplands, which contains all the above-mentioned basins except the Mississippi and Yazoo River Basins, the drainage pattern is fairly well developed. On streams in the state where the USGS maintains streamflow gaging stations, the median stream gradient is approximately 10 feet/mile (ft/mi) for streams draining less than 800 mi^2. The drainage pattern in the Delta region of the Yazoo River Basin is naturally not well defined and is greatly impacted by anthropogenic changes such as canalization, drainage canals, flood-control levees, and other agricultural and engineering practices. The median gradient for streams located in the Delta is approximately 1 ft/mi (Landers and Wilson, 1991). Streamflow patterns become tidally influenced near the Gulf of Mexico coast.

METHODOLOGY

From 2001 to 2003, the 8-digit HUCs (subbasins) in Mississippi were subdivided into watersheds and subwatersheds, which were then assigned unique 10-digit and 12-digit codes, respectively. The 12-digit code identifies each of the six levels of classification within six 2-digit fields. An example of the HUC numbering and naming system is given below for the Blytha Creek subwatershed (HUC 080602010301):

08 -	Region: Lower Mississippi; drainage area 101,324 mi^2
0806 -	Subregion: Lower Mississippi - Big Black drainage area 7,067 mi^2
080602 -	Basin (formerly called Accounting Unit) Big Black - Homochitto; drainage area 6,500 mi^2
08060201 -	Subbasin (formerly called Cataloging Unit): Upper Big Black River; drainage area 1,478 mi^2
0806020103 -	Watershed: Big Bywy Ditch; drainage area 159 mi^2
080602010301 -	Subwatershed: Blytha Creek; drainage area 56 mi^2

A “00” in the basin code indicates that the basin name and the subregion name are the same. Likewise, if the watershed code is “00”, it shares the same name as the subbasin. An example of an assigned 12-digit Hydrologic Unit Code for Mississippi is shown in figure 2.

Watershed and subwatershed boundaries for streams in Mississippi were digitized from an existing set of 1:24,000-scale maps containing drainage areas previously delineated by USGS personnel as part of ongoing water-resource investigations in the state. The USGS and NRCS worked jointly to review and check the digitized boundaries. The USGS assigned all 10- and 12-digit hydrologic unit codes to these watersheds and subwatersheds. Attribution tables listing the HUC and drainage area for each watershed and subwatershed were compiled and input by MARIS.

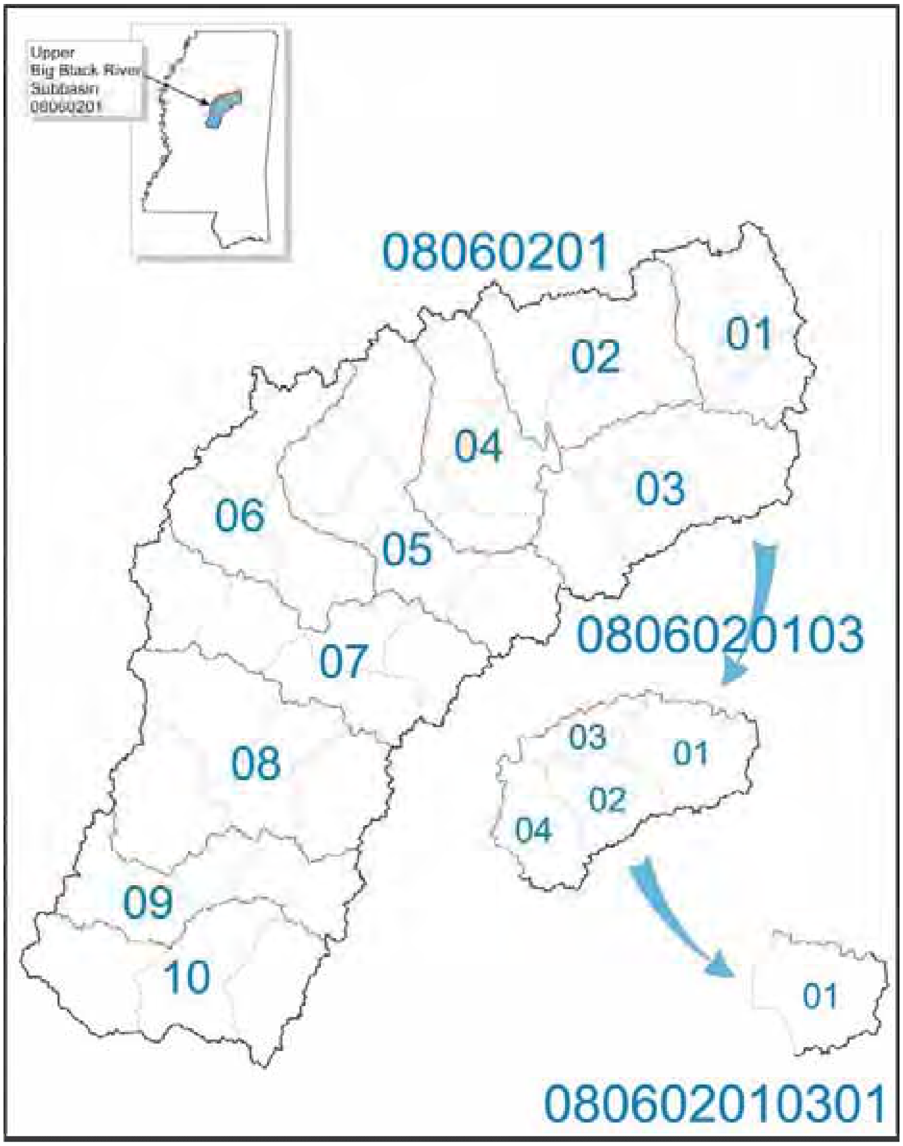

Figure 2. —Example of the 12-digit hydrologic unit numbering system for the HUC 080602010301 in the Upper Big Black River subbasin of Mississippi.

In several areas of Mississippi, 15-minute topographic quadrangles were used by the USGS to delineate watershed boundaries in the 1970s and 1980s. During the current project, it was necessary to transfer watershed and subwatershed boundaries from 15-minute topographic quadrangles to previously-unavailable 7.5-minute topographic quadrangles prior to digitizing and GIS processing.

The quality-assurance procedures used to delineate and code the 10- and 12-digit watersheds and subwatersheds followed guidelines set forth in the FGDC Proposal, Version 1.0 entitled: *Federal Standards for Delineation of Hydrologic Units Boundaries* (U.S. Department of Agriculture, 2001). As a final check, the dataset will be reviewed and certified by the NRCS National Cartography and Geospatial Center in Fort Worth, Texas.

This project further defines the existing 2-, 4-, 6-, 8-digit Hydrologic Unit Codes into 10-, 12-digit watersheds and subwatersheds, respectively. The hierarchal breakdown of Hydrologic Unit Codes for the State of Mississippi is shown in figure 3.

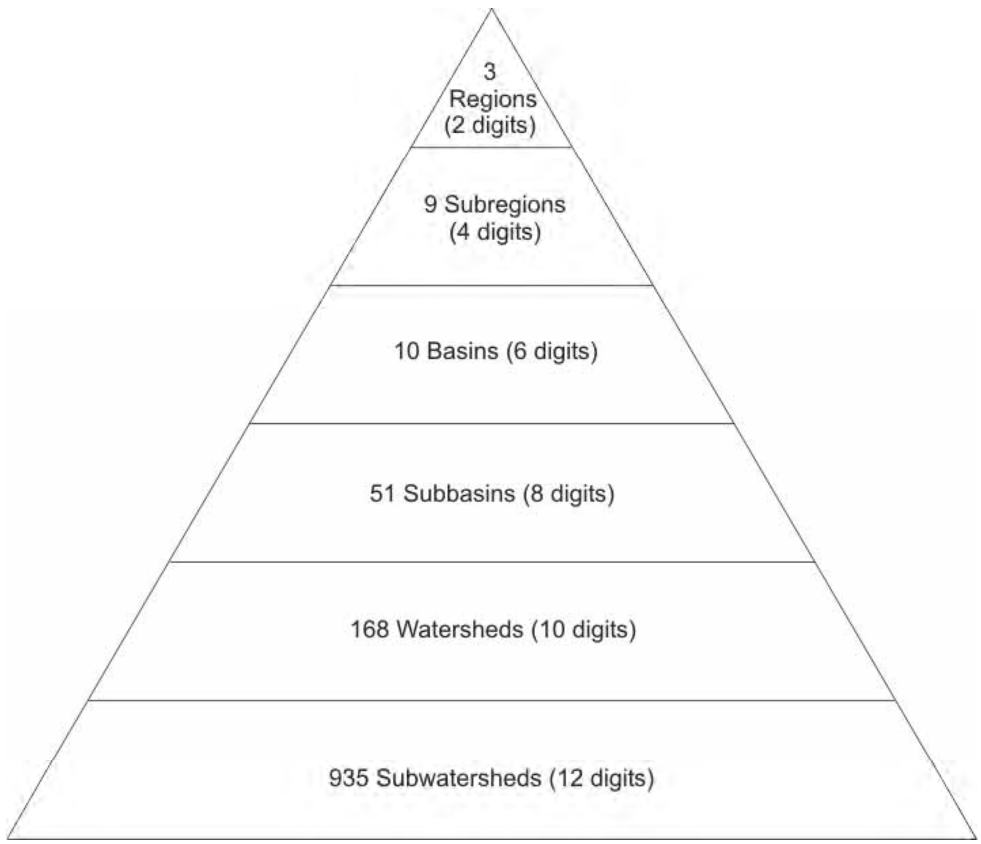

Figure 3. —Hierarchy for the hydrologic unit codes for the State of Mississippi (does not include watersheds and subwatersheds in Delta region of the Yazoo River basin below 8-digits).

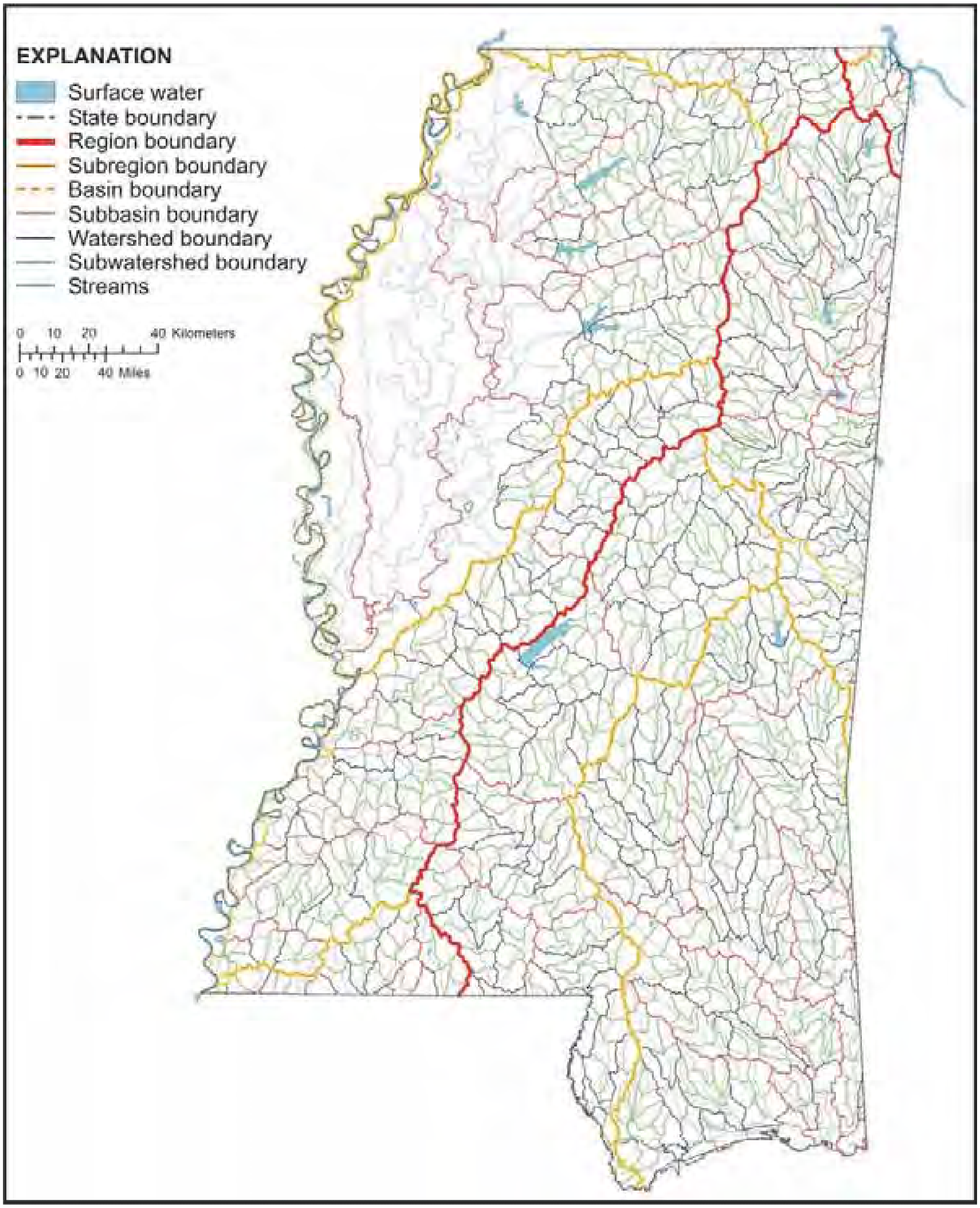

Figure 4. —Region, subregion, basin, subbasin, watershed, and subwatershed boundaries for the State of Mississippi.

SUMMARY

The USGS, in cooperation with the NRCS, the USFS, the MSDEQ-OPC, and the MARIS, will complete development of a watershed and subwatershed map of Mississippi attributed with 10- and 12-digit hydrologic unit codes in 2003. The original 8-digit hydrologic unit code containing 2 digits each for the region, subregion, basin (formerly called accounting unit), and subbasin (formerly called cataloging unit), has been enhanced by further subdividing the 8-digit subbasins into 10- and 12-digit watersheds and subwatersheds, respectively (fig. 4). For this report only subbasins were available for the Mississippi River Alluvial Plain.

Drainage areas originally delineated by personnel of the USGS Mississippi District in the 1970s and 1980s on 1:24,000-scale topographic quadrangles, were digitized and processed using GIS software. A total of 168 10-digit watersheds, ranging in size from 45,616 to 360,392 acres (71.28 to 563.11 square miles), and 935 12-digit subwatersheds, ranging in size from 7,083 to 54,773 acres (11.07 to 85.58 square miles), were delineated and digitized.

The hydrologic unit boundaries, hydrologic unit codes, and drainage-area data are stored in a GIS database, which will be made available on CD-ROM and on the Internet at the time of publication. The hydrologic unit map for Mississippi, provides a standard geographical framework for water-resources and selected land-resource planning.

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PROJECT INTEGRATION FOR BASIN MANAGEMENT: MISSISSIPPI'S UPPER PEARL RIVER BASIN

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Watershed management is a complicated undertaking. Due to funding realities, successful integrated watershed or basin management requires the coordination of numerous "projects" funded through various existing federal and state programs (i.e., source water protection, nonpoint source water pollution, etc.). The process of developing project ideas and proposals provides an ideal opportunity to organize and expand informal cooperative basin or watershed management partnerships. As projects are funded the partnerships can be formalized as Watershed Advisory Groups. This presentation provides a status report on the progress of this approach in Mississippi's Upper Pearl River Basin.

NOTES:

DEVELOPMENT OF A PROGRAM FOR IMPROVED FLOOD PREPAREDNESS, WARNING, AND RESPONSE IN THE LIMPOPO RIVER BASIN OF BOTSWANA

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INTRODUCTION

During 1999-2000, many parts of the Southern African Region experienced devastating floods, most of which occurred from December 1999 through March 2000. Rainfall accumulations during February 2000 in Botswana have been estimated in some areas to have been greater than 1,000 millimeters (39.4 inches) in one storm event, which is more than twice the average annual rainfall. Many lives were lost; tens of thousands of people were displaced from homes, and more than $285 million of damage was reported.

The local water-related agencies in the Republic of Botswana were not well equipped to respond to these rapidly occurring major flood events. At the time of these floods, there was limited coverage of hydrological and meteorological monitoring stations in the Limpopo River Basin in Botswana, and only three stations provided near real-time reporting capability. In addition, the local data-collection agencies had no capacity to convert the raw data collected by Botswanan hydrologic and meteorologic agencies into the type of information needed by the Republic of Botswana National Disaster Management Office (NDMO) to prepare, warn, or effectively respond to these disasters. The information available to the NDMO decision makers during this flooding could have been significantly improved with the installation of additional, strategically placed, near real-time river and rainfall monitoring stations, along with training and the infrastructure to support rainfall/runoff modeling.

In response to these floods the U.S. Geological Survey (USGS) in cooperation with the U.S. Agency for International Development, Regional Center for Southern Africa (USAID/RCSA) developed a plan to improve flood preparedness, warning, and response in the Limpopo River basin in Botswana. The project, which was entitled "Village Flood Watch: A Program for the Improved Preparedness, Warning and Response in the Limpopo River Basin in Botswana," was made possible by a grant from the USAID/RCSA located in Gaborone, Botswana. In addition, the USGS worked closely with many national and international agencies to complete this project:

- European Organization for the Exploitation of Meteorological Satellites
- Republic of Botswana Department of Meteorological Services
- Republic of Botswana Department of Roads
- Republic of Botswana Department of Water Affairs
- Republic of Botswana National Disaster Management Office
- Southern African Development Community
- World Meteorological Organization

This program provided hydrological and meteorological parameters and a pilot hydrological runoff model that will assist the Botswanan governmental agencies in the propagation of hydrological runoff models in all the subbasins of the Limpopo River Basin for use in future flooding disasters. This report presents an overview of all phases of the project, along with selected data about gages within the Limpopo River Basin.

BACKGROUND

Botswana is located in southern Africa (fig. 1). Three river basins that have experienced recent devastating floods in the southern African region are the Zambezi, the Limpopo and the Olifants (fig. 1). Climate in Botswana is primarily continental to semi-arid to arid, with wettest conditions in the eastern and northeastern part of the country. Drought is common, and effective coping mechanisms have evolved to deal with its consequences. Flooding, however, characteristically has been much less frequent, and existing transportation infrastructure was not designed with large flooding in mind. Flooding in Botswana generally has been associated with periods of rainfall of high intensity and short duration; but in recent years, more extended periods of sustained, heavy rainfall have been experienced. The 1999/2000 rainy season was unusually wet in Botswana, with the worst floods occurring during February when tropical cyclone Eline came inland and dumped torrents of rain on the country. It has been reported that this single event resulted in greater than 1,000 mm of rain in some places. Many rivers in Botswana, and especially the Limpopo River Basin in the southeastern part of the country, rose over their banks, covered roads and bridges, and flooded many villages. Extensive damage occurred in 23 of 24 districts in the country. Thousands of homes collapsed or were heavily damaged, and subsequently tens of thousands of people were made homeless. Crops were lost, and transportation infrastructure was damaged or destroyed and made completely impassable at many locations for many days. Economic losses were estimated to be more than P1 billion (about $285,000,000).

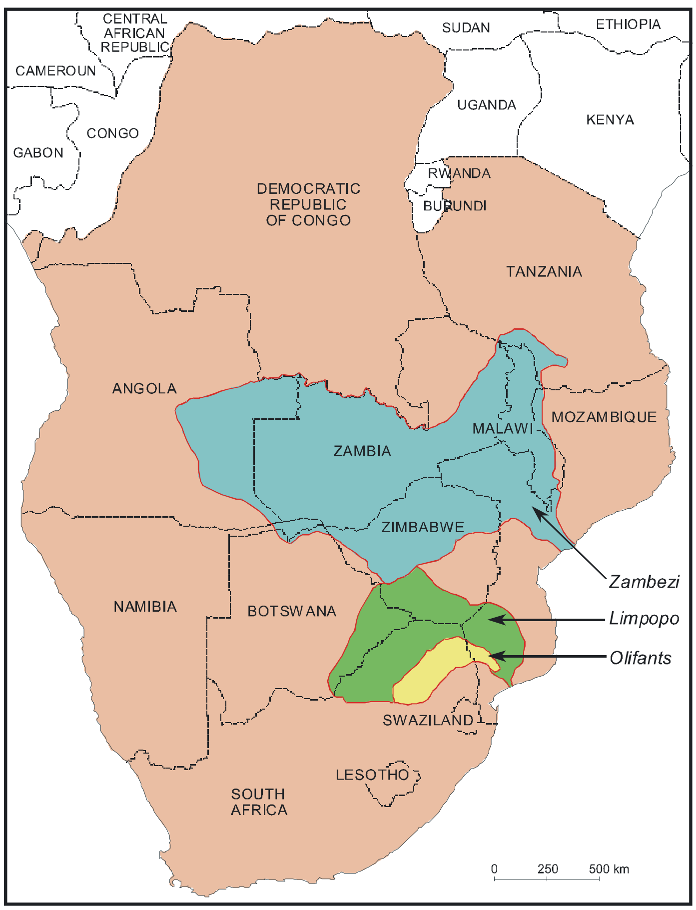

Figure 1.—Map of Southern Africa showing drainage basins of the Zambezi, Limpopo, and Olifants Rivers.

The floods of 1999/2000 in Southern Africa revealed significant gaps in all phases of flood disaster preparedness across the region. As a result, several plans were developed in an effort to improve data collection and dissemination in future events. These include the development of a Multi-Sectoral Disaster Strategy by the Southern African Development Community (SADC) Secretariat, a Floods and Droughts Management Plan prepared by the SADC Water Sector Coordinating Unit (WSCU), and a National Disaster Management Plan prepared in Botswana by the NDMO. The USAID also has initiated multiple activities designed to help with disaster relief in the region. Recognizing that timely hydrological and meteorological information crucial to decision makers at the national level was both limited and inadequate, one of the activities USAID initiated was the Village Flood Watch project described in this document. The USGS was asked by USAID to develop a work plan and to implement the project.

EXISTING INSTITUTIONS AND INFORMATION INFRASTRUCTURE

Mitigation of losses due to extreme precipitation and flooding events requires a sequence of actions: observation, communication, and response. During this project, the USGS worked with institutions presently contributing to this process to help ensure this project did not duplicate other efforts and to foster local involvement and participation.

In Botswana, hydrometeorological observations are made by regional (SADC) and national organizations - Department of Water Affairs (DWA), and Department of Meteorological Services (DMS). Through SADC, the World Meteorological Organization (WMO) has included Botswana in their Hydrologic Cycle Observing System (HYCOS) network of stream-gaging stations that report in a near real-time format. Before the Village Flood Watch Project, four near real-time stations were located in Botswana, and three of those were in the Limpopo River Basin. One of these three stations was destroyed during the severe flooding in 2000, and there currently are plans to replace it. A more extensive stream-gaging network is operated by DWA without real-time reporting capability. Offices at the district level carry out the stream-gaging program.

Precipitation stations are operated by the DMS, which has two offices in Gaborone (one at the airport and one at the city center) and field offices in 14 of the country's 24 districts. Telephone and fax are used regularly to communicate precipitation observations to the DMS headquarters staff in Gaborone. As a national meteorological service, DMS participates in the Global Telecommunications System (GTS) of the WMO. Readings from select stations are forwarded to WMO through the GTS to contribute to the joint data holdings of the world meteorological community. As a GTS participant, DMS also has access to precipitation observations made in neighboring countries. Beginning in 2001, the SADC Regional Remote Sensing Unit in Harare, Zimbabwe, gained access to daily satellite rainfall estimates from the United States National Oceanographic and Atmospheric Agency (NOAA) and precipitation forecast maps produced by the United States Air Force Weather Agency, through its participation in a Famine Early Warning System Network operated by the USGS. These products, in turn, are shared with DMS via the Internet. The DWA operates a separate and somewhat independent network of precipitation stations in many areas of Botswana, which is used by DWA in various catchment basins to support the development of future water resources in the country.

Seasonal forecasting has become a regular practice of SADC in recent years. With the advent of each rainy season in Botswana, DMS meets with NDMO and the media to discuss the forecast provided by a forum of regional and international experts. A press release regarding the expected onset of rains and expected characteristics of the upcoming rainy season is prepared and published in newspapers throughout Botswana. The regional approach of SADC offers a good opportunity and vehicle to implement real-time stream-gaging in Botswana because weather patterns are broad in scope and are not impacted by political boundaries.

Flood response actions are coordinated and directed by NDMO, and are implemented by the District Disaster Management Coordinators (DDMCs). Under the leadership of the District Commissioners, the DDMCs bring together the appropriate disaster relief agencies needed to help resolve the current disaster problem. These agencies may include: Botswana Defense Forces, Botswana Red Cross Society, Botswana Police Service, fire departments, and other District government departments. Services provided include search and rescue; evacuation to higher ground; provision of temporary shelter, sanitation, food and water; and rehabilitation of community services, neighborhoods, and homes. At present, there is no decentralization of institutional disaster management below the district level.

The hydrometeorological information from DMS and DWA are critical inputs to the NDMO, and cooperation with DMS is especially close because of its operational forecasting role. Under ordinary circumstances, DMS forecasts are broadcast twice daily on radio and television. During emergencies, there are additional radio programming slots available for more frequent forecast updates. In extreme situations, the media can be called upon to deliver live news coverage of a flood event.

The DWA is less directly involved with communication of flood watches and warnings. Stream flow data routinely are provided to the DDMCs and the NDMO who incorporate the data into their messages to the public.

GENERAL STRATEGY AND APPROACH

This report describes the general strategy and approach used in the Village Flood Watch Project to help establish the initial network of an effective pilot flood-warning system in Botswana, which is built on public involvement and awareness at the government and community level. The goals of the project were to improve the telemetry of extreme rainfall and stream levels and to provide needed information during times of flood disasters that will help trigger watches, warnings, and response at the government and village level.

The project also focused on the transfer of expert knowledge of hydrometeorological runoff modeling tools to national government agencies which can be used with near real-time rainfall, stream levels, stream flow and other basin characteristics to enhance flood-warning capabilities in the Limpopo River Basin. This knowledge can be transferred throughout the country to improve flood preparedness, warning, and response by national and local government agencies.

An initial USGS fact-finding mission to Gaborone in May 2001 provided sufficient information to outline an approach for the development of a village flood watch program. This initial mission provided sufficient information to propose a general strategy that ultimately was approved by USAID/RCSA. A second mission to Botswana in May 2002 gathered the information necessary to develop a detailed work plan as outlined in this document.

USGS experts worked closely with appropriate agencies at the international, regional, national, district, and community levels in developing and implementing this work. One of the initial tasks of the May 2002 mission was to identify the scope and scale of present precipitation and stream-flow data-collection systems. An effective flood-warning system requires timely precipitation and stream flow data over a wide area. During the May 2002 mission, personnel of the USGS worked with DMS and DWA scientists in mapping and evaluating the current hydrometeorological network and worked closely with them to identify additional sites that would be important for an early warning system. USGS recommended using the SADC-HYCOS network satellite system as a means to transmit the new real-time data being collected and agreed to work with SADC personnel to implement the program. Local authorities were integrally involved in the selection and placement of all-weather stations at additional secondary schools. Augmentation of the national hydrological and meteorological networks by additional and upgraded near real-time monitoring stations will not only serve community preparedness goals, but also will give the

NDMO, DWA and DMS a more complete picture of flood preparedness and needs during the crucial management of future flooding disasters in Botswana. These stations also will provide needed data to begin the development of a flood-warning network built on timely and appropriate hydrometeorological data-modeling techniques.

SPECIFIC OBJECTIVES

The specific objectives of the project were accomplished with close coordination among the USGS, DWA, DMS, USAID/RCSA, SADC, and select District managers and local village authorities. The major objectives implemented in the Limpopo River Basin were to:

- Upgrade and enhance selected key hydrological monitoring stations to provide data in a near real-time capacity to key government agencies and the public through the Internet.
- Provide two all-weather meteorological stations to selected local secondary schools, which will serve the dual purpose of additional automatic meteorological rainfall stations at the national level and provide an additional educational tool to the schools' curricula.
- Document critical floods that occurred from 1995-2000 by surveying channel geometry, selecting roughness coefficients in channel and valley reaches of selected newly constructed and upgraded near real-time stream-gages, indirectly computing peak discharges using open-channel hydraulic methods for these recent floods, and further developing stage/discharge relations at these gages.
- Provide hydrologists and meteorologists within the DWA and DMS with training and computer equipment needed to develop hydrological runoff modeling capabilities necessary to construct an effective flood-warning network for the river systems within Botswana.
- Provide hydrologists and meteorologists within the DWA and DMS with training and equipment for the successful operation, maintenance, and troubleshooting of electronic hydrological and meteorological equipment used in their networks.

This project was constrained by a 7-month time period in which the work had to be completed.

PROCEDURE

In May and July 2002, USGS personnel traveled to Botswana to meet with the department heads of Botswanan water-related government agencies; USAID contracting agents; and U.S. Embassy officials in a data-gathering mission. These trips provided the foundation for the existing project. Site visits were made to many existing and proposed river-gaging sites to provide the project with its initial reconnaissance of proposed hydrological and meteorological monitoring stations to be built and those to be upgraded in the Limpopo River Basin. From this reconnaissance, a total of eight sites were chosen for equipment installations. Of these eight, three were upgrades at existing stream-gaging sites, three were new stream-gaging stations, and two were new meteorologic stations at secondary schools. During June through August, personnel of the Mississippi District designed, and pre-built the river and weather gages that would be installed in the Limpopo River Basin (fig. 2). Personnel of the USGS Hydrologic Instrumentation Facility (HIF) at Stennis Space Center, MS were instrumental in working with personnel of the Mississippi District in the operation and programming of new micro-pulse radar stage sensors.

Instrumentation used in the project was mostly manufactured by Sutron Corp (the use of firm, trade and (or) brand names in this report is for identification purposes only, and does not constitute endorsement by the U.S. Geological Survey). The data collection platform (DCP) acquired for the project is a Sutron 8210 (Model 821-0014), which is equipped with a Meteorological Satellite (METEOSAT) transmitter (Model 8200-2000). The European

Organization for the Exploitation of Meteorological Satellites (EUMETSAT) based in Darmstadt, Germany, allowed the use of their METEOSAT satellite for transmission purposes.

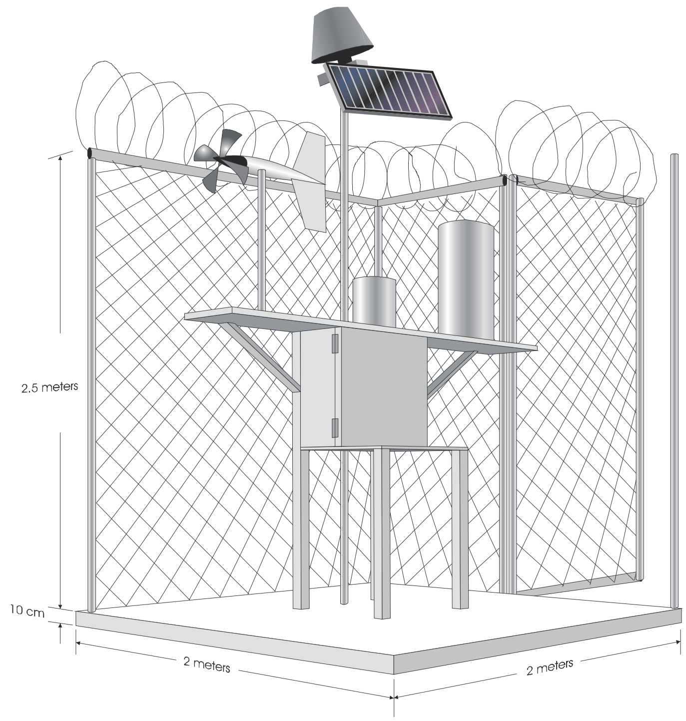

Figure 2.—Schematic of USGS designed meteorological gaging station for secondary schools in the villages of Moeng and Bobanong, Botswana.

A working relationship was also developed with the WMO in Geneva, Switzerland. Through the WMO, all hydrologic and meteorologic stations were assigned a unique WMO number, which allowed free transmission of the data through the METEOSAT. The WMO number also allows the data to be retransmitted from the EUMETSAT downlink in Germany through the WMO GTS. The GTS gives the project more global access to the data.

Sutron 5600-0530-1A incremental shaft encoders were used to measure river stage at the upgraded stilling-well sites. New HIF-tested, micro-pulse radar, stage sensors were used at the three newly constructed sites. The new radar sensors have shown promise in HIF testing at Stennis Space Center and at a USGS gage operated by the Mississippi District. The HIF-designed model, which for the purposes of the African work, was patterned for installation on a bridge handrail, and also for use on the downstream side of a railroad bridge. The HIF-designed model is unique in that it is interfaced with a Campbell Scientific CR-10 data logger that programs the unit and also serves as a redundant backup data logger for the gage.

Sutron Corp. also manufactured the following meteorological instrumentation used in the Village Flood Watch Project.

a. Accubar (Model 5600-0120) Barometric Pressure Sensor
b. Air Temperature (Model 5600-0311) High Accuracy Sensor
c. Relative Humidity (Model 5600-0313) High Accuracy Sensor
d. Wind Speed (Model 5600-0200) Sensor
e. Prop Vane (Model 5600-0201) Wind Direction Sensor
f. Stainless Steel Tipping Bucket (Model 5600-0425) Rain Gage

Highway and railroad bridge plans for proposed new river gages were obtained. Permits to build on Botswana highway and railroad bridges were applied for and granted from the Republic of Botswana Department of Roads and Botswana Railways Commission. Select secondary schools in the Limpopo River basin were contacted for participation in the meteorological station construction. The gages were pre-built, then disassembled, packed on crates, and shipped to Botswana in time for the arrival of the construction team in August through October.

In August and September 2002 three teams of USGS personnel traveled to Botswana for the construction and indirect measurement phases of the project. During this period, three new river gages were constructed, three existing river gages were upgraded to include near real-time transmitting capabilities and two new meteorological stations were constructed in the Limpopo River basin of Botswana (fig. 3).

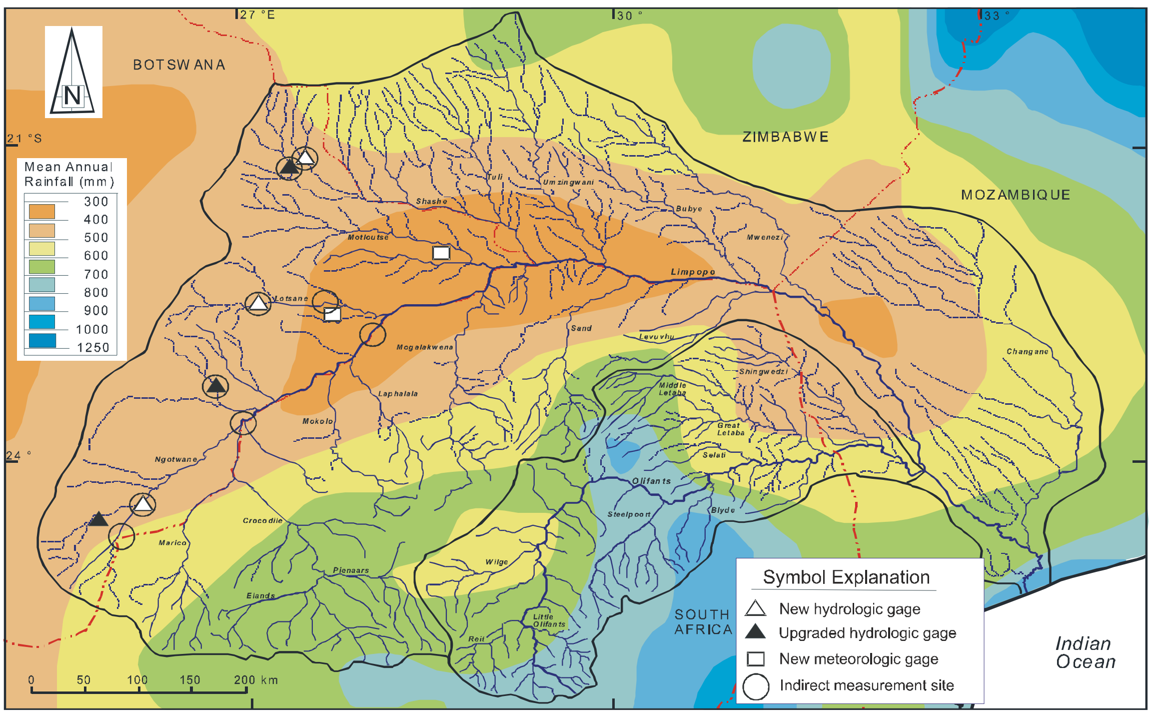

Figure 3.—Map of Limpopo River basin indicating new and upgraded hydrologic and meteorologic stations constructed in association with the Village Flood Watch Project and locations of indirect measurement studies for the documentation of 1995-2000 peak discharges.

From October through December 2002, training workshops on runoff modeling and DCP maintenance and operation were presented to engineers, hydrologists, and meteorologists of the Botswanan water agencies. USGS personnel worked closely with hydrologists and technical staff of the DWA to coordinate the implementation of anti-vandalism measures at all constructed and upgraded gages in the project, the formatting of data and the interface of the transmitted data to a Web-based access page in Pretoria, South Africa, and the completion of the construction phase of the project. The Web-based access page displays all transmitted data from the gages built in concert with the project. The Web page that will be used for the project and also be accessible by host-nation disaster managers and the public, is within the mission of the SADC-HYCOS:

http://www-sadchyco.pwv.gov.za/sadc/

IMPLEMENTATION AND RESULTS

The USGS worked in close cooperation with the USAID/RCSA, the U.S. Embassy, SADC-HYCOS, the DWA, DMS, NDMO, and local District managers to install, or upgrade, six hydrological gaging stations, and install two meteorological gaging stations to provide near real-time stage, precipitation and other meteorological parameters for use during flooding emergencies via the Internet and other appropriate communications methods. In addition the USGS provided training to the DWA and DMS in the operation, maintenance, and troubleshooting of the gages and provided training in the development and operation of a hydrological runoff model for use in developing flood-warning capabilities in the Limpopo River basin. The following paragraphs discuss the implementation and results of each objective.

Upgrade and enhance selected key hydrological monitoring stations to provide data in a near real-time capacity to key government agencies and the public through the Internet. Two USGS teams traveled to Botswana to work with the Republic of Botswana DWA, the DMS, and the NDMO to install three new river monitoring stations and upgrade three selected existing river monitoring stations with satellite transmitters and appropriate instrumentation to provide near real-time river levels and other information for use in the Botswanan and SADC-HYCOS hydrological networks. These data also will be served via the Internet through the SADC-HYCOS web portal. The following three stations were constructed as new river gages in the Limpopo River basin in Botswana. These stations will also serve as forecast points for future hydrologic runoff modeling efforts:

1. Notwane River at Mochudi
2. Lotsane River at Railroad Bridge at Palapye
3. Tati River at Francistown

The following sites were upgraded to near real-time transmitting capabilities by the addition of satellite transmitting equipment. These sites are existing river gages within the DWA network and are all stilling wells:

1. Metsemotlhaba River at weir WNW of Gaborone
2. Bonwapitse River at Ntshwaneng
3. Shashe River at Shashe Mooke

The USGS worked with the NDMO, DWA, and DMS to identify the appropriate organizations to work through for the construction, and lasting security of these new and upgraded hydrological stations. The two USGS teams associated with the construction project traveled to Botswana to install and upgrade the hydrological and meteorological gages, and assist personnel of the DWA and DMS in learning how to operate and maintain the network as well as interpret the data gathered.

Provide two all-weather meteorological stations to selected local secondary schools, which will serve the dual purpose of additional automatic meteorological rainfall stations at the national level and provide an additional educational tool to the schools' curricula. The two USGS teams also installed two all-weather meteorological stations at two secondary schools within the Limpopo River basin. Priority sub-basins and watersheds were identified by DMS for start up of the program during the May 2002 mission. Selected secondary schools in the Bobanong and Moeng areas were contacted for interest and assistance in installing all-weather stations used for the dual purpose of providing near-real time precipitation data to the DMS and for additional needed hydrological and meteorological education curricula. The meteorological stations record: air temperature, rainfall, wind speed, wind direction, barometric pressure, and relative humidity.

Most schools in the country lack Internet connectivity. However, their curriculum recently has been updated to include the effects of global climate change in Botswana. Having all-weather stations equipped for use in classroom instruction will provide “hands-on” activities throughout the school year. There are regular in-service training sessions available for geography teachers that would permit introduction of material on flood watch activities. A system of daily precipitation readings will be instituted on the school grounds with close coordination between selected secondary schools and meteorologists of the DMS, with student participation and integration of the work into the standard curriculum.

Document critical floods that occurred from 1995-2000 by surveying channel geometry, selecting roughness coefficients in channel and valley reaches of selected newly constructed and upgraded near real-time stream-gages, indirectly computing peak discharges using open-channel hydraulic methods for these recent floods, and further developing stage/discharge relations at these gages. A USGS team traveled to Botswana in August to September 2002 to survey selected historically critical flooding areas for channel and valley geometry and select roughness coefficients needed to indirectly compute peak discharge for the 1995-2000 floods. An appropriate one-dimensional open-channel hydraulic model was used to compute stage/discharge relations (fig. 4) to provide information for hydrological runoff modeling. Near real-time stream-level and -flow information will be used in concert with hydrological runoff modeling techniques to help improve pre-evacuation procedures of villages during flood disasters.

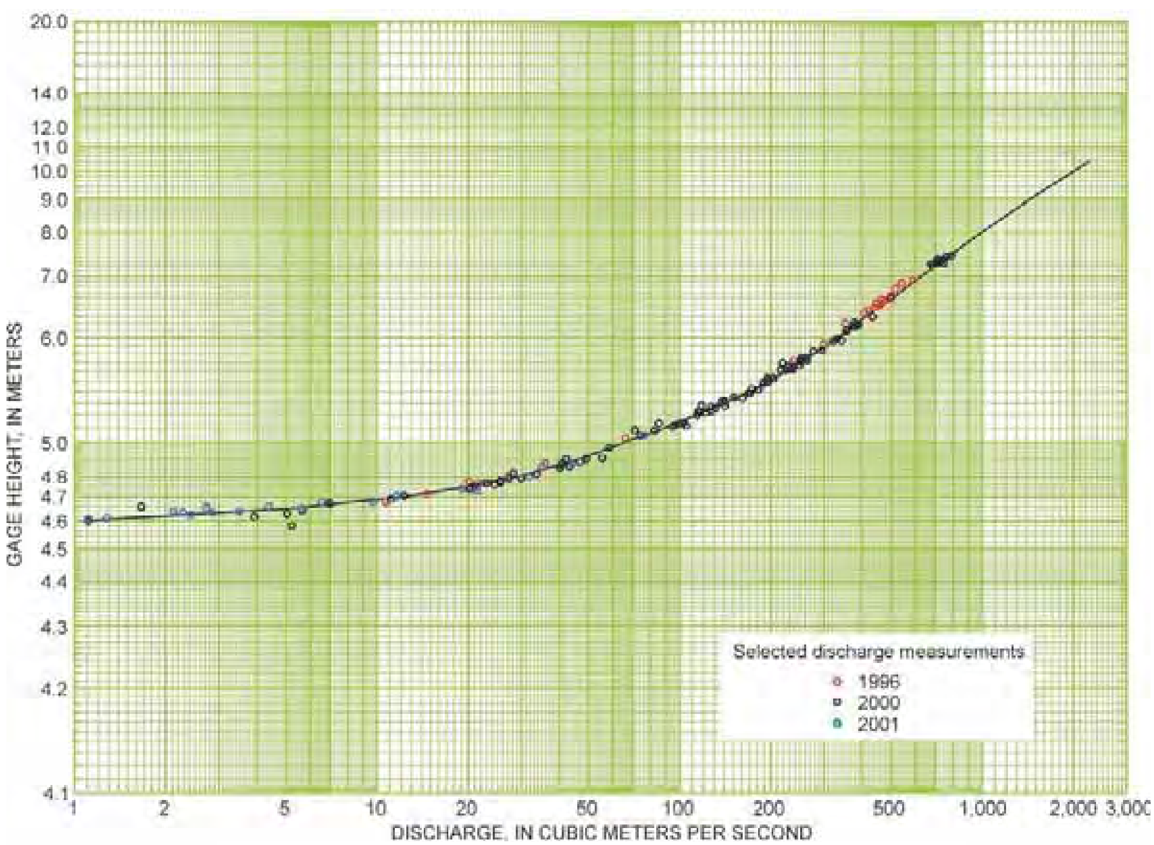

Figure 4.—Stage/Discharge relation, Limpopo River at Martin’s Drift, Botswana.

The following sites were selected and surveyed for the computation of a stage/discharge relation and documentation of peak discharge during extreme floods from 1995-2000:

1. Notwane River at Mochudi
2. Lotsane River at Railroad Bridge at Palapye
3. Lotsane River at Maunatlala
4. Tati River at Francistown
5. Notwane River at Gaborone Dam at Gaborone
6. Limpopo River at Buffel's Drift
7. Limpopo River at Martin's Drift
8. Bonwapitse River at Ntshwaneng
9. Shashe River at Shashe Mooke

Channel and floodplain surveys at the Limpopo River sites required prior permission by the South African Government to survey channel and floodplain geometry on the right (south) bank and right (south) floodplain of the Limpopo River valley which is entirely in the Republic of South Africa. Permissions to survey in South Africa were obtained by the DWA prior to arrival of USGS personnel in Botswana. Surveyed cross-sections (fig. 5) along with selected roughness coefficients were used in selected one-dimensional hydraulic models (Hulsing, 1967, Sherman, 1989 and Brunner, 2002) to develop and extend stage/discharge relations at the 9 stream gages.

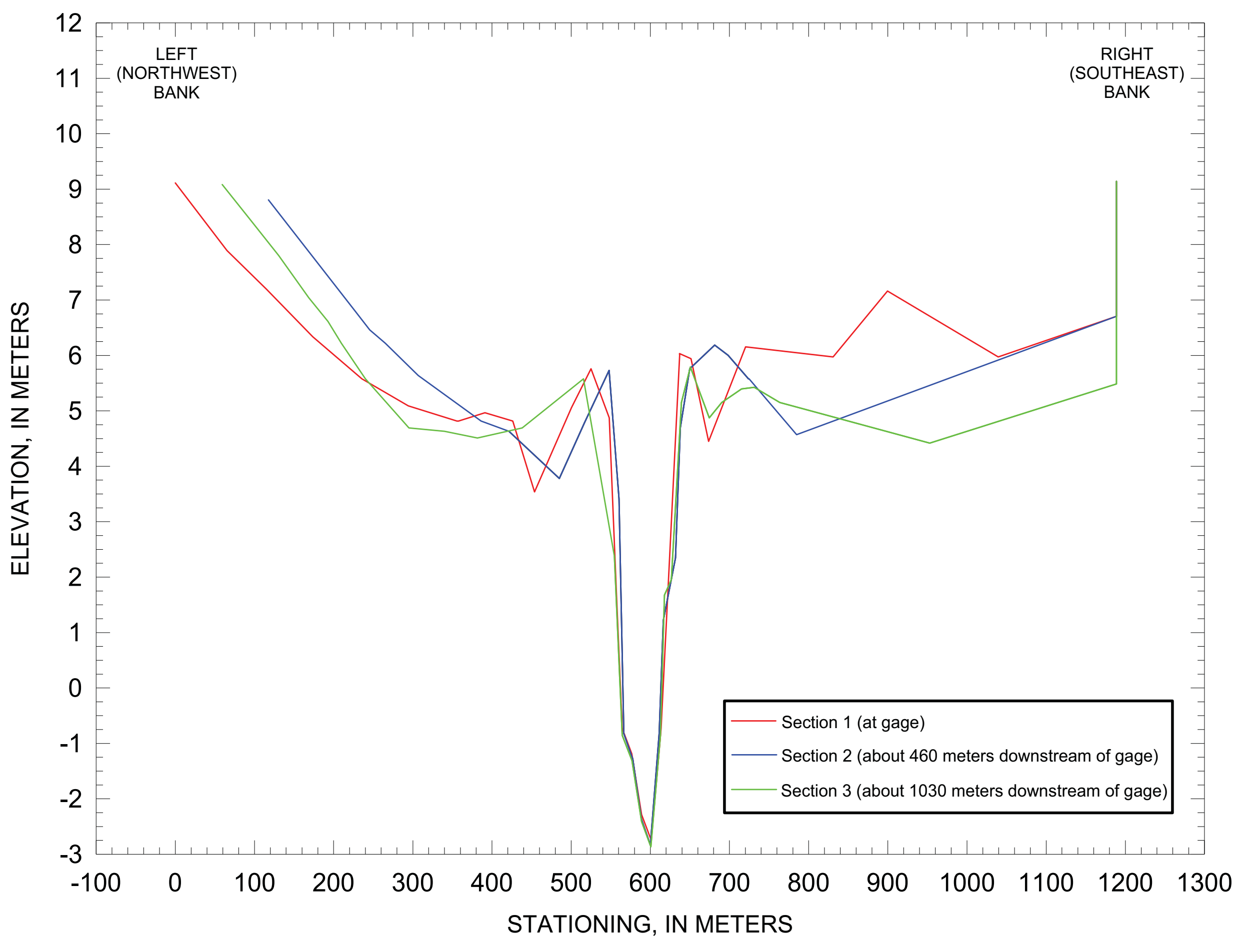

Figure 5.--Surveyed sections, Limpopo River at Buffel's Drift, Botswana.

The documentation of recent flood-peak discharges by indirect methods will be useful in the future development of flood-frequency analyses in Botswana (fig. 4). Figure 4 represents the extension of the stage/discharge relation at the Limpopo River at Martin's Drift, Botswana to allow for the calculation of discharges at this river gage during large floods. The stage/discharge relation extensions will also be used to calibrate hydrologic runoff models for tributaries in the Limpopo River basin. DWA personnel cannot effectively measure flood discharge at many of their gages due to inaccessibility during large floods. Also discharge measuring equipment used on cableways spans only the river channel and is ineffective when significant flow exists in the floodplain. Therefore stage/discharge relation extension to include flood flows was needed at all installed and upgraded gages.

The DWA was well positioned to help investigate this question, since they recorded high water marks at selected bridges throughout the country following the floods of 1995 and 2000. Such information is needed to provide a reference for warning messages emitted as a consequence of rainfall and stream flow exceeding threshold values.

In February 2003, a report of findings was published on the documentation of floods at these 9 stream gages as a provisional administrative report entitled "Stage-discharge ratings for 9 hydrological monitoring stations in the Limpopo River basin of Botswana." The provisional administrative report was published as a CD-ROM and distributed to the USAID/RCSA, DWA, DMS, and NDMO.

Provide hydrologists and meteorologists within the DWA and DMS with training and computer equipment necessary to develop hydrological runoff modeling capabilities needed to construct an effective flood-warning network for the river systems within Botswana. The development of flood warning capabilities in Botswana will help government agencies to alert downstream communities when water levels are rising at a threatening rate. A USGS team traveled to Gaborone, Botswana in October 2002 and provided training to hydrologists and meteorologists of the DWA, DMS, and Road Department of the Ministry of Works, Transport, & Communication on the techniques to develop and utilize rainfall-runoff relationship models. USGS staff from the HIF in Stennis Space Center, MS, the Office of the Regional Hydrologist for the Western Region in Menlo Park, CA and the National Mapping Discipline office in Maputo, Mozambique, implemented the U.S. Army Corps of Engineers Hydrologic Engineering Centers Hydrologic Monitoring System (HEC-HMS) for a pilot rainfall runoff model of a sub-basin in the Limpopo River drainage area. The training focused on a few critical basins. The method requires definition of basin characteristics such as watershed boundaries, shape, slope, and land use. These basin data can be estimated initially, but will have to be further developed and defined by DWA and DMS in order to get increased accuracy in hydrological runoff modeling in the Limpopo River Basin.

Provide hydrologists and meteorologists within the DWA and DMS with training and equipment for the successful operation, maintenance, and troubleshooting of electronic hydrological and meteorological equipment used in their networks. A USGS team from the HIF traveled to Gaborone, Botswana in November 2002, to train selected hydrologists and meteorologists of the DWA and DMS in the operation, maintenance, and troubleshooting of the electronic equipment being provided by the USGS (fig. 6). The team presented hands-on training using Sutron equipment. Laptop PC's were purchased and left with these agencies for the purpose of programming, maintenance and upkeep of DCP's installed in selected sub-basins.

Figure 6. Newly constructed micro-pulse radar, stage-sensor stream-gage at the Notwane River at Mochudi, Botswana.

SUMMARY

From May through December 2002, personnel of the USGS Mississippi District constructed eight hydrological and meteorological monitoring stations, and surveyed and computed peak flows for 1995-2000 flood events at nine river stations. USGS staff from the Hydrologic Instrumentation Facility (HIF) in Stennis Space Center, MS, the Office of the Regional Hydrologist for the Western Region in Menlo Park, CA, and the National Mapping Discipline office in Maputo, Mozambique, implemented the HEC-HMS as a pilot rainfall runoff model of a sub-basin in the Limpopo River drainage area. Six of the eight gages constructed record continuous river stage, and two other gages record continuous rainfall, wind speed/direction, barometric pressure, relative humidity and air temperature. The meteorological stations were constructed at selected secondary schools within the Limpopo River Basin for the dual purpose of providing additional meteorological data and adding to the school curriculum in the study of Earth sciences. In addition to the construction of monitoring stations and hydrological runoff model training, personnel of the USGS HIF provided a training workshop on basic electronics and troubleshooting hydrological instruments to Botswanan hydrologists and meteorologists.

All the hydrological and meteorological stations were designed to transmit data via the METEOSAT operated and maintained by EUMETSAT in Darmstadt, Germany. The data were formatted for output to the SADC-HYCOS real-time web portal at: http://www-sadchyco.pwv.gov.za/sadc/. This effort provides hydrological and meteorological parameters and a pilot hydrological runoff model that will assist the Botswanan government agencies in the propagation of hydrological runoff models in all the sub-basins of the Limpopo River Basin for use in future flooding disasters.

This project can neither stop nor reduce the extent of flooding in Botswana. It should, however, provide significant benefits to the NDMO, by providing them with timely information, rather than just raw data on rainfall. The project has provided the DWA and DMS with expanded data networks into critically sensitive and representative areas, which gives them better spatial coverage. The project also provided these agencies with the ability to collect near real-time data, which gives them better temporal coverage and enables them to provide information to the NDMO much quicker than in the past. Finally, the project provides a transfer of technology that allows scientists from the DWA and DMS to translate some of the raw data they collect into the type of flood forecasting information that is critically important to the NDMO.

Forecast information also will be better understood because of the experience and the insights gained by the DWA through the quantification and documentation of past benchmark extreme events that have occurred from 1995-2000. Warnings issued to the community will therefore have a higher probability of eliciting compliance and of reducing vulnerability and impact in the event of a flood.

The techniques learned by the scientists at DWA and DMS for the Limpopo River Basin then can be applied throughout Botswana, which should provide long-term benefits to the people of Botswana on a national scale. Further, since the Limpopo River forms the boundary between several countries, the enhanced information developed by Botswana should aid the other bordering and downstream countries relative to potential flood hazards.

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CHANNEL CHANGES ALONG A MODIFED FLOODPLAIN: LEAF RIVER, MISSISSIPPI

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ABSTRACT

As part of a larger study involving a geomorphic assessment of the Pascagoula drainage in Mississippi, this paper discusses the preliminary interpretations of channel changes on the Leaf River from a cross-sectional perspective, based primarily on historic USGS data. The continuous gage stations on the Leaf River were evaluated for trends indicating aggradation or degradation using discharge summary data. Several stations have data collected before 1940. Historic cross sections were plotted at both these continuous and a few other discontinuous gage locations with sufficient data. Research on spatial patterns and temporal relationships of channel changes is important because channel instability has numerous ramifications to the environment and private and public properties. Elucidating and quantifying these relationships can assist in defining and refining state regulations regarding floodplain activities, including those associated with deforestation, agriculture, mining and development.

Of the four continuous locations on the Leaf River, the two upstream sites show some (Collins) to pronounced (Hattiesburg) decreases of about 1 and 2m in mean bed elevation and 0.5 and 4m in thalweg elevation. Hattiesburg also shows an increase in maximum depth of about 1.5m, changing most rapidly during the 1970s, and stabilizing since then, possibly due to in-channel mining in the Bowie River, a tributary that joins it just upstream of the gage site. Other types of geomorphic changes are not pronounced and inconsistent. The two downstream sites (New Augusta, McLain) show increases in mean bed elevation of 1m and thalweg elevation to 3m, increases in width and larger increases width-depth ratio.

This study also characterizes several episodes of possible lateral migration and other changes identified from plots of historic cross sections. Several possible changes are listed, and through continuing work more evidence and analysis will help to establish which of these occurred and to gather further information about the timing and magnitude of these possible changes in planform and profile.

INTRODUCTION

While becoming increasingly common, the ramifications associated with river instability are numerous (Bull, 1973, Graf, 1979, Kondolf, 1994, Mossa, 1995, Mossa and McLean, 1997). Problems include: bank erosion and riparian property disputes associated with channel shifting, which sometimes leads to litigation; structural problems associated with undermining or filling at bridges and reservoirs; changes in channel capacity which affect flood patterns and increases the need for flood control; changes in floodplain habitat and effects to aquatic biota; and reductions in the quantity and diversity of fishes and mussels (e.g. Allan and Flecker, 1993; Brim Box and Mossa, 1999). Thus, it is important to riparian property owners, state and federal regulators, local communities and governments, industries, as well as other scientists and other individuals, to understand spatial and temporal variations of river channels, and how various factors contribute to instability and channel change.

This paper describes preliminary findings of channel changes interpreted from historical cross-section data along the Leaf River. Using U.S. Geological Survey discharge measurements at various locations, this paper describes which of these sites shows channel change, discusses the types and magnitude of channel change such as degradation or aggradation and widening or narrowing, discusses the timing of these changes, and where possible, if it might be connected to historical activities, such as land use changes. Two major types of data were used: 1) instantaneous measurements or cross sections; and 2) discharge summary measurements. Although not intended for geomorphology, discharge measurements contain much surrogate information that can assist in characterizing changes in channel form (e.g. Leopold and Maddock, 1953; Leopold and others, 1964; Gregory and Walling, 1973; Knighton, 1974, 1975). Discussed herein are interim findings based on work conducted exclusively in the first year of a three-year project. As with other secondary historical data sources, the inferences are made from the available information to-date, and more understanding will likely be garnered as the project progresses as more relevant data are gathered and analyses are performed towards the objectives of this study.

STUDY AREA

The Leaf River occupies the northwestern portion of the Pascagoula basin and drains about 9280 km2 (3580 mi2) (Fig. 1-1). The Pascagoula River drains southward into the Mississippi Sound, which is a portion of the Gulf of Mexico. The longitudinal profile of the Leaf River shows differences between high and low water, major knickpoints and the declining slopes in the Pascagoula (Pat Harrison Waterway District, 1973) (Fig. 1-2). The topography is generally rolling to hilly with low to moderate relief, with the highest elevations in the basin exceeding 500 ft (160m) (Fig.1-3). The basin has a varied geology of Cenozoic sediments and sedimentary rocks further characterized in Li and Maylen (1994) and Maylen and Li (1995). The state of Mississippi has abundant rainfall, with different locations in the basin averaging from 1300 to over 1700 mm (52 to 68 in) annually, yet some years average four times the flow as other years (Lamonds and Boswell, 1985). The land cover/land use throughout the basin is largely forested, both in silviculture and national forest, with some areas of pasture, farming, residential areas, and mining (Slack, 1991). In general, the basin is generally considered to have much less human alteration than most basins of this size. There are comparatively few large impoundments in the basin compared to the region or country as a whole. However, there are numerous small farm impoundments, privately-built dams, and recreational impoundments or water parks (Bowen, personal comm.), but most streams in the basin are largely unregulated (Lamonds and Boswell, 1985).

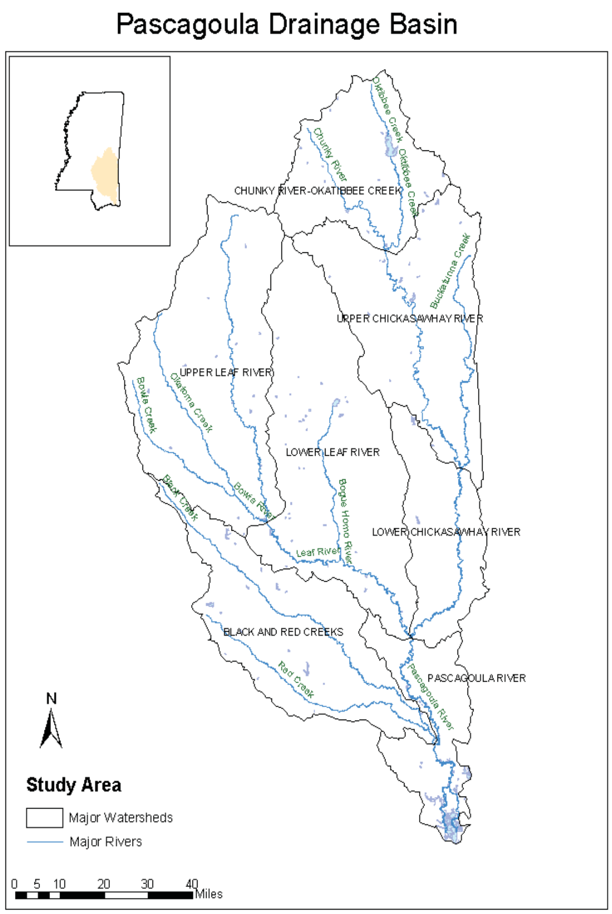


Figure 1-1. Major subbasins of the Pascagoula Basin.

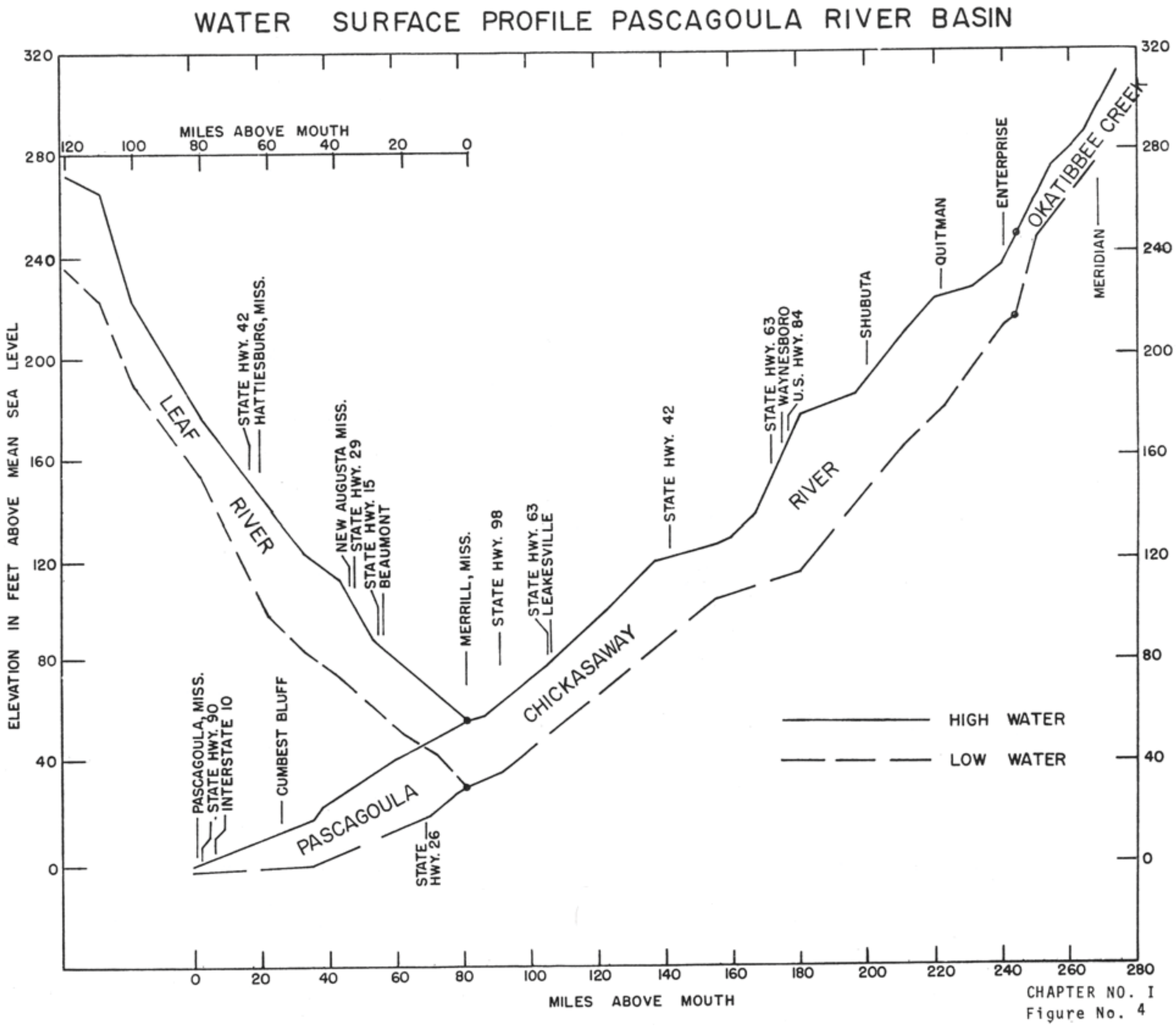


Figure 1-2. Longitudinal profile of the Leaf, Chickasawhay and Pascagoula Rivers, showing differences between high and low water, major knickpoints and the declining slope in the Pascagoula (from Pat Harrison Waterway District, 1973).

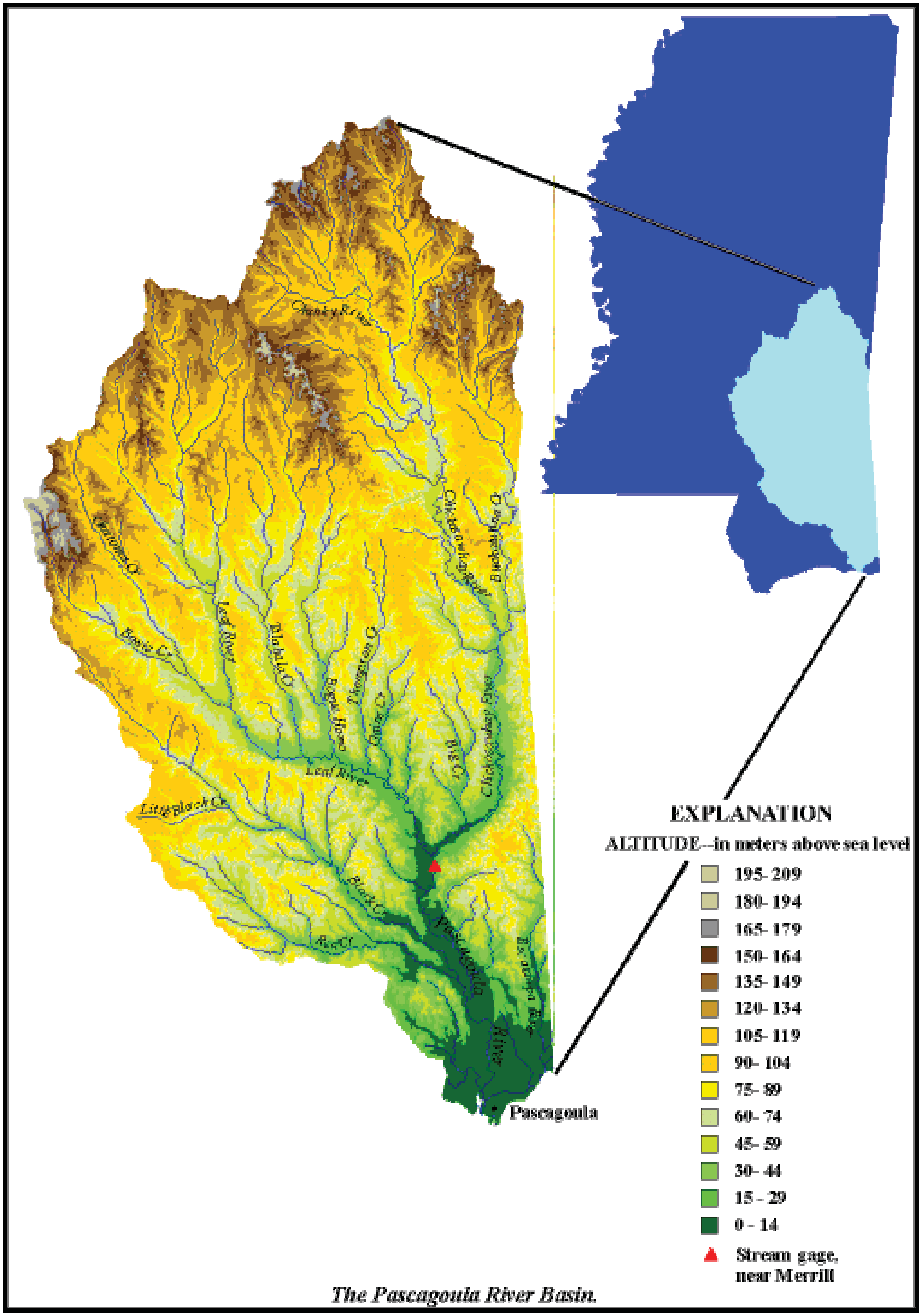


Figure 1-3. Elevations in the Pascagoula River Basin
(from http://wwwmswater.usgs.gov/ms_proj/eric/pasca.html)

TERMINOLOGY AND TYPES OF GEOMORPHIC CHANGE

Because rivers are three-dimensional, but are most easily depicted in two dimensions, there are three different geometric perspectives from which rivers are examined through time or space. The type of geomorphic change that can be documented depends upon the type of data available for comparisons. One view is the cross-sectional perspective, which shows the bed elevation and channel depths versus the distance across the valley, floodplain, or channel (x versus z) (Fig. 1-4). This perspective can illustrate varied changes that include channel widening, narrowing, deepening or filling. Another is the planform perspective, such as from a map, aerial photograph, or a bird-eye view, which shows distance along and distance across the valley, floodplain or channel (x versus y). This can show changes in channel position, meander cutoffs, changes in channel form such as widening or narrowing, changes in sinuosity, and various forms of lateral migration. The third perspective is the longitudinal profile, which shows water or bed surface elevation versus distance along the channel or valley (y versus z). This perspective best illustrates various types of knickpoints, including waterfalls and rapids (Fig. 1-2), and at the reach scale it can show bed variations such as riffles, which are local shallow areas, and pools, which are locally deep. The planform dimensions are linked to the longitudinal and cross-sectional dimensions, where bendways generally correspond with pools and straight reaches with riffles in meandering rivers. Of course, some combination of these changes may occur, as well as no change that is discernible, documentable or observable, at least from that perspective at that particular location with the available data. It is particularly difficult to make interpretations or conclusions if the historical data are short-term (<20 years) and/or collected infrequently, or have large time gaps where the data were not collected or collected in a different manner (e.g., only during floods).

If appropriate data are available it is generally a straightforward process to document the types and magnitude of geomorphic changes. However, determining the causes of change is more complicated. Degradation and aggradation may be caused by natural factors or may be the result of one or more direct stream alterations or basin modifications, including land use activities. Factors that may affect long-term bed elevation changes are dams and reservoirs located either upstream or downstream of the bridge, change in watershed land use (urbanization, deforestation, etc.), channelization, cutoffs of meander bends (natural or human-induced), changes in the downstream base level, in-channel or floodplain sand and gravel mining, flow diversions, lowering of the entire system in response to regional uplift, and bridge location with respect to stream planform and subsequent stream movement in relation to the crossing (Richardson et al., 1991).

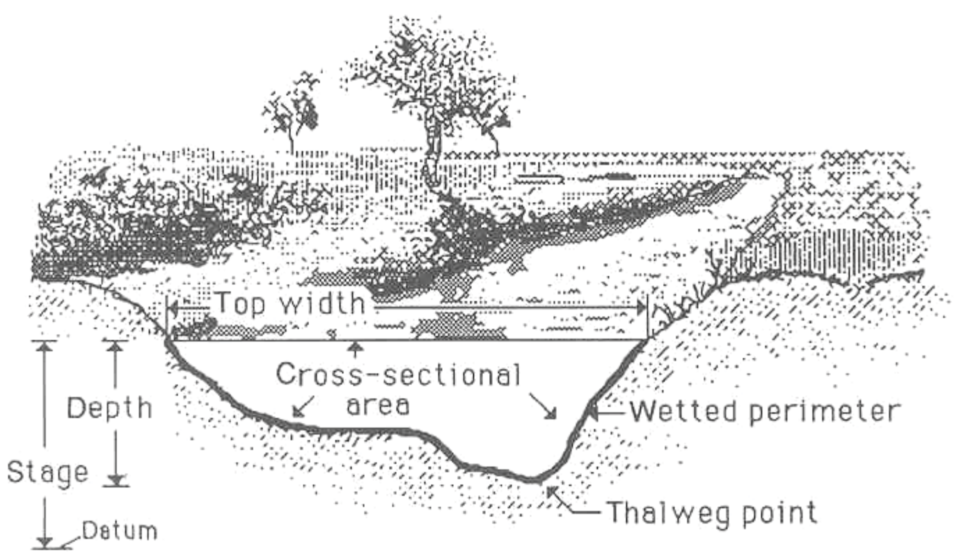


Figure 1-4. A generalized diagram of measurement of a stream cross section showing some of the variables that can be characterized from this perspective (from Gordon and others, 1992).

RELEVANT PRIOR WORK

Only few studies have evaluated geomorphology or channel change at sites in the Leaf River basin. Although this study has more analysis than prior works, the conclusions and interpretations of others reported in this section generally agree with the findings of this study.

Turnipseed (1993) examined channel changes at the Leaf River near McLain, using both historic cross sections and aerial photographs to evaluate planform change in the vicinity of the bridges (Figs.1-5 and 1-6). He documented some changes in meanders, but none located near either the existing or proposed bridges. No lateral movement was detected at the bridge sites, but a maximum of 440 ft of westward movement on the east bank and about 120 ft of westward movement of the west bank occurred upstream of the proposed Hwy 98 crossing on the Leaf River near McLain. There was also significant scouring of the thalweg, about 2.5m (7 to 8 ft), during floods.

As part of a larger study of scour at bridges, Wilson (1995) evaluated 4 sites on the Leaf. He plotted minimum bed elevations or thalweg elevations vs. time for the Leaf River at Hattiesburg, which showed large variation 9.5 m (29 ft) in thalweg elevation and a trend of declining average thalweg elevations throughout the period of record of about 1.5 m (5 ft) (Fig. 1-7). This large quantity of change was unexpected and attributed to mining of the Bowie River.

Brown and Mitchell (1995) examined two sites to examine impacts of American Sand and Gravel mining operations on the Bowie River. The most pertinent data analyzed in the study were annual minimum elevations on the Bowie River at U.S. Highway 49 and the Leaf River at U.S. Highway 11, both in Hattiesburg. Evaluating one point annually from 1961, when this company was actively mining the river, to the late 1980s, when the evaluation period ended, they determined that there was no discernible change at the Bowie River gage and that has been channel deepening on the Leaf River on the order of 0.3 m (1 ft) for every 10 years in the nearly 30-year period (Fig.1-8).

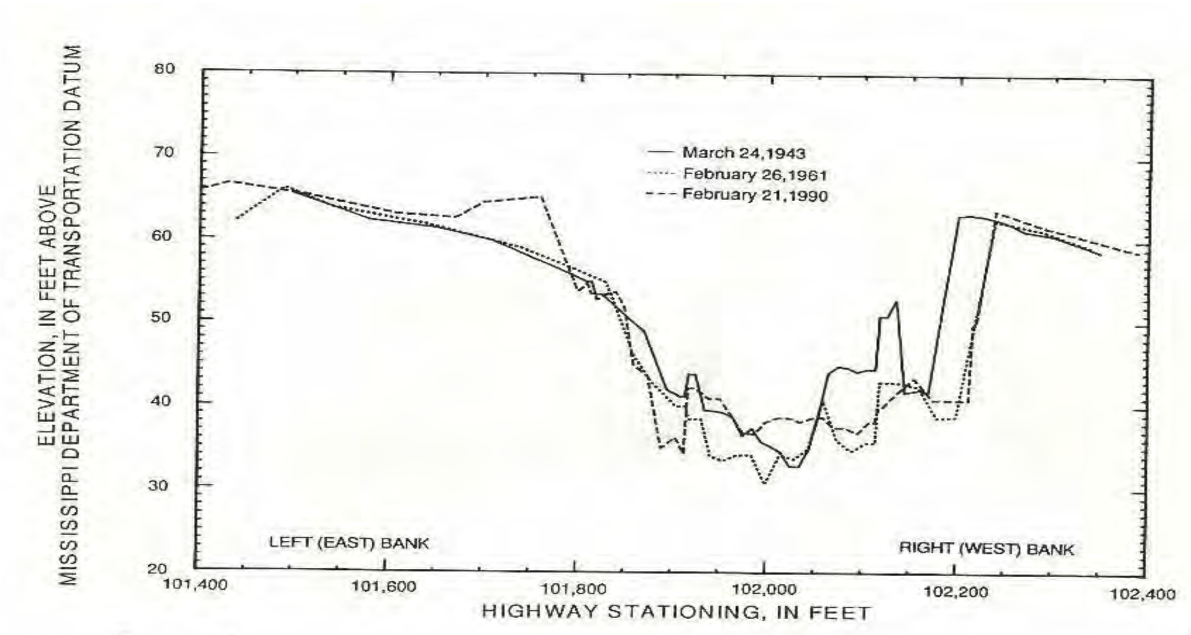


Figure 1-5. Cross-sectional changes at the Leaf River near McLain, Mississippi (from Turnipseed, 1993).

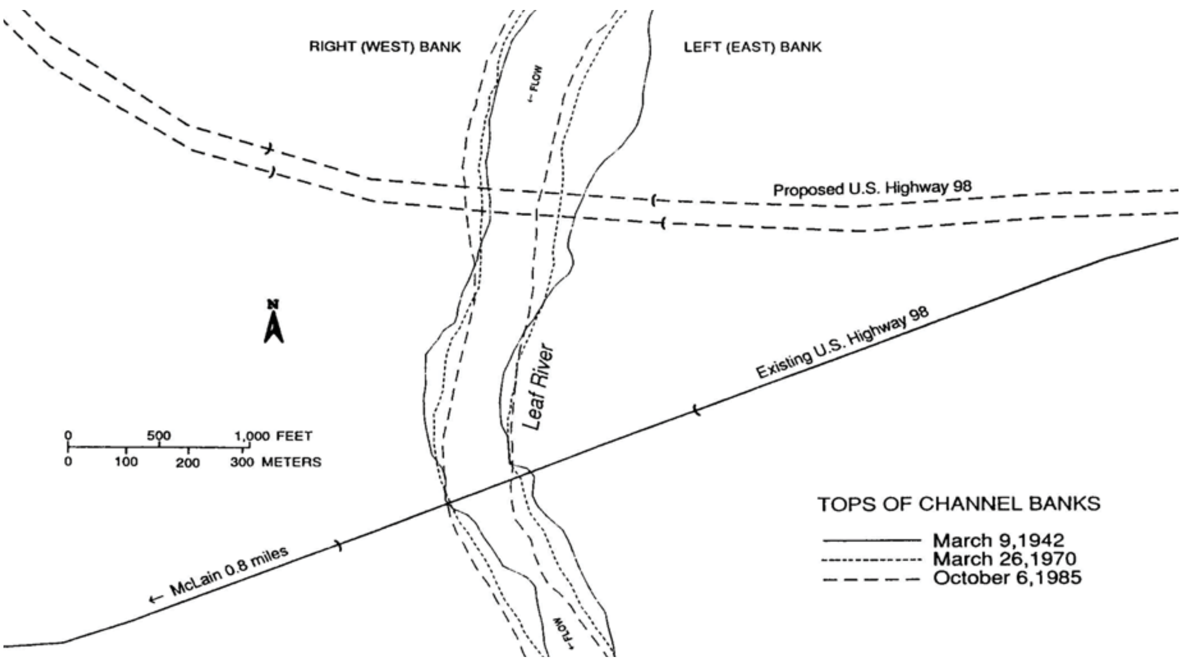


Figure 1-6. Planform channel changes in the vicinity of the bridge at the Leaf River near McLain, Mississippi (from Turnipseed, 1993).

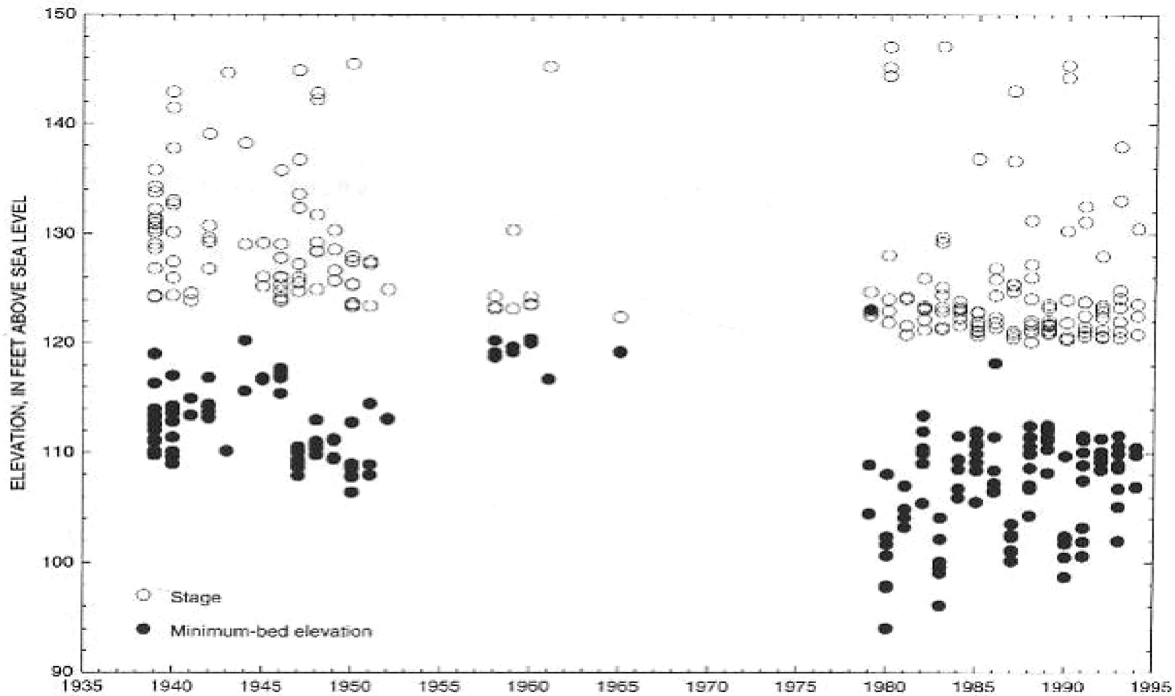


Figure 1-7. Changes in adjusted stage and minimum bed elevation with time for the Leaf River at Hattiesburg, Mississippi (from Wilson, 1995).

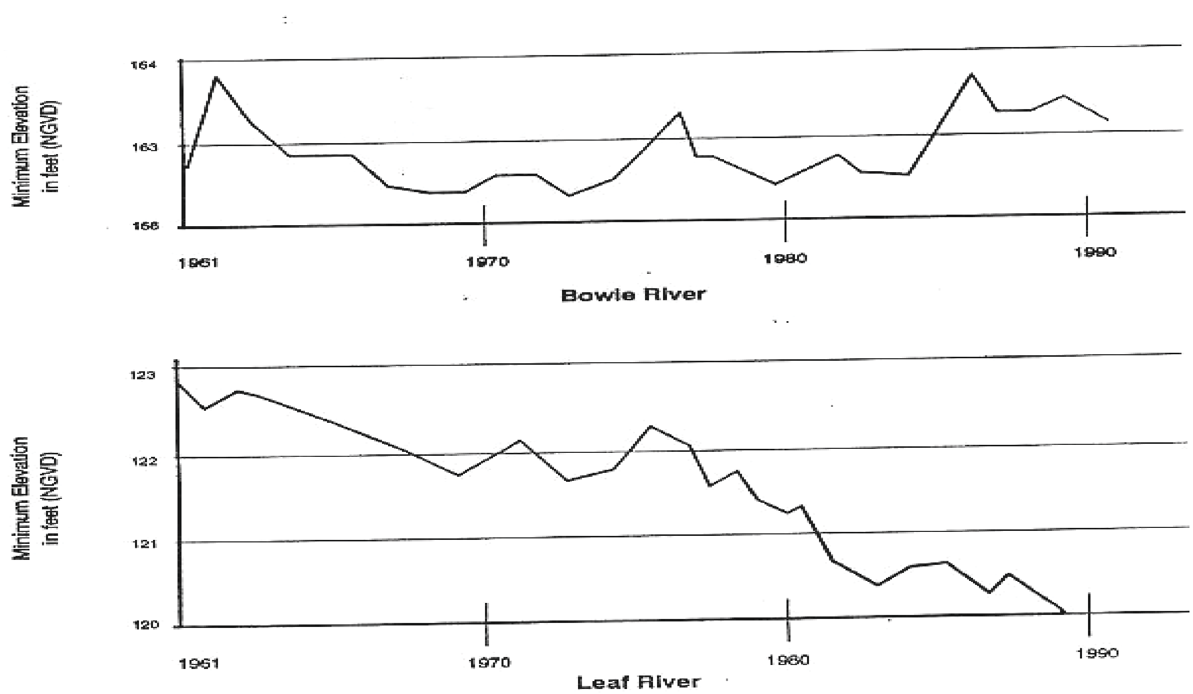


Figure 1-8. Changes in annual minimum bed elevation with time for the Bowie River near Hattiesburg and the Leaf River at Hattiesburg, Mississippi (from Brown and Mitchell, 1995).

METHODS

The use of historical secondary data sources is an established approach for understanding rivers and their changes (Trimble and Cooke, 1991). One of the most useful types of secondary data for evaluation of channel changes are cross sectional discharge measurements collected by the U.S. Geological Survey, Water Resources Division. Advantages of such data include the ability to monitor changes over reasonably long time periods, and a better temporal resolution than many data sets, including data collection during floods.

Site selection was limited to stations located at bridges where measurements were collected at least through some time in the last decade. Sites with continuous data included Collins, Hattiesburg, New Augusta, and McLain (Fig. 1-9; Figs. 2-1 to 2-6, 3-1 to 3-6, 4-1 to 4-6 and 5-1 to 5-6). For all locations data go back to 1938, except for New Augusta where data collection began in 1983. At continuous sites, discharge data were collected about 6 to 12 times annually in the field using the velocity-area method (Buchanan and Somers, 1969), as on most rivers throughout the United States. These field data are known as instantaneous measurements or cross-sectional measurements. They are used to develop stage-discharge relationships, which are used with daily stage data to derive daily discharge measurements. Because the velocity-area technique requires that discharge be computed by adding the discharge in multiple trapezoids, there are repeated measurements of depth and velocity at various distances across the channel. Each trapezoid ideally contains less than 5% of the total flow, thus there are a minimum of twenty, and typically more than thirty, depth measurements made across the channel. Two additional sites with partial data on the Leaf River near Raleigh and Taylorsville were examined. Both have some data at least through the 1990s (Figures 6-1 and 7-1) and are monitored usually only occasional floods or once every several years for other reasons.

Cross-Sectional Comparisons

The discharge measurements collected from rivers in Mississippi are stored in USGS file cabinets in a district office in Pearl, a suburb of Jackson, from which selected historic cross sections were copied. Figure 1-10 shows the cover sheet of a discharge measurement, and Figure 1-11 shows several of the individual distance and depth values associated with an individual discharge measurement.

The objective was to assess and compare the general configuration of the channel at the same transect over long time periods. To maximize information, yet keep the graphs somewhat uncluttered, measurements collected from bridges about every 10 years were selected. Cross sections at higher flow levels were chosen, where possible, so that changes in both channel and floodplain morphology could be examined over decadal timescales. Distance and depth data from these cross sections were input into spreadsheets, comparing distance across the channel and converting the numerous depth measurements across the channel to bed elevations by subtracting depth from adjusted stage for multiple cross sections on a single plot. Locations of cross sections compared were largely from the same side of the bridge because wading and boat measurements are collected at inconsistent locations. Data

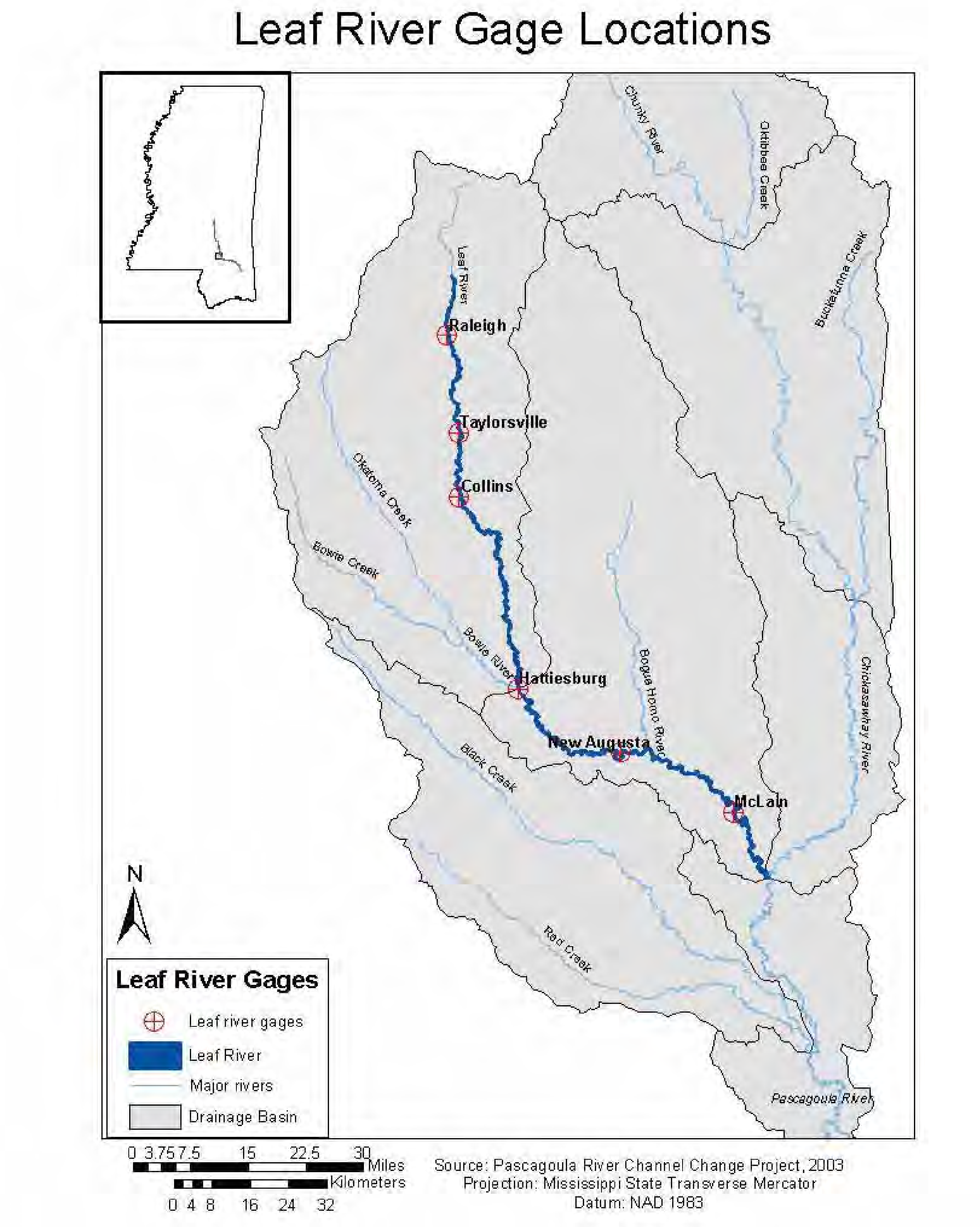


Figure 1-9. USGS gage sites on the Leaf River. The two upstream sites (Raleigh, Taylorsville) only have occasional or partial data whereas the other four sites are monitored continuously.


9-275-F
(Apr. 93)

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

WATER RESOURCES DIVISION

Meas. No. 609
Comp. by DKm

Sta. No. 02475000 DISCHARGE MEASUREMENT NOTES Checked by WPP

Leaf River @ McLain, MS

Date March 6, 2007 Party DK Moss ... , ...
Width 2130 Area 22500 Vel. 2.76 G.H. 25.40 Disch. ~~62,300~~ 62,120
Method .6/.2/.8 No. secs. 35 G.H. change +.04 in ___ hrs. Susp. 200#C
Method coef. 1.0 Hor. angle coef. Noted Susp. coef. 1.0 Meter No. W037502
Type of meter Price AA Date rated CMD ... Tag checked —
Meter 1.5 ft. above bottom of wt. Spin before meas. 3:17 after FREE
Meas. Plots — % diff. from — rating. Levels obtained None

GAGE READINGS					
Time	Inside	DCP			Outside
0955	25.38	25.39			25.43
1220	25.36	25.36			25.45
Weighted M.G.H.		25.36			25.44
G.H. correction		+.04			-.04
Correct M.G.H.		25.40			25.40

WATER QUALITY MEASUREMENTS
No / Yes ___ Time ___
Samples Collected
No / Yes ___ Time ___
Method Used
EDI ___ EWI ___ Other ___

SEDIMENT SAMPLES
No / Yes ___ Time ___
Method Used
EDI ___ EWI ___ Other ___

BIOLOGICAL SAMPLES
Yes ___ Time ___
No / Type ___

Check bar, chain found 48.92 -.04 changed to ___ at ___
Wading, cable, ice, boat, upstr., downstr., side bridge / feet, mile, above, below gage.
Measurement rated excellent(2%), good (5%), fair (8%), poor (over 8%); based on the following cond:
Flow Smooth/ Swift / Angular in Flood plain
Cross section Sand /Debris
Control Flood Plain
Gage operating yes Weather Sunny /Cool
Intake/Orifice cleaned No Air — °C@ — Water — °C@ —
Record removed No Extreme Indicator: Max. — Min. —
Manometer N_2 Pressure Tank — Feed — Bbl rate — per min.
CSG checked NO Stick reading —
Observer NONE
HWM NONE obtained outside, in well
Remarks

G. H. of zero flow NOT DET ft. Sheet No. 1 of 1 sheets

Figure 1-10. The cover sheet of a discharge measurement shows characteristics including the date and time of the measurement, the measurement party, the equipment used, the channel conditions and summary measurements, and the estimated quality of the measurement overall.

.0 .10 .20 .30 .40 .50 .60 .70 .75

River at—

Angle coefficient	Dist. from initial point	Width	Depth	Observation depth	Revolutions	Time in seconds	VELOCITY At point	VELOCITY Mean in vertical	Adjusted for hor. angle or	Area	Discharge
			No	Flow	IN		Left		Box	Culvert	
3100							.5mile	from	left	abutment	
	STP	1015	Box	Culvert			Right	of	Bridge	full +	
			Flowing.								
LWE	50	125	0		v=0					0	0
↖.80	300	175	5.6	.6	24	40.1	1.34		1.07	980	1050
↗.92	400	100	7.3	.6	23	41.2	1.25		1.15	730	840
↗.93	500	75	16.7	.2	46	40.5	2.52	1.70	1.58	1250	1975
				.8	16	40.7	.884				
↗.94	550	50	13.0	.2	29	40.1	1.61	1.16	1.09	650	708
				.8	13	41.0	.717				
↗.96	600	50.	13.7	.2	18	40.7	.993	.786	.755	685	517
				.8	11	43.3	.578				
↗.98	650	50	14.1	.2	11	41.2	.606	.568	.557	705	393
				.8	10	43.1	.529				
↑1.0	700	35	15.1	.2	23	40.9	1.26	1.09		528	576
				.8	17	41.3	.925				
↖.99	720	20	15.9	.2	25	40.0	1.40	1.46	1.44	318	458
				.8	28	40.4	1.53				
↖.98	740	30	16.7	.2	46	40.5	2.52	2.34	2.29	501	1150
				.8	39	40.0	2.17				
↑1.0	780	40	19.4	.2	50	40.3	2.75	2.96		776 ~~788~~	2297 ~~2330~~
				.8	58	40.7	3.16				
↖.98	820	30	20.7	.2	86	40.3	4.72	4.23	4.14	621	2570
				.8	68	40.3	3.74				
↖.98	840	20	23.4	.2	92	40.4	5.04	4.60	4.51	468	2110
				.8	76	40.3	4.17				
Boiling	860	20	27.4	.2	52	40.2	2.87	3.16		548	1730
				.8	63	40.3	3.46			$\boxed{8772}$	$\boxed{16407}$

.0 .10 .20 .30 .40 .50 .60 .70 .75

Figure 1-11. The following sheets of a discharge measurement show several of the individual distance and depth values from water's edge on the left bank onwards to the other water's edge. On this sheet the maximum depth is 27.4 ft, but the data continue to the next page.

Discharge Measurement Summary Data

Derived from, but stored, copied and analyzed separately from, cross-sectional measurements are discharge measurement summary data. Because direct use of cross-sections requires much photocopying and inputting, and because it would be difficult to discern differences with more than ten cross sections on a graph, this summarized source provides higher temporal resolution of aggradation and degradation at gaging sites. Such data are listed on the cover sheet of a cross section (Fig. 1-10) and then each of several hundred measurements is transferred onto a summary sheet (Fig. 1-12). Such data are now available on the internet for most locations in the basin. Most of the following are typically recorded on discharge summary measurement sheets: discharge measurement number, date, measurement team, width, area, mean velocity, gage height, discharge, method, measured sections, gage height change (during recording), recording time, rating of measurement (excellent to poor), and transect method (bridge, wading, boat) (Figs. 1-10 and 1-12). The method used also may contain some information regarding approximate distance from the gage location. Associated with the fact that the river has multiple channels during floods (typically listed as “channels” on the measurement summary sheets), some data were either missing or irregular. In such cases, where numbers were given, it was not clear whether they characterized the entire system or the main channel. Determination of this would require detailed scrutinizing of cross sections in the district office.

Besides those variables on the summary data sheets, maximum depth was recorded as an additional variable by reviewing the listing of depth measurements for several selected historic cross sections in the USGS office. The probability of obtaining a value representative or close to the true maximum depth was considered high because there were numerous (usually > 30) depth measurements across the channel. Depth typically was measured at close intervals near the edges of piers and in zones of highest velocity, which often coincided with deepest points.

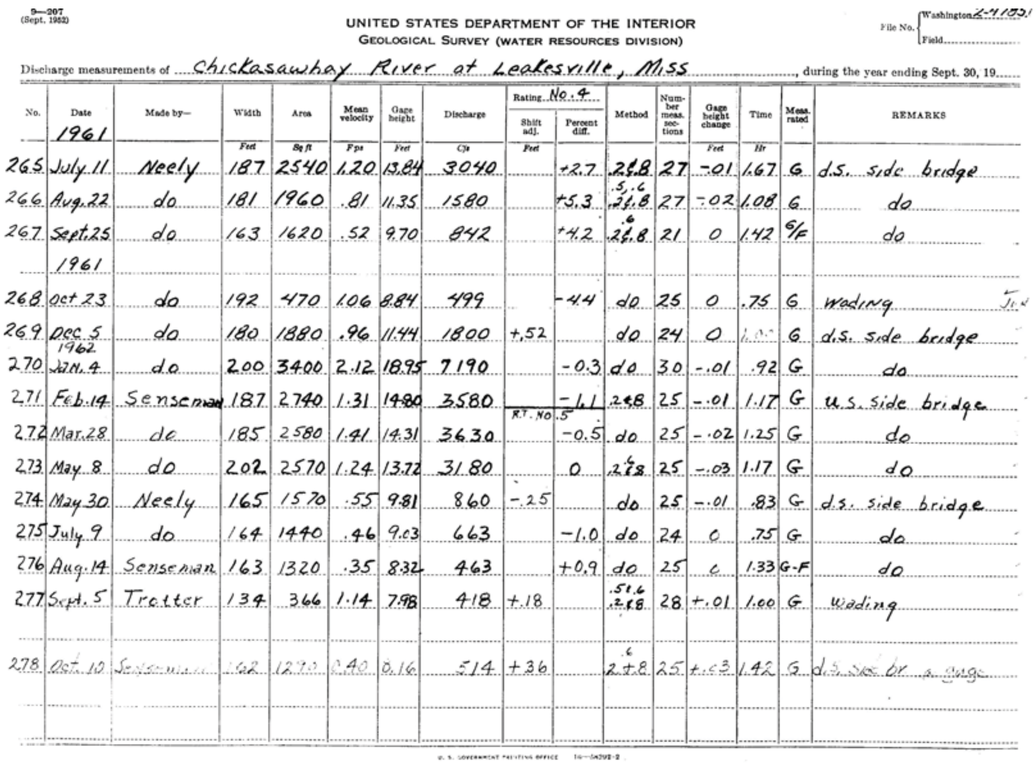
Some additional variables were derived or adjusted from the recorded variables. The gage height was adjusted according to changes in the datum of the local gage over the period of record, using information found in USGS publications such as Water Resources Data (e.g. Morris and others, 2002). Mean depth is computed by dividing the area by the width, and then mean bed elevation is computed by subtracting the mean depth from the adjusted stage. Mean depth trends show whether the cross-section is getting deeper or shallower, but also rises and falls with high and low flow. Mean bed elevation is considered a better measure of channel change than mean depth, because the scatter associated with stage or water levels is subtracted out of this variable, characterizing form changes such as aggradation or degradation more directly. The thalweg elevation is the deepest point in a given cross section, and reflects the bottom stability of a particular cross section. It is computed by subtracting the maximum depth from the adjusted stage or gage height. In some reports (e.g. Wilson, 1995), this variable is called minimum bed elevation. As mean bed elevation is a better measure of channel change than mean depth, thalweg elevation is a better measure of channel change than maximum depth because the scatter associated with stage levels is subtracted out of this variable, characterizing form more directly. The variables complement one another since thalweg elevation is not stage-dependent but provides information only at a specific point, whereas the mean bed elevation provides information for the entire cross-section but is stage-dependent. Although trends of mean depth and maximum depth provide important complementary information, these are included in a more comprehensive report (Mossa, 2003) and not in this paper due to space considerations.

Width is a very different measure of channel change, and is the distance between the right and left edge of the water if there is only one channel is present. The width-depth ratio is considered to be an important measure of channel form, derived by dividing width by the mean depth. Increasing width-depth ratios are characteristic of channels with abundant bank erosion, sedimentation or both. Decreasing width-depth ratios are less common, but they would be indicative of scour or deepening, and possibly narrowing. More direct measures of deepening or filling can be discerned through examining trends in mean depth and maximum depth.

Long-term channel changes such as aggradation and degradation have been interpreted from discharge measurements by plotting specific variables over time, and by examining stage-discharge relationships and specific stage-discharge trends, and stage-discharge rating curves (e.g. Furness et al., 1967; Walters, 1975, 1976; Watson, 1982; Lagasse et al., 1991). The use of specific stage trends, where the stage associated with a particular discharge level is examined over time, is the least subjective and statistically simplest approach (Fig. 1-13). Numerous studies have assessed changes in channel morphology, especially aggradation and degradation using specific discharge-stage trends over time (Furness et al., 1967; Blench 1969; Bull and Scott, 1974, James, 1997). It has some advantages over assessing stage-discharge relationships in that the time periods are not arbitrarily divided. If the water level for a given discharge is dropping over time that suggests that the channel is either deepening or widening to accommodate the same flow volume. If the water level for a given discharge is rising over time that suggests that the channel is either narrowing or filling to have caused a rise for the same flow volume However, various sources of scatter in stage-discharge relationships, can complicate such relationships. If the cross section is altering in a complex manner (bar deposition in the bottom and widening at the banks) evaluating trends at various levels provides additional information. Stage-discharge trends were evaluated by sorting the data by discharge in ascending order, ranking the field measurements into percentiles. Then, the associated stage values were plotted for discharges ranked ± 5% of the 25th, 50th, and 75th percentiles to evaluate whether the stage or water level showed increases, decreases or stability at the various discharge levels.

ISSUES OF DATA QUALITY

There are numerous sources of scatter in the data due to collection procedures, measurement error, and natural variations. Where there are multiple channels, one reason for scatter is the problem of distinguishing the main channel from the channel complex. The geometric measures usually characterize a single channel at lower flows, and a channel and floodplain or a channel complex with several interconnected channels at higher flows. A second source of potential scatter is the transect location, which included the upstream side of bridge, downstream side of bridge, wading and boat measurements at various approximate locations (e.g. 300’ upstream of gage), or not recorded. Bridges may be rebuilt at or nearby old bridges during the study period, which may cause apparent shifts in the data. Construction of bridges and alteration of the channel near the gage station can greatly affect the channel geometry and the subsequent interpretations of channel change. Bridge construction often alters the channel and floodplain form to improve flood conveyance and minimize potential scour effects. Discrepancies increase where bridge data are intermixed with non-bridge data, and where new bridges are built some distance away with different local modifications. Thus, ideally, it is helpful to learn as much as possible about the history of bridge reconstruction at a site when interpreting data. Measurement error is also another source of scatter in the data, and data vary in quality accordingly to research team constraints (number on team, hours expended) and the conditions of the system at that time. In some cases, discriminating based on quality (plotting only good and excellent measurements, and omitting fair and poor measurements) may improve the graphs, but in other cases it would just leave many omissions. Additionally, scatter occurs due to variability associated with the natural system, including differences in hydraulic behavior on rising and falling stages, migration of bedforms, and channel instability such as erosion and deposition. Yet, despite all of these sources of variation, these data often show pronounced trends in channel form and/or position that are clearly indicative of channel changes of different types.



9—207
(Sept. 1952)

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY (WATER RESOURCES DIVISION)

File No. Washington 2-4785.1
Field

Discharge measurements of Chickasawhay River at Leakesville, Miss, during the year ending Sept. 30, 19

No.	Date	Made by—	Width	Area	Mean velocity	Gage height	Discharge	Rating No. 4 Shift adj.	Percent diff.	Method	Number meas. sections	Gage height change	Time	Meas. rated	REMARKS
	1961		Feet	Sq ft	Fps	Feet	Cfs	Feet				Feet	Hr		
265	July 11	Neely	187	2540	1.20	13.84	3040		+2.7	.2&.8	27	-.01	1.67	G	d.s. side bridge
266	Aug. 22	do	181	1960	.81	11.35	1580		+5.3	.5, .6 .2&.8	27	-.02	1.08	G	do
267	Sept. 25	do	163	1620	.52	9.70	842		+4.2	.6 .2&.8	21	0	1.42	G/F	do
	1961														
268	Oct 23	do	192	470	1.06	8.84	499		-4.4	do	25	0	.75	G	wading
269	Dec 5	do	180	1880	.96	11.44	1800	+.52		do	24	0	[illegible]	G	d.s. side bridge
270	1962 Jan. 4	do	200	3400	2.12	18.95	7190		-0.3	do	30	-.01	.92	G	do
271	Feb. 14	Senseman	187	2740	1.31	14.80	3580		-1.1	2&8	25	-.01	1.17	G	u.s. side bridge
272	Mar. 28	do	185	2580	1.41	14.31	3630	RT. NO.	5 -0.5	do	25	-.02	1.25	G	do
273	May 8	do	202	2570	1.24	13.72	3180		0	.6 .2&.8	25	-.03	1.17	G	do
274	May 30	Neely	165	1570	.55	9.81	860	-.25		do	25	-.01	.83	G	d.s. side bridge
275	July 9	do	164	1440	.46	9.03	663		-1.0	do	24	0	.75	G	do
276	Aug. 14	Senseman	163	1320	.35	8.32	463		+0.9	do	25	0	1.33	G-F	do
277	Sept. 5	Trotter	134	366	1.14	7.98	418	+.18		.5&.6 .2&.8	28	+.01	1.00	G	wading
278	Oct. 10	Senseman	162	1290	0.40	8.16	514	+.36		.6 2&8	25	+.03	1.42	G	d.s. side br. at gage

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Figure 1-12. A summary of several discharge measurements provides an important data source with which to analyze channel cross-sectional changes over time. This sheet includes several measurements made during water year 1962 on the Chickasawhay River at Leakesville.

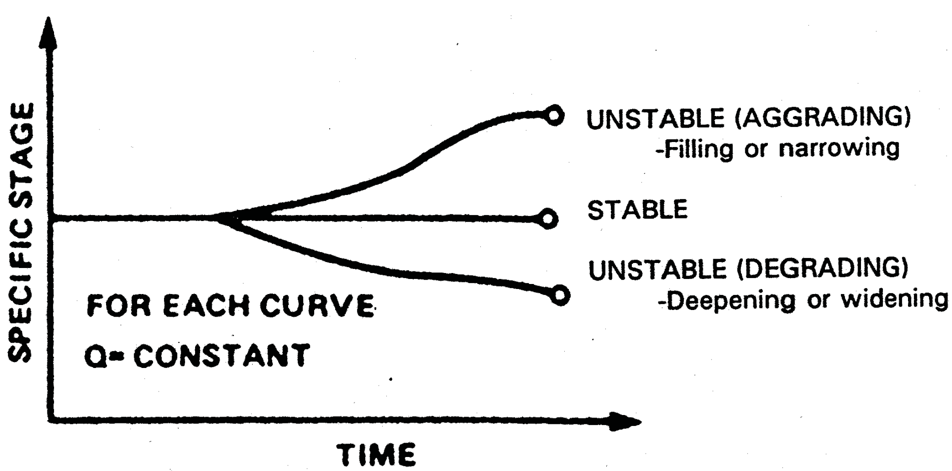

Figure 1-13. Specific stage trends show how the stage associated with a particular discharge level changes over time. A rising trend is caused by with aggradation, whereas a falling trend is caused by degradation.

RESULTS

Several geomorphic variables were plotted in the spreadsheets, some of which are included as figures for each location (Fig. 2-1 to 2-5, 3-1 to 3-5, 4-1 to 4-5, 5-1 to 5-5). Some of the most pertinent variables and key observations are described below and are summarized in Tables 1 and 2. As discussed earlier, further data gathering from future USGS visits, continuing data quality control, compilation of bridge data, GIS analyses of planform data, and other types of information collected may result in somewhat differing interpretations later in this study.

DISCHARGE SUMMARY DATA

Perhaps the most definitive findings are from the discharge summary data, which contain several hundred measurements of the stream cross-section characteristics plotted versus time. Of the four continuous locations on the Leaf River, the two upstream sites show some (Collins) to pronounced (Hattiesburg) decreases of about 1 and 2m in mean bed elevation and 0.5 and 4m in thalweg elevation (Table 1; Figs 2-1 to 2-4 and 2-1 to 3-4). Although not plotted in this paper, Hattiesburg also shows an increase in maximum depth of about 1.5m, changing most rapidly during the 1970s, and stabilizing since then, possibly due to in-channel mining in the nearby tributary. The specific stage-discharge trends also shows degradation, dropping approximately 0.5 m at Collins and more than 1m at Hattiesburg (Figs. 2-5 and 3-5). Other types of geomorphic changes are not pronounced and inconsistent.

The two downstream sites (New Augusta, McLain) show increases in mean bed elevation of 1m and thalweg elevation to 2m, some increases in width and larger increases width-depth ratio (Table 1; Figs 4-1 to 4-4 and 5-1 to 5-4). There were also decreases in mean and maximum depth, not included as plots in this paper. The stage-discharge data corroborate aggradation at New Augusta, even with the short period of record. However, at McLain there are no discernable trends in stage for a given discharge, suggesting that the channel is widening at the same time as it is experiencing aggradation, and therefore can hold a similar flow level.

HISTORIC CROSS SECTIONAL CHANGES OVER DECADAL TIMESCALES

Several cross-sectional measurements, showing changes every decade are shown as the last figure on each site (Figs. 2-6, 3-6, 4-6 and 5-6) and for stations with only sporadic measurements (Figure 6-1 and 7-1). Results presented in this report consist dominantly of visual illustrations of the decadal changes at various transects. Depending on data availability and other factors, sites may have as few as three time periods and other as many as eight time periods plotted.

Table 2 identifies periods of possible lateral migration and apparent rises or falls in bed elevation through plotting of sequential graphs. Channel bottoms can fluctuate markedly in short periods of time, however, so the measurement of depth at that time is less reliable than the more comprehensive statistical summary shown as each of the first five figures at the four continuous sites. Both the plots here (e.g. Fig. 3-4) and Wilson (1995), show nearly 10 m (>30 ft) of fluctuation in minimum bed elevation, much of which can occur in a single year. The historic cross sections represent two days of many in that sequence and may not, and often do not, show quite the same range as more comprehensive long-term data.

In most cases, the input of distance and depth points was straightforward and resulted in plots that reflected what appear to be accurate comparisons of channel positions at different times. In some cases, however, it was unclear or uncertain whether the channel did undergo such shifts as appear on the plots or whether this represents some type of difference in bridge markings or distance measurements associated with different transects, including the construction of new bridges, which would case apparent shifts in stream position. It is clear that there are issues here with data recording and plotting because the channel appears to shift back and forth one or more times during the period of record. Extensive efforts were made to apply appropriate corrections when it was relatively clear what the necessary adjustments should be to represent the stream channel accurately in terms of comparing one channel to the other. Most of the sites examined on the Leaf River appear realistic, but in the case of the Leaf River at Collins and possibly others, one or more of the so-called periods of "possible lateral migration" might be attributed to other factors or errors. In such cases, the interpretations derived from this data source currently require further investigation and data collection for validation. Based on some initial planform comparisions, it does appear that at least some of the lateral shifts in channel position at Hattiesburg did occur. Continuing work and analysis will help to establish which of these occurred and assist in assessing the timing and magnitude of these possible migrations.

DISCUSSION AND CONCLUSIONS

The changes documented here are mostly consistent with prior studies, although more locations and more variables were examined overall in this study. The trend towards river widening on the Lower Leaf concurs with that findings of Turnipseed (1993) who documented recent widening on the Leaf River near McLain. As this study, the cross sections plotted by Turnipseed (different ones than plotted in this study) show increases in bed elevation on the Leaf River near McLain, as shown on cross sections plotted here and on the more temporally comprehensive summary data. Similar to Brown and Mitchell (1995) and Wilson (1995), this study confirms degradation of about 0.3m (1 ft) per decade on the Leaf River at Hattiesburg, but documents such rates for a longer period overall.

The trends in mean bed elevation and thalweg elevation show varied changes as do the trends in stage-discharge relationships. In some cases, there are nonlinear trends, including sharp rises or falls at particular times and possible cycles of rises and falls over the period of record. There could be more follow-up, involving use of more sophisticated statistical tests in some cases, such as those described in Helsel and Hirsch (1991) to evaluate whether trends are significant, etc., and other inferences that can be made from the data.

Also of some concern interest is whether there is lateral erosion, or channel change in the x-y dimension. This is relevant for a number of reasons, related to the fact that changes in the x,y, and z dimensions are linked. If the stream is unstable as viewed from planform dimensions, this is important as subsequent stream movement in relation to the crossing influences the potential for scour (Richardson et al., 1991). It is expected that the examination of changes in channel planform will yield important information. Some preliminary work at various Leaf River sites suggests that the recent planform changes, from the early 1980s to mid-1990s, correspond well with areas sand bars during the most recent maps. Further work will assess this possibility, and will provide far more extensive spatial information regarding areas of channel change in a planform dimension.

It is unknown if there is a causative relationship between land use changes and bed elevation changes spatially or temporally. Tables 1 and 2 also provide some indication of the timing of these changes. Further study may help connect these changes with causative factors, at least in some instances. Continuing effort is ongoing regarding collecting various forms of historical temporal and spatial information about land use, agriculture, forests and mining. Cycles of aggradation and degradation are likely influenced by the emplacement of structures in river corridors, dredging for navigation, snag removal, and land use changes in the basin such as deforestation, agricultural activities, mining and urbanization. In all likelihood, the pronounced changes observed on the Leaf River at Hattiesburg in this study and others, is likely caused by the extensive in-channel sand and gravel mining on the Bowie River. Ideally, it would be helpful to obtain more data in this area, and thus the Bowie River and Leaf River at Hattiesburg are potential sites for field data collection. There certainly should be more work to understand the role of both natural factors (geology, soils, slopes) and human factors (land use changes, snag removals and dredging) on channel cross-sectional and channel bottom stability. Still, the data plotted herein suggest degradation on the Upper Leaf and aggradation on the Lower Leaf, helping to document spatial variations in channel change in the basin. Knowledge of the changes observed may be of benefit to planners, managers, and engineers. These data are not predictive but rather historic evidence of what has happened at bridges in southeastern Mississippi in the past century.

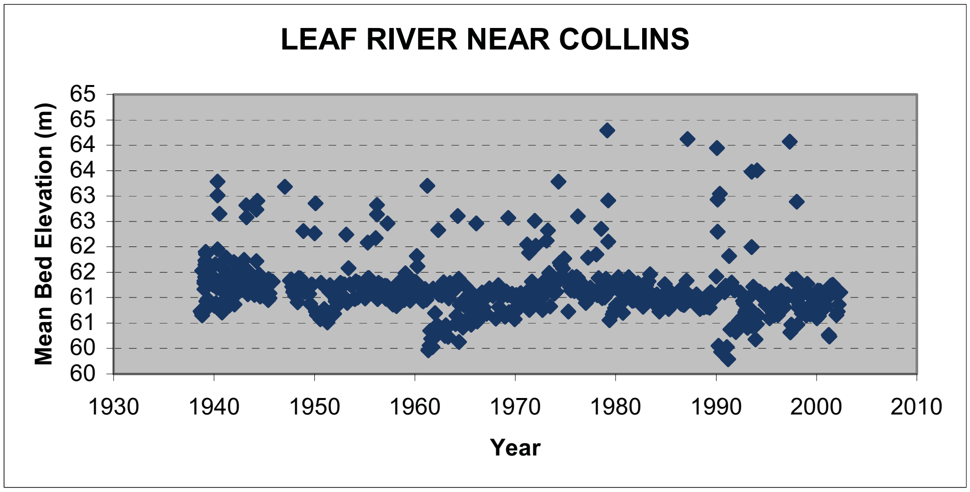

Figure 2-1 Mean Bed Elevation at Leaf River Near Collins/U.S. Hwy 84

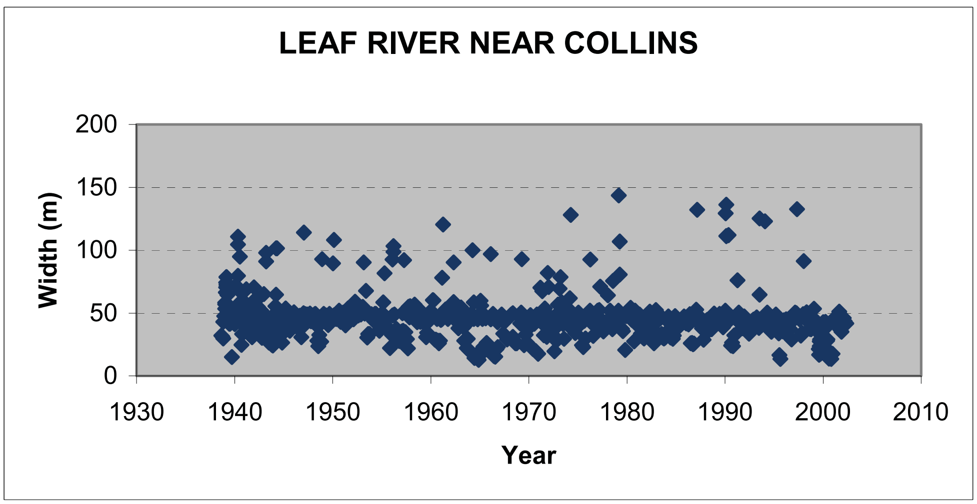

Figure 2-2 Width at Leaf River Near Collins/U.S. Hwy 84

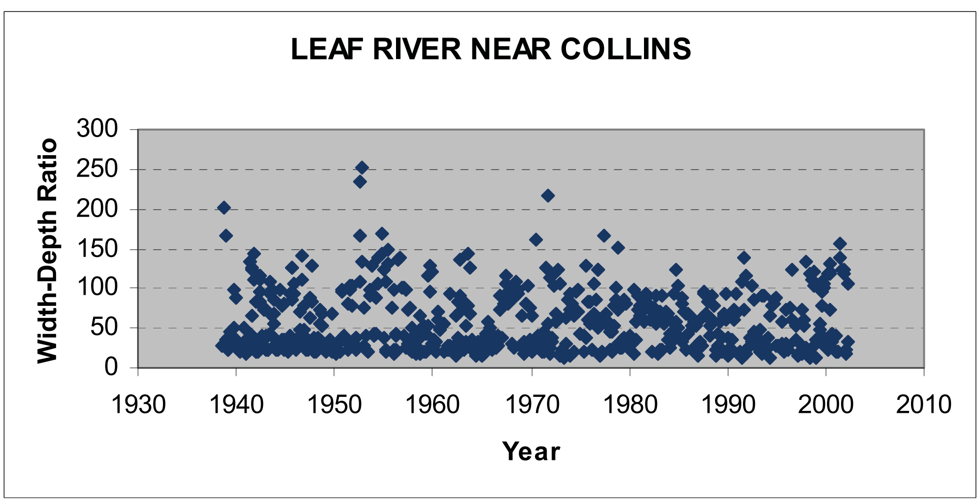

Figure 2-3 Width-Depth Ratio for Leaf River Near Collins/U.S. Hwy 84

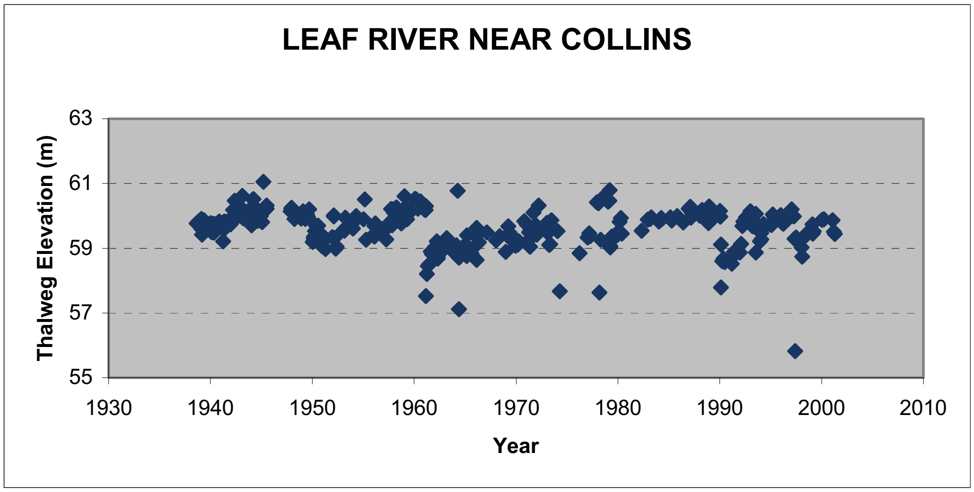

Figure 2-4 Thalweg Elevation (m) Leaf River Near Collins/U.S. Hwy 84

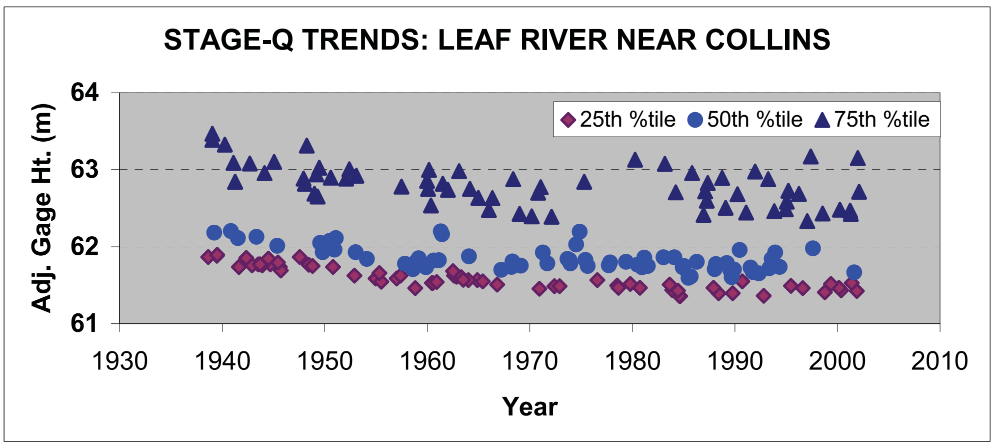

Figure 2-5 Stage-Q Trends: Leaf River Near Collins/U.S. Hwy 84

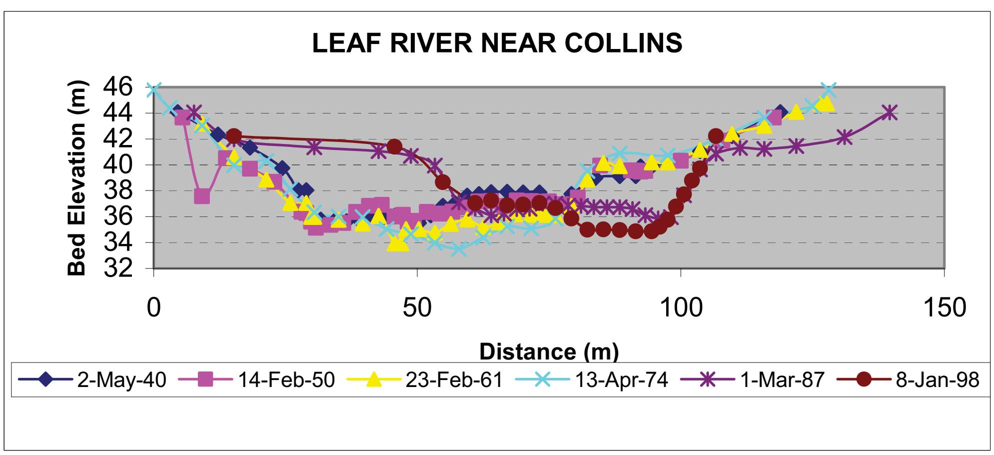

Figure 2-6 Bed Elevations: Leaf River Near Collins/U.S. Hwy84

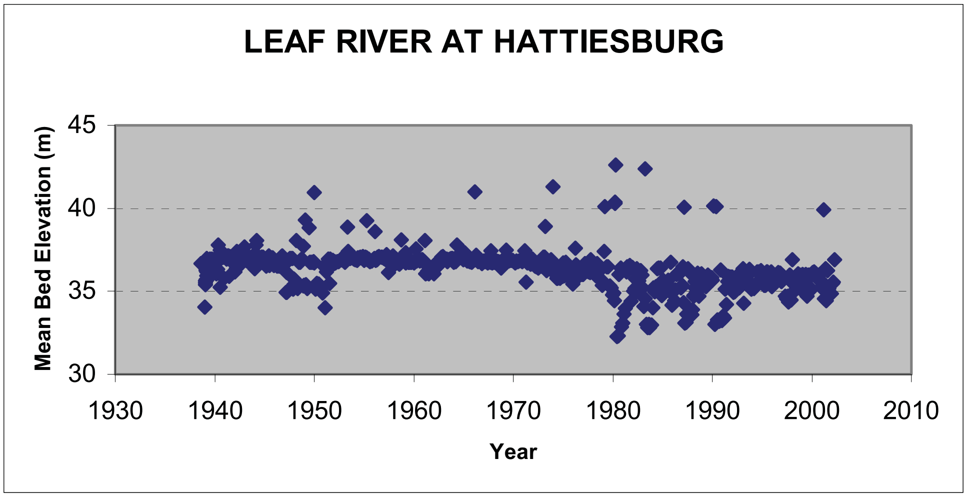

Figure 3-1 Mean Bed Elevation for Leaf River At Hattiesburg/U.S. Hwy 11

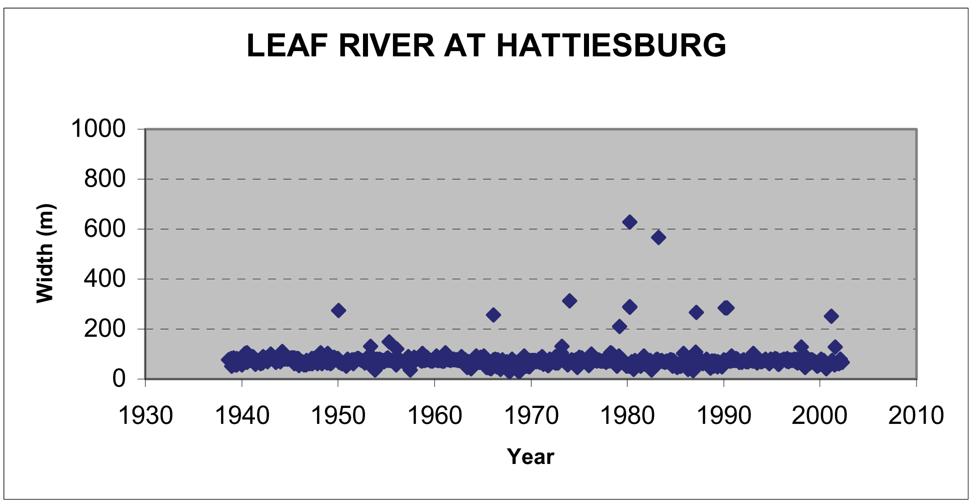

Figure 3-2 Width (m) for Leaf River At Hattiesburg/U.S. Hwy 11

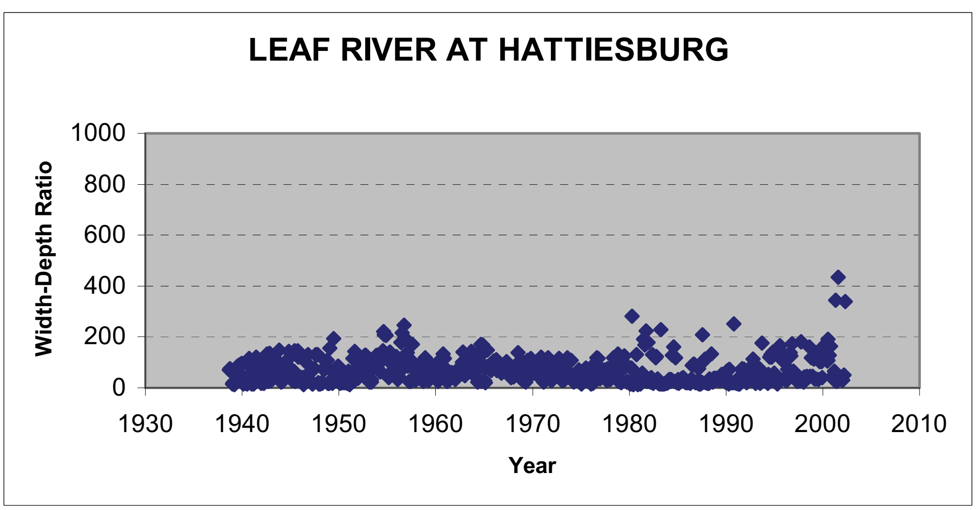

Figure 3-3 Width-Depth Ratio for Leaf River At Hattiesburg/U.S. Hwy 11

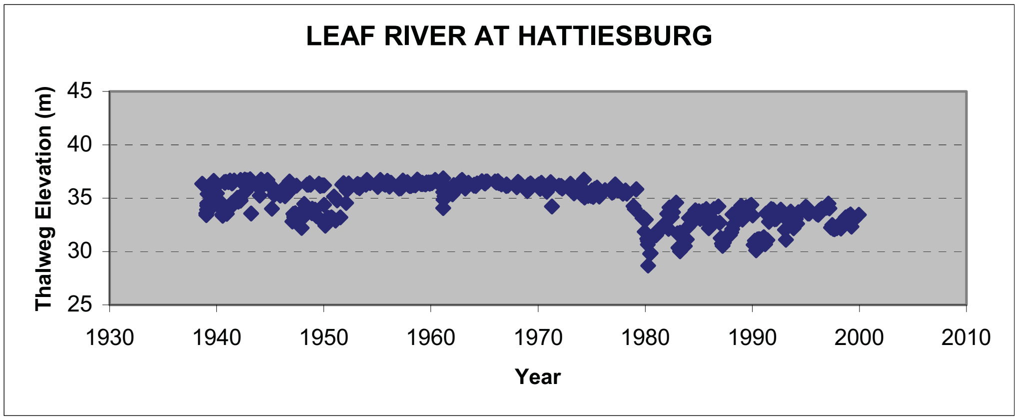

Figure 3-4 Thalweg Elevation (m) Leaf River At Hattiesburg/U.S. Hwy 11

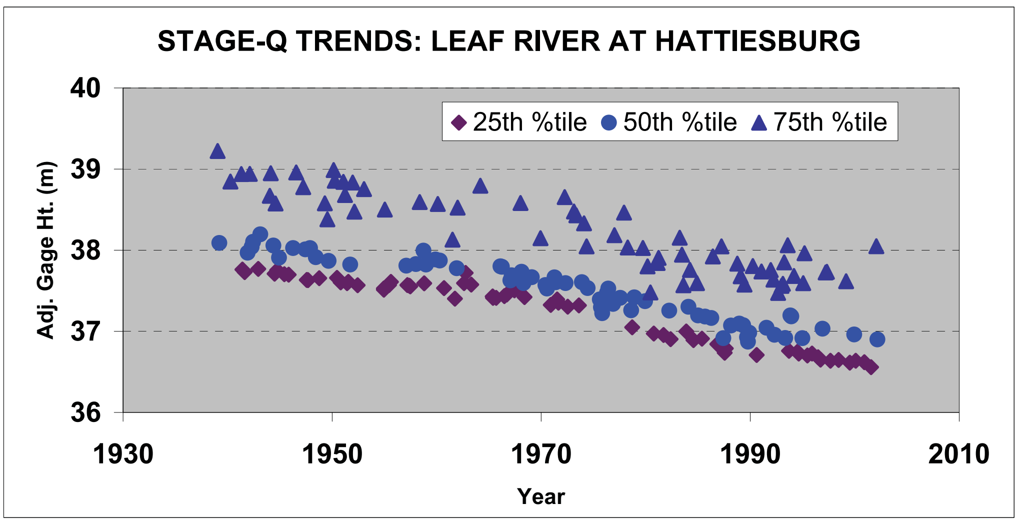

Figure 3-5 Stage-Q Trends: Leaf River At Hattiesburg/U.S. Hwy 11

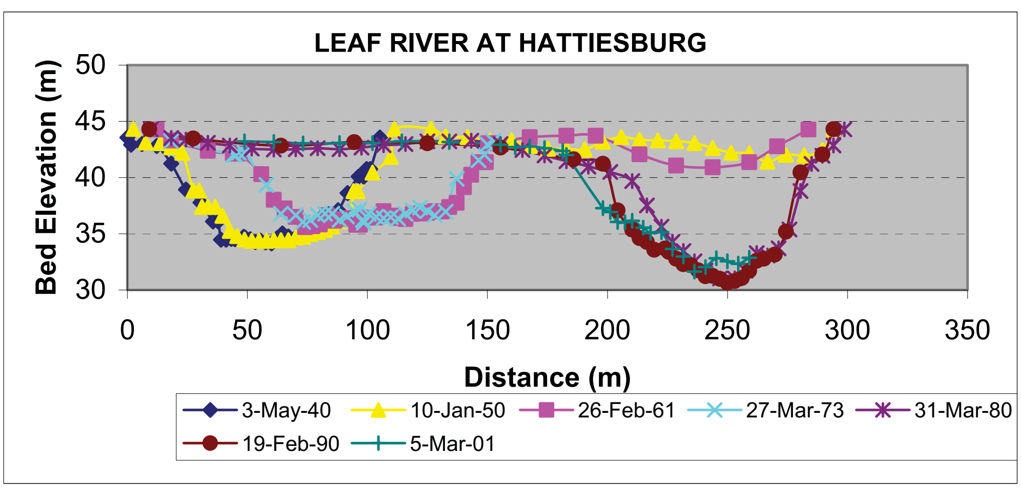

Figure 3-6 Bed Elevations for Leaf River at Hattiesburg

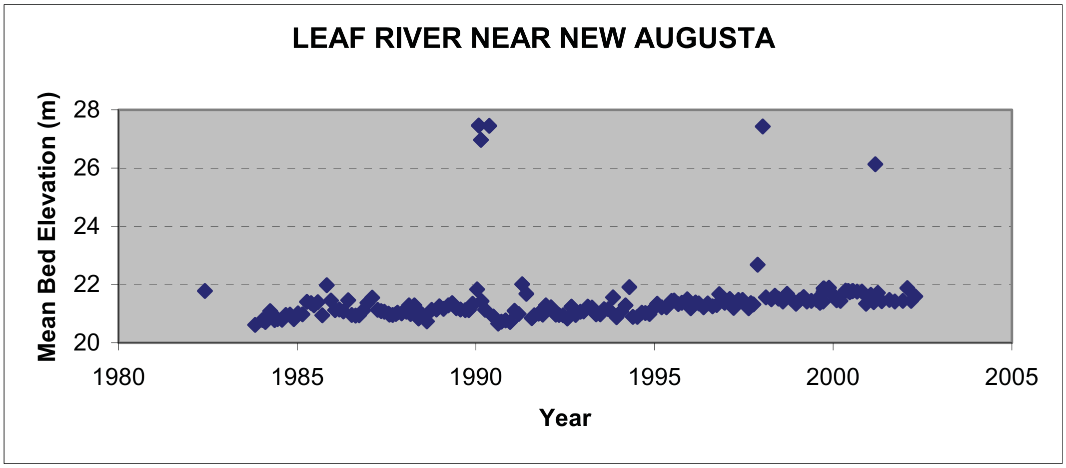

Figure 4-1 Mean Bed Elevation (m) Leaf River Near New Augusta/State Hwy 29

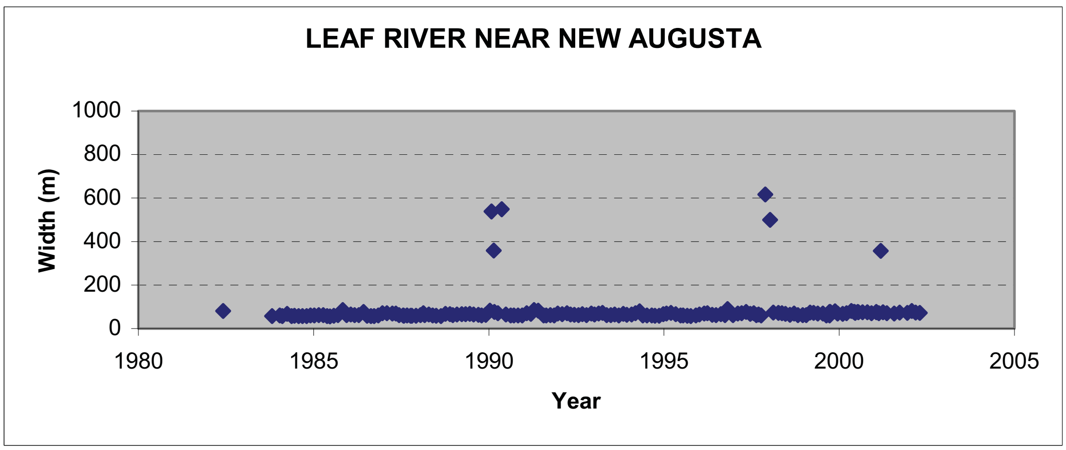

Figure 4-2 Width (m) for Leaf River Near New Augusta/State Hwy 29

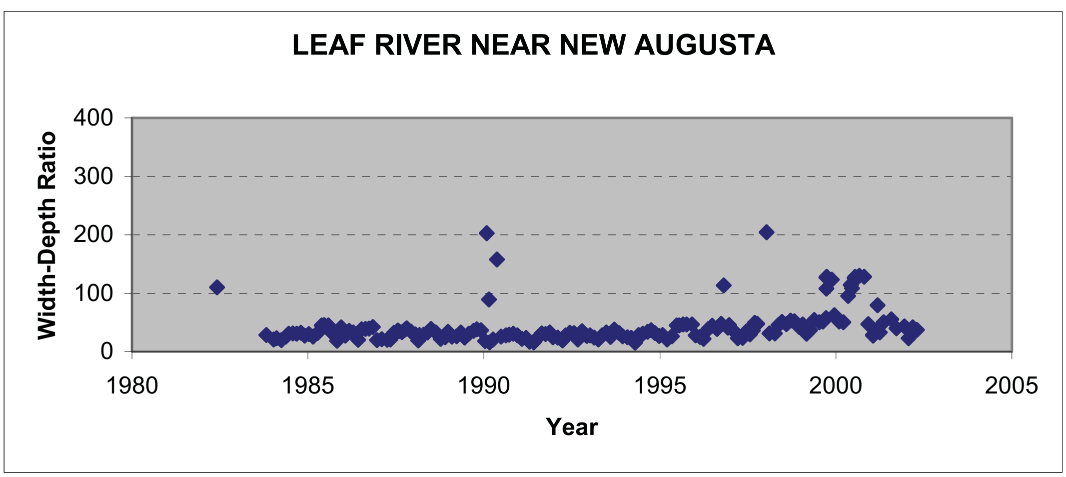

Figure 4-3 Width-Depth Ratio for Leaf River Near New Augusta/State Hwy 29

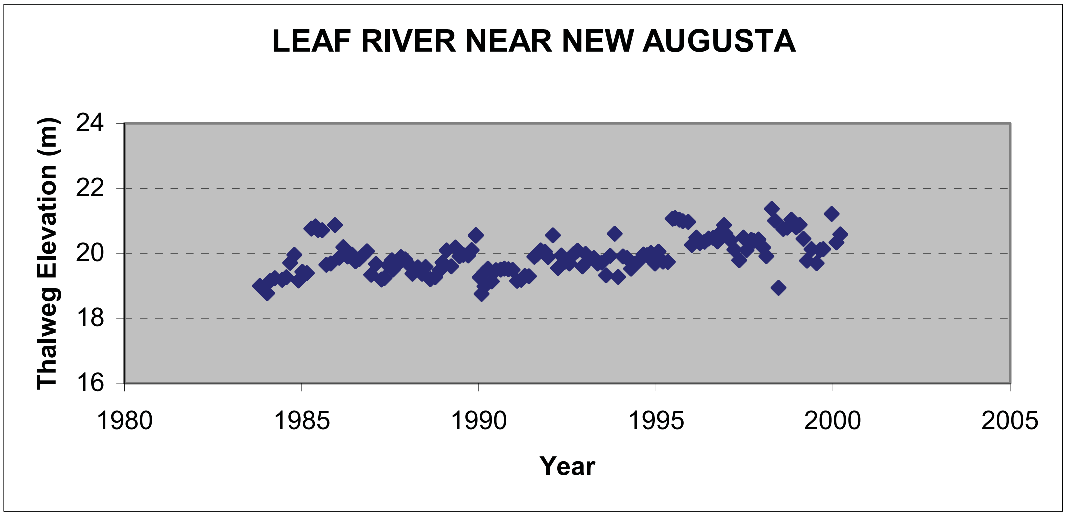

Figure 4-4 Thalweg Elevation (m) for Leaf River Near New Augusta/State Hwy 29

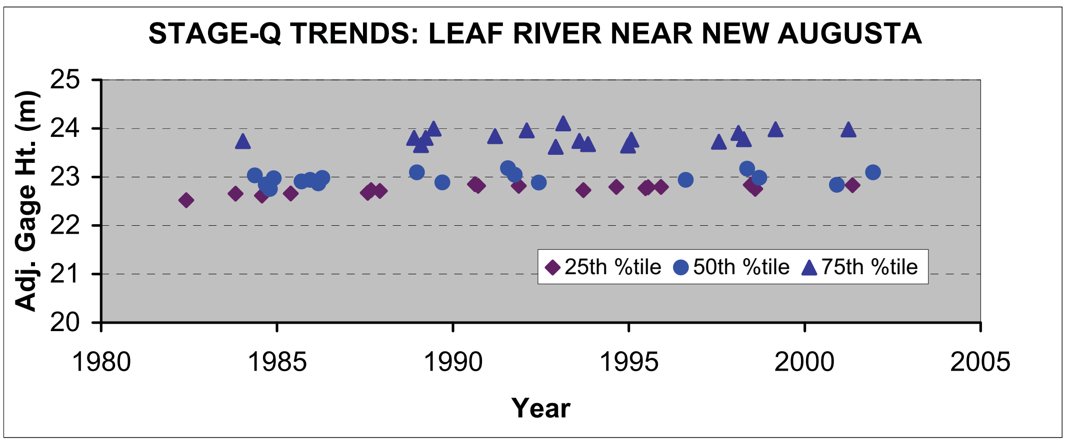

Figure 4-5 Stage-Q Trends: Leaf River Near New Augusta/U.S. Hwy 29

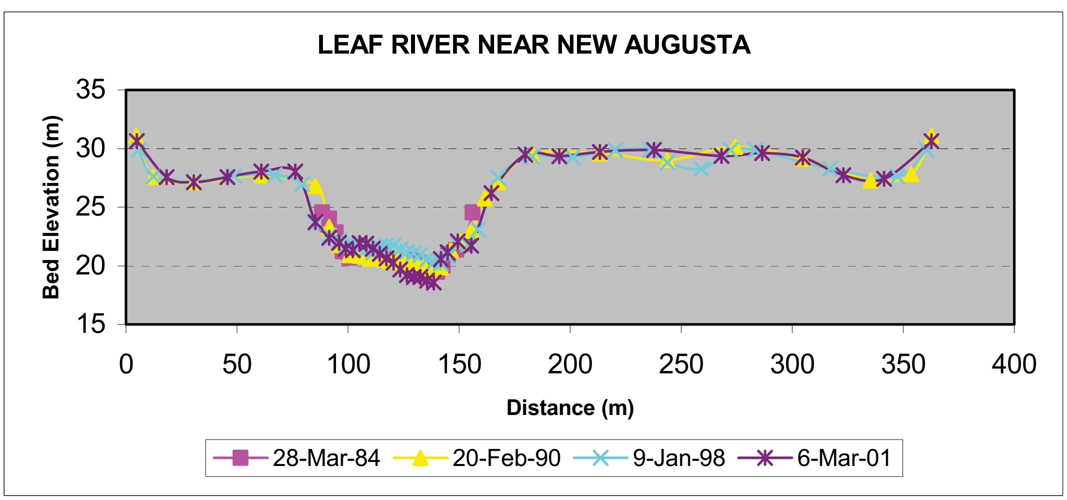

Figure 4-6 Bed Elevation for Leaf River at New Augusta

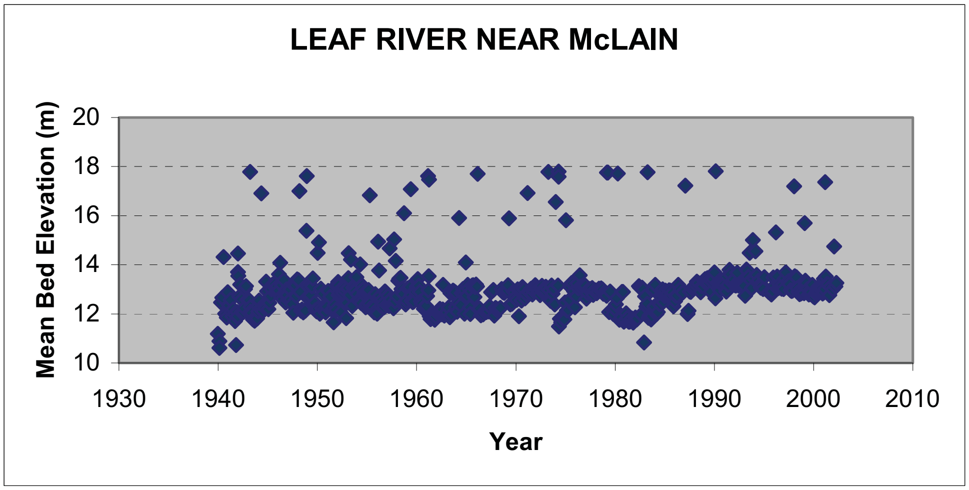

Figure 5-1 Mean Bed Elevation (m) for Leaf River Near McLain/U.S. Hwy 98

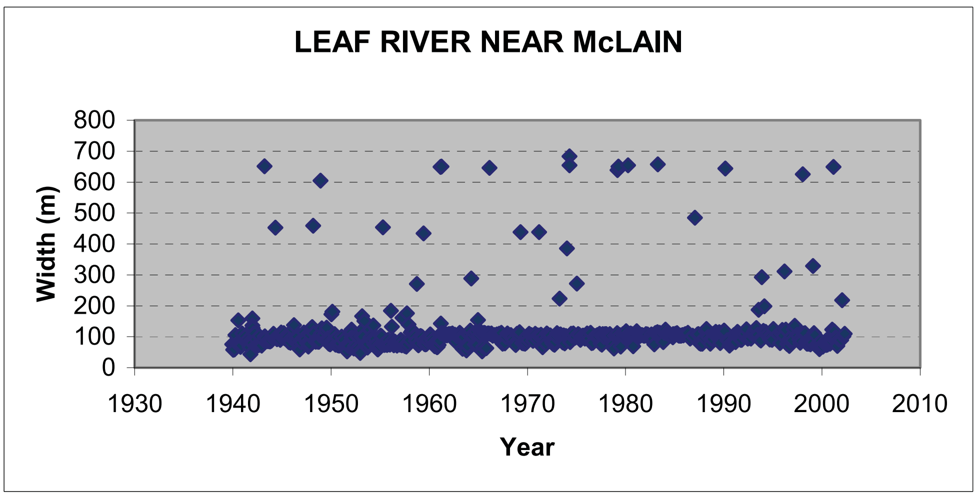

Figure 5-2 Width (m) for Leaf River Near McLain/U.S. Hwy 98

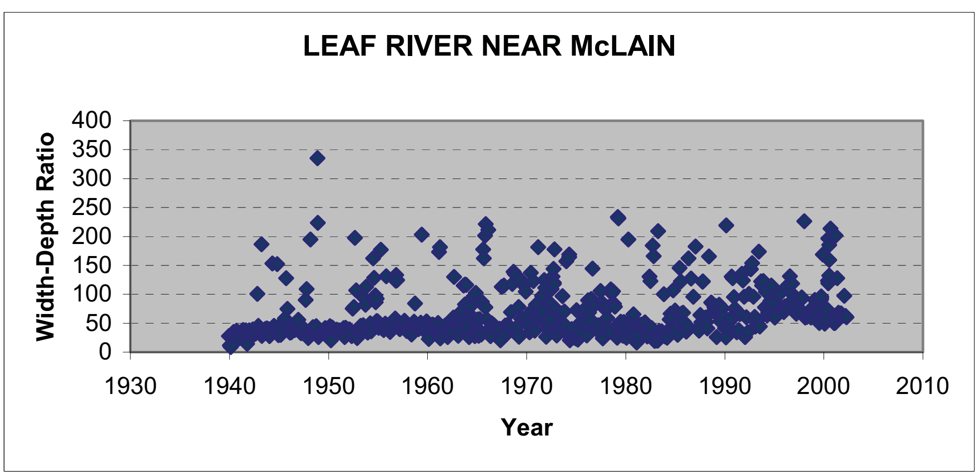

Figure 5-3 Width-Depth Ratio for Leaf River Near McLain/U.S. Hwy 98

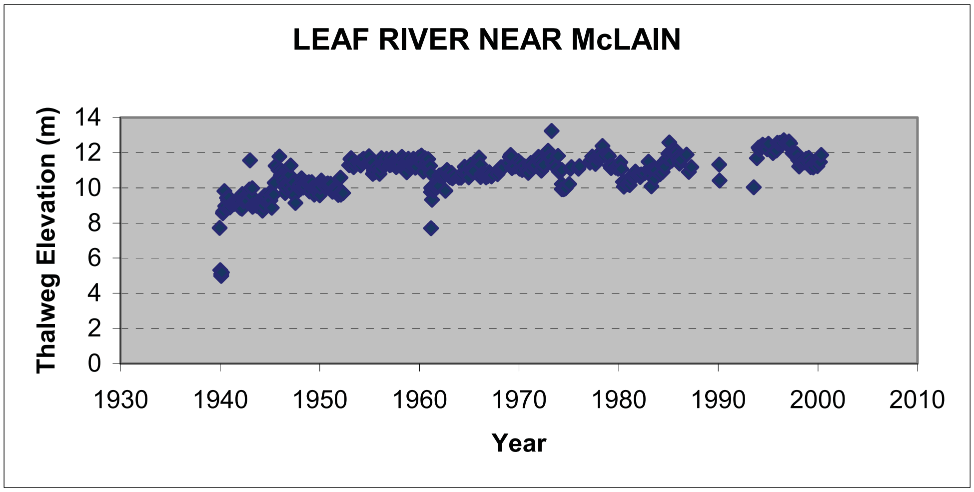

Figure 5-4 Thalweg Elevation (m) for Leaf River Near McLain/U.S. Hwy 98

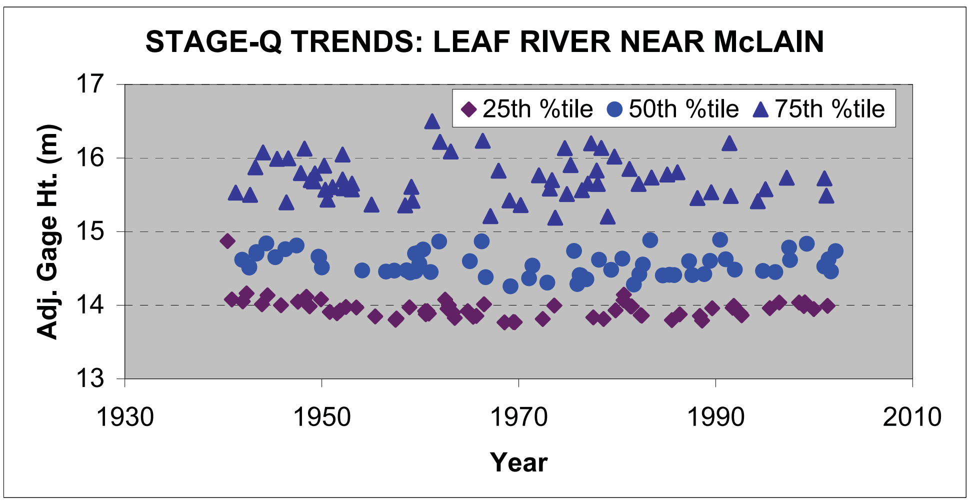

Figure 5-5 Stage-Q Trends for Leaf River Near McLain/U.S. Hwy 98

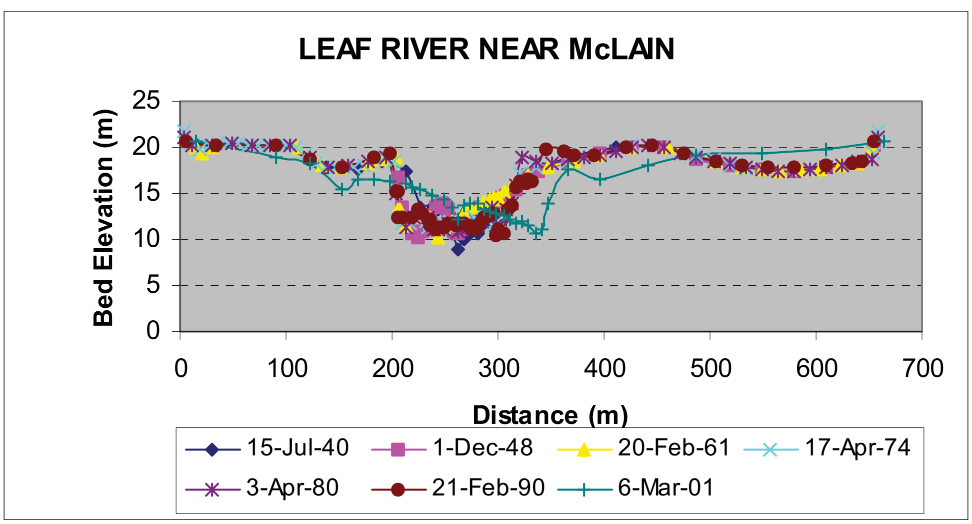

Figure 5-6 Bed Elevation for Leaf River near McLain

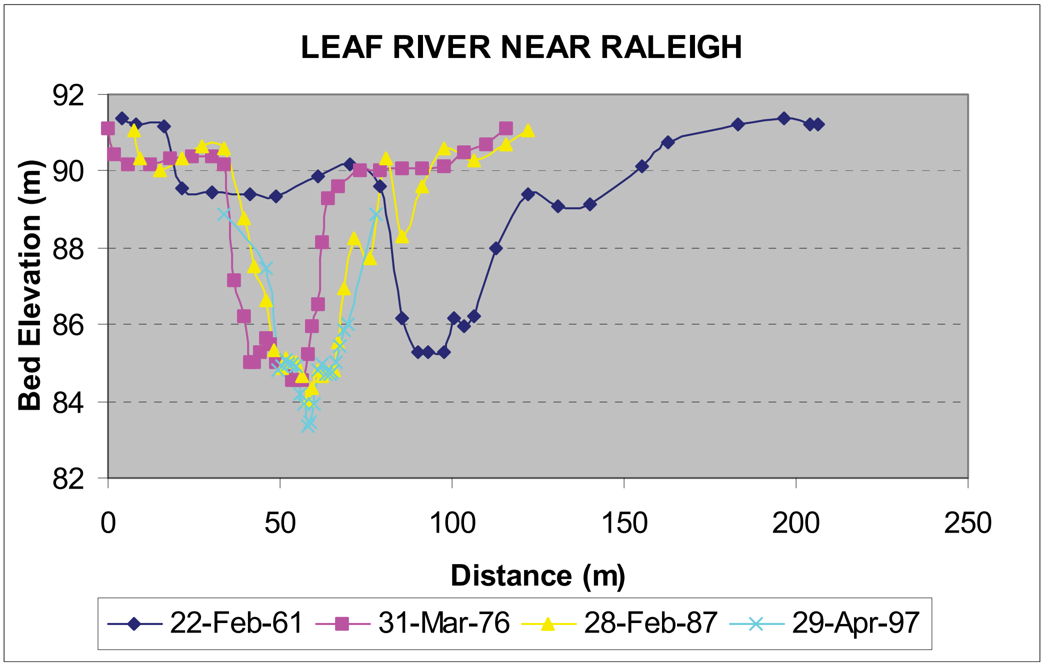

Figure 6-1 Bed Elev. (m) for Leaf River Near Raleigh/State Hwy 18

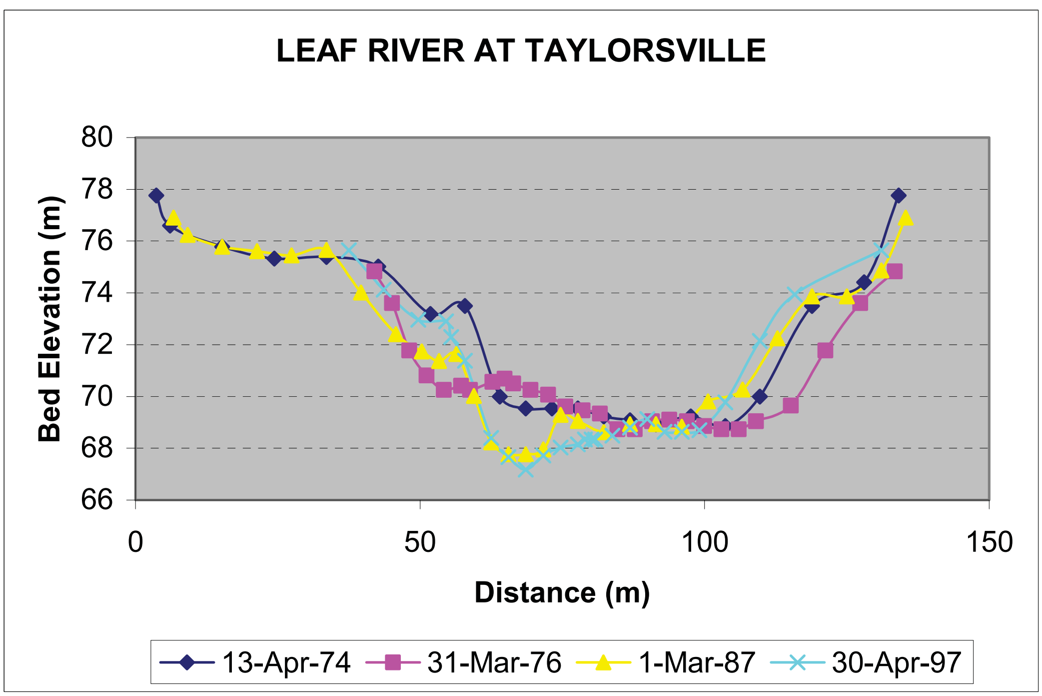

Figure 7-1 Bed Elev. (m) for Leaf River At Taylorsville/State Hwy 28

Table 1. Trends Interpreted from Discharge Cross Sectional Summary Data

	Area (mi2)	MBE (m)			Thalweg (m)			Stage-Q(m)			Width (m)			W/D Ratio		
LEAF RIVER		Trend	Amount	Timing	Trend	Amount	Timing	Trend	Amount	Timing	Trend	Amount	Timing	Trend	Amount	Timing
Collins	**743**	D	1	Throughout	D	0.5	40s	D	0.5	Throughout	S			S		
Hattiesburg	**1742**	D	2	Throughout	D	4	40s, 50s	D	1.2	Throughout	S			S		
New Augusta	**2542**	U	1.2	Throughout	U	2	00s	U	0.2	Throughout	U	10	Throughout	U	20	90s, 00s
McLain	**3495**	U	1	40s, 50s	U	3	90s	S			U	20	Throughout	U	30	70s, 90s

U=UPWARDS D=DOWNWARDS S=STABLE

Table 2. Historic Cross Sections and Timing of Notable Changes including Possible Lateral Migrations

LOCATION	Years Evaluated	Interval of 1st Possible Mig.	Interval of 2nd Possible Mig.	Interval of 3rd Possible Mig.	Lat Mig.(m)	Bed Elev Change (m)	Comments
near Raleigh	**61,76,87,97**	1961-1976	1976-1987		35	2 fall	data recording issues?
at Taylorsville	**74,76,87,97**				20	2 fall	minimal shifting
near Collins	**40,50,61,74,87,98**	1974-1987			40	1 fall	extensive mig. throughout
at Hattiesburg	**40,50,61,73,80,90,01**	1950-1961	1973-1980		190	2 fall	extensive shifts in elev.
near New Augusta	**84,90,98,01**					0	negligible mig. throughout
Near McLain	**40,48,61,74,80,90,01**	1940-1948	1990-2001		80	2 rise	lat. shifts throughout

ACKNOWLEDGEMENTS

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HYDROLOGIC CONTROLS ON BALD CYPRESS GROWTH IN SEASONALLY INUNDATED WETLANDS

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Several studies have reported a correlation between precipitation and the thickness of annual growth rings in bald cypress, including trees growing in saturated sediments where growth should not be water-limited. In wetlands where bald-cypress roots remain partially or fully immersed throughout the year, the growth-precipitation correlation may be a result of increased nutrient availability following precipitation and subsequent runoff into the wetland. Nutrients may be delivered by flushing the root zone with nutrient-rich water, or attached to sediments washed into the wetland during precipitation events. Both possibilities are being investigated at Sky Lake in Humphrey's County, Mississippi. Sky Lake is an oxbow-lake wetland formed by the ancestral Mississippi River. Surface outflow from the lake is ephemeral, with seasonal flow through Wasp Lake into the Yazoo River. Flow periodically reverses when the Yazoo River is high. Backflow from the Yazoo River can raise water levels in the vegetated fringe of Sky Lake in excess of 4 m, creating the potential for reversals in subsurface flow in the root zone. Water chemistry, isotopic composition and hydraulic head are being monitored using a series of nested piezometers completed in and below the root zone along an elevation transect beginning at the perennial low water line. Evaporation of lake water during the drier summer season is evident from enriched $\delta^{18}O$ values in lake water relative to precipitation and stream inflows. Both head and isotopic data collected from the piezometers during the Fall of 2002 suggest that shallow groundwater flow is toward the lake as expected when the lake level is low. Monitoring through the winter will allow evaluation of possible flow reversals when the lake level is high. The influence of sediment influx on tree growth is being evaluated by measuring sedimentation rates in high and low flux areas of Sky Lake, and the width of annual growth rings in bald cypress growing in these areas. Preliminary data suggests that bald cypress grow more rapidly when sedimentation rates are higher.

NOTES:

MACROINVERTEBRATES ASSOCIATED WITH HEADWATER STREAMS AT CAMP McCAIN TRAINING SITE, MS

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Keeping with good environmental stewardship in 1997 the Mississippi Military Department implemented an Aquatic Biomonitoring Program at the Camp McCain Training Site in Grenada County, MS. The objective of this program is to determine the status of the water resources (Are the designated/beneficial and aquatic life uses being met?). Rapid bioassessment using the benthic macroinvertebrate assemblage has been the most popular set of protocols among water resource agencies since EPA published their first edition of Rapid Bioassessment Protocols for use in Wadeable Streams and Rivers in 1989, and the second in 1999. Systematic sampling of three headwater streams (Crowder, Epison and Campbell) has been conducted each autumn, beginning in 1997-current, at designated 100 m reaches exiting the camp. Biannual sampling began in 2002 with the inclusion of a spring sampling period. Sampling twice a year will accommodate seasonal variation of the macroinvertebrate community. A multihabitat procedure using a D-frame dip net is the sampling method used. EPA indicates that this technique is scientifically valid for low-gradient streams. Taxonomy is to genus/species, which provides more accurate information on ecological/environmental relationships and sensitivity to impairment. Benthic metrics used to evaluate aspects of both elements and processes within the macroinvertebrate assemblage are; Taxa Richness, EPT index, EPT/Chironomidae, Functional Feeding Groups, NC Biotic Index and, Shannon "diversity and evenness" indexes. Water quality assessments and autumnal community trends of each headwater stream are based on current site-specific monitoring data.

NOTES:

COMMUNITY COMPOSITION OF SAND-DWELLING CHIRONOMIDS IN THREE BLACKWATER STREAMS

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The majority of streams in Mississippi have sand bottoms. In this study we investigated the larval chironomid (Diptera: Chironomidae) composition in the spring and summer in three sandy-bottomed blackwater streams located in southern Mississippi. The principal objective of this study was to describe how the chironomid communities in sand substrates varied among sites within a stream, as well as among streams. We were also interested in seasonal changes in chironomid communities. Most of the animal biomass collected from sandy substrates is in the form of relatively small invertebrates, including the chironomids. In all sites the most common chironomid larvae was *Rheosmittia* sp., which accounted for 50-90% of the chironomids collected. *Rheosmittia* sp. is a very small chironomid and is an obligate sand dweller in streams and rivers. The mean density of *Rheosmittia* sp. from the spring data in Black Creek is approximately 133,000 individuals/m^2 in sandy substrate. Based on evidence from our laboratory, this genus of chironomid dominates sand substrates from streams of the size investigated in this study up to and including the lower Mississippi River. Other chironomid taxa found in the present study included *Polypedilum scalaenum* group, *P. halterale* group, *Paracladopelma* sp., and *Stictochironomus* sp. In addition to characterizing the invertebrate fauna of sand substrates, we plan to determine if these communities will serve as indicators of pollutional disturbance.

NOTES:

EVALUATION OF HEADWATER STREAMS ON THE CAMP SHELBY TRAINING SITE IN SOUTH MISSISSIPPI BASED ON THE EPT COMPLEX (EPHEMEROPTERA, PLECOPTERA, AND TRICHOPTERA)

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Mayflies, stoneflies, and caddisflies are pollution sensitive aquatic insects in their immature stages and make up the Ephemeroptera-Plecoptera-Trichoptera (EPT) Index, often used to characterize the “environmental health” of streams. The number of distinct taxa within these orders determines the EPT Index of a sample collection; the numerical value of this index increases as water quality increases. Another water quality index is the Biotic Index that uses species tolerance values to determine a stream’s overall water quality. Tolerance values range from 0 to 10, with 0 indicating no tolerance to pollution. The Biotic Index uses the same ranges, therefore, the lower the Biotic Index of a stream, the “healthier” the stream. We have been using EPA’s Multi-Habitat Approach to evaluate the macroinvertebrate communities associated with seven headwater streams at Camp Shelby Training Site in south Mississippi since 1997. Results for 16 collections show that the EPT species complex is reasonably consistent in composition across streams and seasons. Seasonal averages for the EPT Index range from four to seven, while site averages range from two to eight. In all, there were 24 species of Ephemeroptera, 14 species of Plecoptera, and 23 species of Trichoptera. Seasonal Biotic Indices range from 5.5 to 6.6. Site Biotic Indices range from 5.4 to 6.4.

NOTES:

CHEMICAL OXIDATION PRIMING FOR ENHANCING PETROLEUM HYDROCARBON REMOVAL IN SOILS BY BIOLOGICAL TREATMENT

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Petroleum Hydrocarbons represent one of the most predominant forms of pollution contaminating soils worldwide. Sources of this contamination include accidental and intentional releases during production, transportation, and storage. Biological treatment has gained significant stature as an economic means of removing petroleum products from soils. However, removal of mid-weight fractions, primarily polycyclic aromatic hydrocarbons, is kinetically slow due to difficulties with strong sorptive bonds and induction of key oxygenases required for degradation. Research at Mississippi State University has focused on the combining of chemical oxidation and biological treatment into a new, innovative "hybrid" process. The concept being that chemical oxidizers are very adapt at cleaving aromatic rings, while having difficulty with removal of straight chain products. Biological treatment is just the opposite, it is quite capable of degrading straight chain compounds, but has problems with the degradation of ringed compounds.

Recent results indicate that initially treating soils with biological treatment until the rate of degradation is kinetically slow can be enhanced by a short period of chemical priming using ozone or Fenton's Reagent; later, followed by the re-establishment of biological treatment. One series of experiments initially removed over 70% of the total petroleum content via biological treatment. After that initial phase, Fenton's Reagent was applied removing an additional 20%, then biological treatment was re-started removing an additional 8%. It is hypothesized that the chemical oxidation step removes a portion of the residual petroleum, plus degrades some of the recalcitrant fractions into smaller, more soluble compounds for subsequent removal via the re-started biotreatment. It is also speculated that the application of the oxidizers to the soil disrupts the adsorptive capacity of the soil toward the petroleum products, via oxidation of organic matter, making the organic compounds more susceptible to subsequent biological treatment.

NOTES:

THE USE OF PHOSPHATES TO REDUCE LEAD MOBILITY AT MILITARY SMALL ARMS TRAINING RANGES

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The primary goal of the United States Military is to train and equip troops to maintain military readiness to defend the United States and its interests. Small arms range (SAR) training represents a major element in keeping the military ready to accomplish this mission.

Projectiles utilized as part of SAR training have accumulated in the soil at the SARs as a result of many years of use. These projectiles are composed of toxic metals, such as lead and copper. The projectiles, with weathering, transform from a relatively insoluble elemental form of metal to an oxidized or ionized complex. This transformation increases the mobility of the metal which may allow it to migrate to surface and ground water sources. Due to the toxicity associated with the metals, the SAR may pose a threat to humans and the environment.

Recent studies show that the treatment of the soil with phosphate-based binders may react with the metals, which results in lowering the solubility of the lead and other metals. The phosphate based-binders react with the metal ions, such as lead, to form insoluble metal phosphate complexes called pyromorphites as shown in equation 1.

$$10M^{2+} + 6H_2PO_4^- + 2OH^- \longrightarrow \underline{M_{10}(PO_4)_6(OH_2)} + 12H+ \quad \text{Eq (1).}$$

Several types of phosphate binders can be used to form the desired pyromorphites, however, the kinetics of the reaction depend on the phosphate complex. This may be due to the ability of the specific binder to mix efficiently in the contaminated soil or due to the reactive nature of the specific form of phosphate applied to the site.

This paper presents the results of a study to investigate the effect of phosphates on the lead contained in soils collected at military SAR training areas. Laboratory evaluations consisted of adding various phosphates at different dosages to SAR samples. After treatment the soils were subjected to a series of leaching tests. The result of laboratory effort as well as the planned field activities will be presented.

NOTES:

PHOSPHORUS INACTIVATION AND ODOR CONTROL IN ANIMAL WASTE LAGOONS, GROWING FACILITIES, AND NATURAL SURFACE WATER

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Nutrient Inactivation, specifically Phosphorus Inactivation is the interception and chemical precipitation of phosphorus from the soluble reactive form into an insoluble un-bioavailable form. The algae responsible for eutrophication of surface waters need their nutrients soluble—they have no roots to chemically solubilize and absorb nutrients. Precipitation of phosphorus with aluminum and iron compounds has been an integral part of lake restoration since 1968. Over 200 lakes have been treated to eliminate P as a nutrient. Using the same chemistry animal wastes can be treated to precipitate P prior to final disposal, or better reuse. Ferric iron sulfate has the added benefit of precipitating the odiferous, toxic, and corrosive hydrogen sulfide (H_2S) from sludges and liquid streams. Hydrogen sulfide can also be effectively controlled by sodium nitrite. The use of alum or iron in waste streams will also control struvite. These chemicals, their applications and case studies will be presented in an overview format.

NOTES:

THE CIVIL WORKS PROGRAM AND PLANNING PROCESS: A GREENER CORPS IN 2003

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The Federal objective of water and land resources planning remains to contribute to National Economic Development (NED) consistent with protecting the Nation's environment. The U.S. Army Corps of Engineers planning process is grounded in the economic and environmental Principles and Guidelines promulgated in 1983. National economic development (NED) plans and national ecosystem restoration (NER) plans attempt to maximize net benefits and balance economic and environmental objectives.

Today, the planning program of the Corps is pursuing a multifaceted approach of additional education, leadership development, and model upgrades to produce better planning products.

The Corps environmental restoration mission is expanding and expenditures for environmental investment are increasing. The Chief of Engineers, in recent testimony on the Corps Fiscal Year 2004 Civil Works Program, stated that almost 20 percent of the Civil Works budget supports the environment. This amounts to approximately $800 million annually being spent on environmental restoration, mitigation, the regulatory program, and remedial cleanup programs.

The Corps has reaffirmed its commitment to the environment by formalizing a set of Environmental Operating Principles applicable to all decision making and programs. The Vicksburg District's reforestation efforts (in February 2003, the District celebrated the planting of 20,000 acres of bottomland hardwoods) are one example of our implementation of the environmental operating principles. National partnering agreements with the Environmental Protection Agency, the U.S. Fish and Wildlife Service, the Nature Conservancy, and Ducks Unlimited also substantiate the principles. The total impact of these environmental positives promotes balance and sustainability in Corps water resources projects.

NOTES:

2003 Conference Attendees

Srinivas Annavarapu	University of Mississippi - Pharmacology
Scott Armstrong	Pickering, Incorporated
Kerry Arthur	U.S. Geological Survey
Brent Bailey	Mississippi Farm Bureau
Trent Baldwin	U.S. Geological Survey
Jeff Ballweber	MS State University - GeoResources Institute
Jerry Banks	MS Department of Environmental Quality
David Barnes	MS Department of Environmental Quality - OPC
Phil Bass	MS Department of Environmental Quality - OPC
Russell Beard	U.S. Department of Commerce - NOAA
Don Becker	TN Valley Authority
Mike Beiser	MS Department of Environmental Quality - OPC
Michael Bestor	MS State University - Chemical Engineering
Jimmy Bonner	MS State University - Extension Service
Pete Boone	MS Rural Water Association
Hamid Borazjani	MS State University - Forest Products
Shirley Bounds	Public Service Commission
Chris Bowen	Pat Harrison Waterway District
Bill Branch	Louisiana State University - Ag Center
Mark Bricka	MS State University - Chemical Engineering
Harshala Butala	University of MS - Pharmacology
Jerry Brashier	MS Department of Marine Resources
Debi Brewington	MS State University - GeoResources Institute
Tom Bryant	Pickering, Incorporated
Jeannie Bryson	U.S. Geological Survey
Laurance Carter	MS Levee Board
Antonio Luiz Cerdeira	Embrapa Environment, Ministry of Agriculture, Brazil
Charles Chisolm	MS Department of Environmental Quality
Michael Clair	U.S. Geological Survey
Charles Cooper	U.S. Department of Agriculture - ARS NSL
D.E. Cotton	Yazoo-MS Delta Levee Board
Emily Cotton	MS Department of Environmental Quality - OPC
Richard Coupe	U.S. Geological Survey
Jamie Crawford	MS Department of Environmental Quality
Joe Culpepper	U.S. Geological Survey
James Curry	U.S. Army Corps of Engineers - Mobile District
Anna Daggett	U.S. Army Corps of Engineers - Mobile District
Zoffee Damish	MS Department of Environmental Quality
Gregg Davidson	University of MS - Geology
Ann Marie Denman	MS Department of Environmental Quality
Scott Dennis	U.S. Geological Survey
Walt Dinkelacker	Pickering, Incorporated
Alice Dossett	MS Department of Environmental Quality - OPC
Earl Ducote	University of Southern MS - Biological Sciences
Honorable Jim Ellington	MS Legislature - House Conservation Committee
Gary Ervin	MS State University - Biological Sciences
David Felder	U.S. Fish and Wildlife Service
Robert Fitch	University of Southern MS - Biological Sciences
Ronald Forsythe	Pickering, Incorporated
Janice Fulford	U.S. Geological Survey - Stennis
Mark Gilbert	MS Soil and Water Conservation Commission
Earl Gordon	U.S. Department of Agriculture - ARS
Will Green	MS Department of Environmental Quality - OPC

Kenneth Griffin	Pearl River Valley Water Supply District
Bryon Griffith	Environmental Protection Agency - Gulf of Mexico Program
George Grugett	MS Valley Flood Control
Frank Gwin	Mississippi Delta Management Systems Evaluation Area
Rick Hagar	MS Soil and Water Conservation Commission
Vernon Hartley	MS Department of Environmental Quality - Surface Water
Rafael Hernandez	MS State University - Chemical Engineering
Matthew Hicks	The Nature Conservancy
Chuck Hill	MS State University - GeoResources Institute
Eugene Holmes	University of MS
Pete Howard	MS Department Environmental Quality - Surface Water
Fred Howell	University of Southern MS - Biological Sciences
Russ Howell	U.S. Geological Survey
Richard Ingram	MS Department of Environmental Quality - Surface Water
Greg Jackson	MS Department of Environmental Quality - Surface Water
David Johnson	U.S. Army Corps of Engineers - Vicksburg District
Norwyn Johnson	U.S. Army Corps of Engineers - Vicksburg District
Vic Johnson	General Chemical Corporation
Daryl Jones	MS State University - GeoResources Institute
Jackie Key	MS Department of Environmental Quality - Surface Water
Scott Knight	U.S. Department of Agriculture - ARS NSL
Jeremy Korzenik	U.S. Department of Justice
Brian Laine	University of MS - Geology
Christopher Lind	General Chemical Corporation
Jim Lipe	MS Department of Agriculture and Commerce
Melanie Magee	Environmental Protection Agency - GMPO
Sitaram Makena	MS Department of Environmental Quality - OPC
Joe Massey	MS State University - Plant and Soil Sciences
David Massingill	U.S. Geological Survey
Deirdre McGowan	MS Water Resources Association
Jim Moak	MS Department of Transportation - Ports & Waterways
David Mockbee	Mockbee, Hall & Drake
Fred Morris, III	U.S. Geological Survey
Jim Morris	MS Department of Environmental Quality
Carol Moss	U.S. Geological Survey
Joann Mossa	University of Florida - Geography
Karen Myers	U.S. Army Corps of Engineers - Vicksburg District
Peter Nimrod	MS Levee Board
Damon Nowlin	MS Department of Agriculture and Commerce
Glenn Odom	MS Department of Environmental Quality - Surface Water
Chuck O'Hara	MS State University - GeoResources Institute
Larry Oldham	MS State University - Extension Service
Monali Patel	University of MS - Pharmacology
Dean Pennington	Yazoo MS Delta Joint Water Management District
George Peters	U.S. Geological Survey
Charles Pittman	MS State University - Chemistry
Mickey Plunkett	U.S. Geological Survey
Gabe Powell	MS State University - Plant and Soil Sciences
Richard Price	U.S. Army Corps of Engineers - Vicksburg District
Richard Rebich	U.S. Geological Survey
Randy Reed	MS Department of Environmental Quality
Bill Reid	Pat Harrison Waterway District
Allen Roberts	U.S. Geological Survey
Commissioner Bo Robinson	Public Service Commission
Michael Runner	U.S. Geological Survey
Scott Sanderson	Hazclean Environmental Consultants

Robert Seyfarth	MS Department of Environmental Quality - Surface Water
David Shaw	MS State University - GeoResources Institute
Larry Slack	U.S. Geological Survey
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John Storm	U.S. Geological Survey
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Sam Testa	U.S. Department of Agriculture - ARS NSL
Keith Turner	Watkins, Ludlam, Winter & Stennis
Phil Turnipseed	U.S. Geological Survey
Don Underwood	MS Soil and Water Conservation Commission
Kim Usry	U.S. Geological Survey
George Vockroth	MS Geology Board / MS Water Resources Advisory Council
Michael Wade	U.S. Geological Survey
Don Waldon	Tennessee -Tombigbee Waterway Development Authority
Jim Wanamaker	MS Levee Board
Mark Weaver	U.S. Department of Agriculture - ARS
Heather Welch	U.S. Geological Survey
James Weston	University of MS - Pharmacology
Amy Wilberding	University of Southern MS - Biological Sciences
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STATEMENT OF AAEO

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