

**LOUISIANA WATER RESOURCES
RESEARCH INSTITUTE**

**FISCAL YEAR 1990
Program Report**

Report No. G 1565 - 03

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by

Louisiana Water Resources Research Institute
Louisiana State University
Baton Rouge, LA 70803

W. David Constant, Director

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ABSTRACT

The 1990 cooperative research program of the Louisiana Water Resources Research Institute (LWRRI) addressed priority water resources problem areas identified for Louisiana - management of surface water supplies, groundwater control and restoration, wastewater treatment alternatives, and treatment of point and nonpoint sources of pollution.

Four research projects funded to address these priority issues were: (1) A Feasibility Analysis of the Use of Louisiana Wetlands for Wastewater Treatment, (2) Use of Soil Biofilter Beds for Treating High Organic, Low Toxicity Wastewater, (3) Studies on the Uptake, Accumulation and Metabolism of 2,4-Dichlorophenol and Pentachlorophenol by *Lemna gibba*, and (4) Application of Colloidal Gas Aphrons for Soil Washing and Groundwater Remediation.

Cooperative efforts, both in research and in information transfer, were expanded in Fiscal Year 1990. Projects reflect a more focused effort by LWRRI toward seeking solutions to Louisiana water issues. Joint activities between the Institute and other university organizations were enhanced. There have been significant efforts by the Director to enhance coordination of LWRRI research with other units at LSU and the state. The Advisory Board has worked to enhance and streamline the project review process.

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WATER PROBLEMS AND ISSUES OF LOUISIANA

Louisiana is blessed with an abundance of water resources, agriculture/aquaculture, and resources for industry. Key water resources issues, therefore, become managing the resources present and protecting the quality of those resources to assure continued availability and useability for future generations. Important water resources issues include the problems associated with wetlands and coastal zones, water resources planning and management, water quality protection, and wastewater management.

Louisiana's vast wetlands make up approximately 40% of the nation's wetlands. These areas are composed of very sensitive, often delicately balanced ecosystems and are, therefore, particularly vulnerable to contamination or destruction due to man's activities and natural occurrences. Understanding these problems and finding management alternatives for these unique resources are priority issues needing attention.

Resource planning and management are also ever-present issues for Louisiana. Flooding of urban and residential areas periodically causes severe economic loss and human suffering. Yet through flood water control and diversion, valuable sediment load previously available to nourish the state's coast line is diminished or unavailable to the areas most in need. Water resources and environmental issues are intricately interconnected, therefore changes in one aspect produce a change in another. To effectively manage these resources, global strategies need to be developed.

Water quality protection, particularly of groundwater resources, due to industrial and agricultural development is an issue of ongoing concern in Louisiana. Delineating aquifer recharge areas, understanding the impacts of activities on these water resources, evaluating the impact of nonpoint sources of pollution, and exploring protection alternatives are issues at the forefront.

The Institute is committed to finding solutions to these problems and issues. Projects are focused on finding cost-effective, environmentally sound answers to the water problems and issues of Louisiana.

PROGRAM'S GOALS AND PRIORITIES

The primary goal of the Louisiana Water Resources Research Institute (LWRRRI) for the Fiscal Year (FY) 1990 was to help meet the present and future water resources research needs to the state and region, with the research contributing to national water research needs. Specific objectives of the Institute were to encourage and support research efforts that help provide answers or alternative solutions to protect and properly manage the state's valuable surface and ground water resources, to train students to be water resources scientists and engineers capable of solving present and future water resources problems, and to transfer research results and findings and provide technical assistance to governmental and industrial personnel as well as the citizens of Louisiana.

The priority problems addressed by the Institute in its FY 1990 program were:

1. unique treatment methods for high organic, low toxicity wastewaters,
2. natural systems for wastewater treatment,
3. treatment of point and nonpoint sources of contaminated water and wastewater from rural, unsewered areas,
4. use of shallow aquifers in southern Louisiana for domestic and industrial potable water supplies,
5. impact on shallow aquifers in southern Louisiana of sea level rise and other environmental changes,
6. water quality considerations for the Mississippi River, and
7. groundwater remediation.

The Louisiana priority problems were also identified within the South Atlantic Gulf Region Priorities; therefore, research to address these will benefit the regional and national issues.

Other priorities of the Institute have been and continue to be the development of the Institute to a position of leadership within Louisiana for water resources issues and concerns. Objectives through which this is being achieved are to increase operational efficiency of the Institute, to increase funds available to faculty researchers, and to develop and implement an aggressive information transfer program that will bring recognition to the Institute and its researchers while providing valuable information and education to Louisiana's citizens.

During FY 1990, the award was used to (1) continue to address priority problems and (2) focus the research efforts toward more specific issues. This focus will be further reflected in following years. However, during FY 1990, the restructured Institute Advisory Board, now a single unit drawing from a number of

resources (Appendix A), has placed an emphasis on research issues of nonpoint source pollution. Concern over nonpoint sources of pollution is significant in Louisiana, with major efforts underway within state agencies. A goal of the Institute is to develop a strong reputation for research in this area and provide research resources to the state, region and nation on nonpoint source pollution issues. Projects in this report reflect the transition toward this focus area. They also reflect the Institute goal of seeking solutions to the water resources issues.

RESEARCH PROJECT SYNOPSIS

The Institute's FY 1990 cooperative program addressed the specific research priorities identified above. Four projects were funded. Projects addressed: wetlands/wastewater treatment (02), biodegradation/wastewater treatment (03), sources and fate of pollution (04), and groundwater remediation (05). The projects were:

- 02 - A Feasibility Analysis of the Use of Louisiana Wetlands for Wastewater Treatment - John Day, Jr. and Stephen C. Farber.
- 03 - Use of Soil Biofilter Beds for Treatment of High Organic, Low Toxicity Wastewater - Ronald DeLaune, John Pardue, William Patrick, Jr.
- 04 - Studies on the Uptake, Accumulation and Metabolism of 2,4-Dichlorophenol and Pentachlorophenol by *Lemna gibba* - Harry Ensley and John Barber.
- 05 - Application of Colloidal Gas Aphrons for Soil Washing and Groundwater Remediation - Dipak Roy.

A synopsis of each project follows.

SYNOPSIS

Project Number: 02

Start: 09-01-90
End: 08-31-91

Title: A Feasibility Analysis of the Use of Louisiana Wetlands
for Wastewater Treatment

Investigators: Dr. John W. Day, Jr., Oceanography and Coastal
Sciences
Dr. Stephen C. Farber, Economics
Louisiana State University
Baton Rouge, LA 70803

COWRR: 05 D

Congressional District: 6th

Descriptors: wetlands, wastewater, wastewater treatment,
industrial wastewater, municipal water

Problem and Research Objectives:

Louisiana is currently confronted with the following two critical water problems and only limited or deficient funds to effectively address them: (1) severely degraded water quality which reflects a need for more effective wastewater treatment for both sewered and unsewered areas, and (2) subsiding wetlands and rising sea levels which are causing land loss of unprecedented proportions.

The overall objective of this project is to determine the ecological and economic feasibility of using wetlands to treat wastewater effluent from municipalities and selected industries in the Louisiana coastal zone. The project addresses the problem of achieving clean water goals by using low cost wetland treatment. Results of this year's work indicate that use of this approach will result not only in achieving better water quality goals but also in enhancing wetland productivity and in offsetting sea level rise.

Methodology:

To accomplish the above objectives the following methodology is being pursued over the course of the two year project:

1. identification of municipalities and small industries in the Louisiana coastal zone which are suitable for wetland treatment.
2. identification and classification of wetlands which are suitable for receiving wastewater.

3. selection of pilot study areas for more in-depth study and analysis.
4. performance of an economic analysis to determine the economic benefit to both public and private sectors.

Principal Findings and Significance:

OBJECTIVE 1: Identification of municipalities and small industries.

This phase of the project began in FY 1990 with a survey of potentially suitable municipalities and small industries in the Terrebonne and Barataria Basins. The analysis began with a review of the Department of Environmental Quality's (DEQ) Discharger Inventory and was supplemented with information contained within DEQ and LSU Cooperative Extension representatives, and local civil engineers. DEQ information on schools was revised based on information from the current Louisiana School Directory.

Over 150 industrial and municipal dischargers have been mapped and more may be added during the second project year. Seven of the eight basin segments in the Terrebonne Basin have been analyzed and municipal dischargers within those segments were categorized as subdivisions (total = 33), schools (40), other city or parish owned facilities (134), trailer parks (9), hospitals (2), or small businesses (7). Total effluent for municipal dischargers is approximately 17.2 mgd. Suitable industries within the seven segments totalled 12 based on DEQ data, which excludes the approximately 28 seafood processors not listed in the DEQ inventory.

For the eleven segments comprising the Barataria Basin, municipal discharger effluent is approximately 10.5 mgd for the entire basin. Except for a slight increase in the number of small businesses in the Barataria Basin, the remaining categories are all substantially higher in the Terrebonne Basin with a correspondingly higher effluent discharge among the three largest contributors, namely, subdivisions, schools, and public facilities.

OBJECTIVE 2: Wetland identification

This objective will be pursued during Year 2 of the project.

OBJECTIVE 3: Selection of pilot study areas

Construction of a study site began in March 1991 at Zapp's Potato Chip Factory in Gramercy, LA to examine the effects of channelized wastewater application on a forested wetland behind the plant. Initial measurements included elevation transects, tree size, and marker horizons to determine sedimentation rates. Routine monthly measurements began in May 1991 and include decomposition rates, litter fall, water chemistry, and soil redox

chemistry. These baseline measurements will be compared to wetland plots within the study area that are scheduled to begin receiving direct application of wastewater over the course of the second project year. The comparison should reveal the short term ability of the wetland system to assimilate the biodegradable effluent.

The potential of wetlands in the Dulac/Boudreaux area along Bayou Grand Caillou to assimilate shrimp processor waste is currently being analyzed.

OBJECTIVE 4. Economic Analysis

The purpose of the economic analysis is to quantify, as far as possible, the monetary valuation of benefits and costs associated with wetland treatment systems. The analysis consists of three major parts:

1. comparison of wetland treatment costs to costs of comparable level alternative treatment, under various scales of systems.
2. estimate of the economic value of wetland enhancement, or reduced degradation rates, due to the use of wetlands as treatment systems.
3. estimate of the economic value of not using traditional discharge areas under traditional treatment systems, including cost savings and enhanced ecosystem quality.

Considerable work has already been done to establish a theoretical basis of analysis, to estimate treatment cost savings, and to estimate the value of wetlands enhancement. This includes an economic review and analysis of the Thibodaux Feasibility Plan Report which provides revised estimates of capital and operating/maintenance costs for conventional sand filter treatment versus wetland treatment. The Thibodaux analysis will contribute to the cost range derived for municipalities for wetland treatment. In addition, it is expected that a cost range will also be developed for schools, general food industries such as Zapp's, and seafood processors.

Publications and Professional Presentations:

Work proposed was presented at Seventh Annual Louisiana Water Resources Symposium, Baton Rouge, LA, October 30, 1990.

M.S. Thesis: None.

Ph.D. Dissertations: Project provided support for one year for a Ph.D. candidate; work will be majority of dissertation.

SYNOPSIS

Project Number: 03Start: 09-01-90End: 08-31-91Title: Use of Soil Biofilter Beds for Treatment of High Organic,
Low Toxicity WastewaterInvestigators: Dr. Ronald D. DeLaune
Mr. John H. Pardue
Dr. William H. Patrick, Jr.
Wetland Biogeochemistry Institute
Center for Wetland Resources
Louisiana State University
Baton Rouge, LA 70803-7511COWRR: 05 DCongressional District: SixthDescriptors: wastewater treatment, wastewater, biodegradation,
microbial degradation, overland flow, organic
compoundsProblem and Project Objectives:

Large volumes of wastewater are produced annually by Louisiana's municipalities and industries. A large amount of this waste stream is of low toxicity, primarily water and is of concern from a water quality perspective. Treatment of these discharges in rural areas or in areas near large bodies of water is minimal and the cumulative impact of these discharges has resulted in decreased water quality for many bodies in the region. Many of these discharges are not amenable to standard wastewater treatment practices because of the location of the discharge or the cost involved for most currently accepted practices. Simple, but innovative treatment technologies need to be developed to meet these treatment needs. Most of the experiments focused on wastewater from a rapidly growing aquaculture industry in Louisiana (alligator farming). Currently, treatment of this wastewater is performed by lagoons which provide only limited removal of pollutants.

The purpose of this study was to investigate the application of a type of overland flow wastewater treatment system (soil biofilter beds) to high organic, low toxicity waste streams found in Louisiana. The objectives of the project are:

- (1) establish the effectiveness of treatment of several high organic waste streams (wastewater from an alligator farm and a sugar cane refinery canal) in laboratory model soil biofilter systems constructed of Louisiana soils.

- (2) Investigate the kinetics of BOD breakdown in soil under different conditions of aeration.
- (3) Investigate treatment of N and P fractions during application of wastewater to the system.

Methodology:

Treatment of high organic wastewater was investigated using laboratory-scale models of a land application system. Concentrations of BOD, N and P were measured using standard methods. Kinetics of BOD breakdown and P adsorption were investigated in controlled microcosms. Theoretical scale-up of the laboratory model to treat the waste stream from the alligator farm was done using currently accepted design guidelines from EPA and the Corps of Engineers.

Principal Findings and Significance:

The chemical characteristics of the alligator farms wastewater resembles a strong domestic wastewater with approximately double the N content. Treatment of BOD in the soil biofilter system was demonstrated in these experiments (94% of the BOD in the sugar refinery canal wastewater and 64% of the alligator farm wastewater BOD was removed at a loading rate of 1 cm/day. In addition, the optimal loading rate was determined for reducing the BOD in the alligator wastewater below secondary treatment standards. Removal of N from the alligator wastewater was very efficient with 95% removal of organic N and ammonia-N requiring a retention time of 130 minutes. Removal of N is important since alligators excrete much higher levels of N on a weight basis as compared to man. Removal of P was less efficient due to the anionic form of this pollutant. The P capacity of the soil biofilter was estimated using P adsorption isotherms. Scale-up of the system for the working alligator farm was performed using currently accepted design guidelines of EPA and the Corps of Engineers. These experiments have shown that land application is a valid treatment alternative for high organic, low toxicity wastewaters. Additional treatment of N and P will also occur during the treatment process.

Publications and Professional Presentations:

Treatment of Alligator Farm Wastewater Using Overland Flow. (Pardue, DeLaune and Patrick). In preparation, to be submitted to Water Research. Also presented as proposed work at Seventh Annual Louisiana Water Resources Symposium, Baton Rouge, LA, October 30, 1990.

M.S. Theses: None

Ph.D Dissertations: Project provided support for one year for a Ph.D candidate (J. Pardue).

SYNOPSIS

Project Number: 04

Start: 09-01-90

End: 08-31-91

Title: Studies on the Uptake, Accumulation and Metabolism of
2,4-Dichlorophenol and Pentachlorophenol by *Lemna gibba*

Investigators: Dr. Harry E. Ensley, Department of Chemistry
Dr. John T. Barber, Department of Ecology,
Evolution and Organismal Biology
Tulane University
New Orleans, LA 70118

COWRR: 05 B

Congressional District: 2nd

Descriptors: duckweed, metabolism, accumulation, phenols,
metabolites, toxicity

Problem and Research Objectives:

Halogenated organics include some of the most important and toxic environmental pollutants. In this study we have examined the effects of two such compounds, 2,4-dichlorophenol (2,4-DCP) and pentachlorophenol (PCP), on aseptically grown *Lemna gibba* (duckweed), an aquatic vascular plant. *Lemna gibba* is being used as a "model plant" in that its physiological responses should be indicative of the responses that could be expected from other aquatic angiosperms or, even angiosperms in general. Also, since *L. gibba* is widespread and participates in a many food chains it is important to understand not only the effects of pollutants on the plant but also to understand what happens to these chemicals in the presence of the plants. This aspect becomes particularly important in rural areas such as southern Louisiana where the consumption of wildlife is commonplace and where much of the wildlife participates in wetland food chains, e.g. fish, crawfish, waterfowl, frogs, etc.

The major goals of this project were 1) to determine the effects of varying concentrations of 2,4-DCP and PCP on the vegetative growth rate of duckweed, 2) to determine the metabolic fate of 2,4-DCP and PCP in the presence of duckweed and 3) to determine the structure and the toxicity of the metabolites.

Methodology:

Stock cultures of *L. gibba* G3 were aseptically grown in a minimal medium, plus sucrose and tryptone to reveal any microbial contamination. The cultures were maintained in growth chambers under continuous light at 82°F. Light energies in the 300-1100 nm range at plant level were 2.0×10^{-3} watts/cm². Experimental

cultures, ten replicates of each, using various concentrations of 2,4-DCP (0 to 10 ppm) or PCP (0 to 5 ppm), were started by sterile transfer of five 304 frond colonies from a stock culture. Cultures were grown for a period of 10 days, the number of fronds were counted and percent frond increases were calculated. Standard statistical analyses were performed. Experiments were conducted under two sets of environmental conditions: 1) "summer", continuous light at 82°F and 2) "winter", 12 hr photoperiod at 60°F.

The metabolism of PCP and 2,4-DCP were monitored in a similar fashion except the sucrose and tryptone were omitted from the media and radiolabeled substrates were added. The 2,4-DCP (initial concentration 10 ppm) metabolism was followed by SIM GC-MS of the CH_2Cl_2 extracts of 1 ml portions of the plant growth media at 24 hr intervals over the 10-day growth period. Isolation of the 2,4-DCP metabolite was accomplished by performing large scale incubations using 2 mg of 2,4-DCP at an initial concentration of 10 ppm. These large scale incubations were laced with radiolabeled 2,4-DCP. Monitoring the media for total radioactivity indicated that the majority of the label was retained in the plant after a 6-day growth period. The plants were harvested, washed with distilled water and homogenized in ethanol. The ethanolic extracts were centrifuged and the supernatant was flash chromatographed. The radioactive fractions were further purified by RP-HPLC using a 65% water/35% acetonitrile to 30% water/70% acetonitrile gradient. Purification of the metabolite was complicated by the large number and quantity of organics extracted from the plants; however material which was > 80% pure was obtained.

The metabolism of PCP could not be followed by SIM GC-MS since the starting concentration for the metabolism studies was only 0.5 ppm. Instead, it was monitored at 24 hr intervals by RP-HPLC of 100 ul portions of the growth media and collecting the eluant in 1 ml fractions. The fractions were then assayed for radioactivity.

Principle Findings and Significance:

Both 2,4-DCP and PCP are toxic to *L. gibba* as evidenced by their effect upon the vegetative growth (% frond increases were plotted vs. concentration of the chemical). A plot of this data, as log mean percentage increase vs. concentration of the chemical). A plot of this data, as log mean percentage increase vs. concentration of chemical, resulted in straight lines and tests for parallelism revealed no significant differences in slopes between "summer" and "winter" lines for each chemical [$t(9)=-1.33$, $p=0.22$ for 2,4-DCP and $t(6)=-0.33$, $p=0.75$ for PCP] indicating that the toxicity of each chemical was not seasonally dependent (photoperiod/thermoperiod). However, EC_{10} 's and EC_{50} 's calculated for each chemical under the two environmental conditions, demonstrated that, under the conditions employed, PCP was more toxic than 2,4-DCP ("summer" EC_{50} for PCP was 0.53 ppm but 0.96 for 2,4-DCP; "winter" EC_{50} for PCP was 0.50 ppm but 1.45 ppm for 2,4-DCP.

Structural studies on the 2,4-DCP metabolite, isolated from plants that had been grown in the presence of 5 ppm 2,4-DCP, with radiolabeled tracer, indicated that the substituted aromatic moiety remains intact as evidenced by the similarity of the NMR of the aromatic region of the metabolite to 2,4-DCP itself. The NMR also shows a 7 Hz doublet at 5 ppm and a complex pattern centered at 3.5 ppm. This pattern and the considerable water solubility of the metabolite is consistent with a β -glucoside conjugate of 2,4-DCP.

The metabolism of PCP was followed over 10 days by RP-HPLC radiochromatography of the media in which the plants had been growing (since initial studies showed that the labeled substrate was not retained by the plant but was released back to the medium). It was shown that, as PCP was removed from the growth medium, a more polar compound appeared which built to a maximum concentration and then decreased as it was replaced by another product which was even more polar and which eluted rapidly on RP-HPLC using the water/acetonitrile gradient described above. While isolation and identification of the PCP metabolite(s) should prove to be more readily accomplished than was the equivalent task with 2,4-DCP (due to the presence of fewer interfering compounds in media vs plant extracts) it has not, as yet been attempted.

Publications and Professional Presentations:

Studies on the uptake, accumulation and metabolism of 2,4-dichlorophenol and pentachlorophenol by *Lemna gibba*. H. E. Ensley and J.T. Barber. Presented at the Seventh Annual Louisiana Water Resources Symposium, Baton Rouge, La., October 30, 1990.

M.S. Theses: None

Ph.D. Dissertations: None

SYNOPSIS

Project Number: 05

Start: 09-01-90
End: 08-31-91

Title: Application of Colloidal Gas Aphrons for Soil Washing and Groundwater Remediation

Investigators: Dr. Dipak Roy
Department of Civil Engineering
Louisiana State University
Baton Rouge, LA 70803

COWWR: 05D Congressional District: Sixth

Descriptors: wastewater treatment, biological treatment, water quality control

Problem and Research Objectives:

Chemical contamination of surface and groundwater resources results principally from industrial and agricultural activities. The environmental consequences of such contamination are of global concern because of potential health effects and enormous economic costs. Improved technology for safe clean-up of land and water is urgently needed.

Colloidal Gas Aphrons (CGAs) are micron size gas bubbles generated with a film of surfactant around them. The CGAs do not coalesce and are remarkably different from conventional air/soap bubbles in their stability, flow through properties and transport properties.

Developments proposed from this research study will find an economic way of cleaning up the soil and groundwater contamination using an innovative separation technique which applies colloidal microbubbles to the soil and groundwater environment. Research on CGAs will also help develop other separation processes to recover resources from the chemical and petrochemical wastes.

Methodology:

Colloidal gas aphrons were generated using a set-up consisting of a spinning disc at 8,000 rpm, mounted a few centimeters below the surface of a surfactant solution. The rotation of disc creates strong waves which strike the baffles and upon re-entering the water, they entrain gas as small microbubbles. Several CGA generators have been fabricated in our lab. Characterization of cationic, anionic and nonionic CGA was completed using particle size analyzers. Soil washing using CGA was initiated in one-dimensional columns. Separation of synthetic organic dyes and heavy metals from industrial wastes was completed.

Principle Findings and Significance:

The principal findings of the research tasks completed during the first year of this two year project are listed below:

- a) CGA generated using cationic, anionic and nonionic surfactants were stable with mean diameter in the range of 80 to 140 microns.
- b) CGA was successful in separating organic dye from industrial wastes generated by dye manufacturing industry.
- c) CGA was effective in removing heavy metals and organics from soil slurry systems.
- d) Experiment set-ups to conduct soil washing experiments have been fabricated.

Publications and Professional Presentations:

D. Roy and S. Kottai, "Application of Colloidal Gas Aphrons in the Separation of Organic Dyes", Submitted for presentation at Hazardous Materials Control Research Institute Conference, Houston, Texas, April 24-26, 1991.

D. Roy and V. J. Amedee, "Use of Microbubble Dispersions to Remove Heavy Metals and Organics from Drilling Fluids", presented at American Filtration Society National Fall Meeting on Environmental and Productivity Merits of Separation in Petroleum Engineering, Baton Rouge, LA, October 29-30, 1990.

Dipak Roy, "Colloidal Gas Aphrons for Soil Washing and Groundwater Remediation", presented at the Seventh Annual Louisiana Water Resources Symposium, Baton Rouge, LA, October 30-31, 1990.

Dipak Roy and Vincent J. Amedee, "Treatability of Water-Based Drilling Fluids Using Colloidal Gas Aphrons", Presented at the International Congress on Innovation, Industrial Progress and Environment, Paris, France, June 4-6, 1991.

Vincent J. Amedee, Dipak Roy, Barbara Shane and Andrew Wojtanowicz, "A Comparison Between the Microtox and Mysidopsis bahia Bioassay for Assessing Water-Based Drilling Fluid Toxicity", presented at the Second International Conference on Waste Management in the Chemical and Petrochemical Industries - Toxic Management, New Orleans, Louisiana, June 17-20, 1991.

Dipak Roy and Vincent J. Amedee, "Removal of Heavy Metals and Organics from Drilling Fluids by Colloidal Gas Aphrons", presented at the Second International Conference on Waste Management in the Chemical and Petrochemical Industries -Toxic Management, New Orleans, Louisiana, June 17-20, 1991.

D. Roy and V. J. Amedee, "Use of Microbubble Dispersions to Remove Heavy Metals and Organics from Drilling Fluids", Recommended for Publication in the Fluid/Particle Separation Journal, 1990.

D. Roy, K.T. Valsaraj, and S. Kottai, "Separation of Organic Dyes Using Colloidal Gas Aphrons", accepted for publication in Journal of Separation Science and Technology.

M.S. Theses:

Vincent Amedee MS An Assessment of the Toxicity and Treatability of Water-Based Drilling Fluids - 1990.

Shabeen Kottai MS Separation of Synthetic Dye Using Colloidal Gas Aphrons - 1991.

Ph.D. Dissertations: None.

INFORMATION TRANSFER ACTIVITIES

The information transfer activities of the Institute were continued and expanded during Fiscal Year 1990.

Water resources news and information of the Institute, previously only partially documented, has been compiled and will be annually updated. The updated list provides water resources information and publications and is found in Appendix B. This list was recently updated back to 1984 to include a number of new publications and presentations from research projects. A water resources bulletin board is maintained to announce upcoming meetings, job opportunities for both students and faculty, award opportunities for students, and calls for papers. A new newsletter, "Intracoastal Waterways", was started in February 1991, and three issues were distributed in FY 1990. It includes activities of the Institute, research project summaries, meeting and proposal announcements, and brief biographies on supported researchers. Approximately 500 copies are distributed on a quarterly basis. The library has been cataloged and is regularly updated by computer database, and the Institute is participating in distribution on campus of NTIS abstracts.

A major information transfer activity of the Institute for FY 1990 was co-sponsoring the Seventh Annual Louisiana Water Resources Symposium in October 1990. The conference, with approximately 150 professionals in attendance (50 attending the LWRI session) included FY 1989 project presentations and FY 1990 plans. An overview of the Institute was given by the Director in the morning session of the first day to the full audience. USGS representatives and Advisory Board members were present to receive presentations from the investigators. These events provided an ongoing dialogue with researchers, agencies, and the public. The Institute also annually co-sponsors the "Louisiana Ground Water Seminar", working closely with several Louisiana Departments, private companies, AWRA, other Louisiana State University units, and the USGS District Office in Baton Rouge. In FY 1991, the Institute will take the lead in this seminar, presenting results from the FY 1990 projects, and projects underway in FY 1991. This seminar is planned for the spring of 1992. The Director also participated, as time permitted, in the planning of the Annual AWRA meeting in September 1991 in New Orleans.

The Institute's staff has, in FY 1990, maintained emphasis on acquainting Louisiana's research community with the research funding opportunities through the U.S. Geological Survey Sections 104 and 105 research programs. Announcements for both research programs were widely distributed to Louisiana's colleges and universities and to research organizations throughout the state. In addition, public announcements were made at professional and faculty meetings to encourage wide participation in the programs.

Table 1 depicts this participation in response to the announcements. During FY 1990, with the program more focused, the call for 104 proposals for FY 1991 was made and a significant increase in proposals received (twice the FY 1990 number) indicating a renewed interest and growth in the LWRRI program, with a focus on nonpoint sources of pollution.

Table 1. Louisiana's Participation in Section 104 and 105 Research Programs, Proposals Submitted

<u>Year</u>	<u>Section 104</u>	<u>Section 105</u>
1990	11	6
1991	23	4

Presentations by the Director have been given to a number of organizations to help acquaint these audiences with the activities of the Institute. The Director annually attends NAWID, UCOWR and other professional meetings to discuss Institute and Program activities.

Future information transfer activities include a new brochure about the Institute, seminar and conference activity, and regular circulation of the Institute's newsletter "Intracoastal Waterways". The Director is also working with the La. Dept. of Environmental Quality to promote information transfer about water resources (models and databases) to the High Institute of Public Health in Alexandria, Egypt.

COOPERATIVE ARRANGEMENTS

In an effort to better coordinate research and administrative activities of the Institute, the Director relocated the LWRRI office in August 1991 in conjunction with the Hazardous Waste Research Center (HWRC), an EPA "Center of Excellence", which he serves as Assistant Director. This move has streamlined operations, and enhanced staff and resource capabilities to better serve the Institute program. Also, LSU was recently awarded a new EPA Center, which the LWRRI Director is also involved in conjunction with Rice University and the Georgia Institute of Technology. Thus, LWRRI is more closely associated, although missions of each unit are separate, with other research centers. It is anticipated that this integrated effort will enhance the reputation of LWRRI and other units due to the complimentary nature of the research focus areas. In addition, research in each unit reflects upon water resource issues, with LWRRI focusing on nonpoint source pollution, HWRC on remediation technologies (which protect ground and surface water) and the new Hazardous Substance Research Center/South and Southwest with a focus on management of contaminated sediments.

The Institute Advisory Board (Appendix A) has and continues to provide valuable guidance to the Institute. The Board assists with proposal reviews and evaluations of ongoing projects, makes recommendations to the Director regarding timely research topics, and provides contacts for external support.

Finally, it should be noted that although these units are being closely coordinated, as units within the College of Engineering at LSU, they stand separate and apart in missions, accomplishments, and goals.

TRAINING ACCOMPLISHMENTS

The LWRRI is committed to training science and engineering students to assume leadership roles in current and future water resources and environmental problem solving. Research projects that incorporate extensive student training elements in the proposed research are given preferential consideration over proposed research involving faculty participation only. Table 2 summarizes the student training benefits of the current program.

Table 2. Training Accomplishments

<u>Field of Study</u>	<u>Academic Level</u>				<u>Total</u>
	<u>Undergraduate</u>	<u>Master's Degree</u>	<u>Ph.D. Degree</u>	<u>Post-Ph.D.</u>	
<u>Chemistry</u>	1				1
<u>Engineering</u>					
Agricultural					
Civil					
Environmental	1		2 (one in progress)		3
Soils	1				1
Systems					
Other*					
<u>Geology</u>					
<u>Hydrology</u>					
<u>Agronomy</u>					
<u>Biology</u>	1				1
<u>Ecology</u>					
<u>Fisheries, Wild-life and Forestry</u>					
<u>Computer Science</u>					
<u>Economics</u>					
<u>Geography</u>					
<u>Law</u>					
<u>Resource Planning</u>					
<u>Other - Wetland Resources</u>			2 (in progress)		2
<u>TOTAL</u>	4	2	2		8

* Less than 6 students in any one field of study.

APPENDIX A
INSTITUTE ADVISORY BOARD

INSTITUTE ADVISORY BOARD
Louisiana Water Resources Research Institute

- Purpose: To develop specific task-oriented Request for Proposals statements from the research needs identified in the state, region and nation.
- To assist the Director in prioritizing the identified research areas.
- To identify potential investigators who can participate in the priority research areas.
- To identify and promote areas where cooperative research programs can be developed between LWRI and other organizations.
- Membership: Board members are selected from faculty and water resources professionals, and are selected for their knowledge of and active participation in an area of water resources research. Each member represents a distinctly different water resources focus area and serves a 3 year term.
- Requirements: Each member shall participate in the annual meeting of the Board. This meeting shall be called by the Director, Louisiana Water Resources Research Institute, and shall be held at the convenience of all Board members.
- Benefits: Service to LSU
- Service to Louisiana
- An opportunity to guide the research activities of Louisiana Water Resources Research Institute.
- An opportunity to communicate with fellow water resources professionals in the university and state, sharing ideas and expressing research needs.

1990-1991 LOUISIANA WATER RESOURCES RESEARCH INSTITUTE
ADVISORY BOARD

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APPENDIX B
Publications List

PUBLICATIONS
OF THE
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October 1991

LWRRI PUBLICATIONS: Bulletins

Handbook of Basic Water Law	Bulletin 1	June 1966
The Measurement and Comparison of Costs for Alternative Water Replacement Projects	Bulletin 2	October 1966
Salt-Water Encroachment Into Aquifers	Bulletin 3	October 1968
Water-Resources Manpower Supply and Demand Patterns to 1980	Bulletin 4	May 1970
The Present and Future Ground-Water Supply of the Baton Rouge Area	Bulletin 5	February 1970
Subsidence and Ground-Water Offtake in the Baton Rouge Area	Bulletin 6	October 1970
An Economic Reappraisal of the Toledo Bend Multiple-Purpose Water Project	Bulletin 7	October 1970
Geochemical Hydrology of the Baton Rouge Aquifers	Bulletin 8	March 1972
The Mississippi River - A Water Source for Texas?	Bulletin 9	March 1973
Cyclic Storage of Fresh Water in Saline Aquifers	Bulletin 10	May 1975
Aquifers as Processing Plants for the Modification of Injected Water	Bulletin 11	August 1980
If the Old River Control Structure Fails?	Bulletin 12	September 1980
Alternate Water Sources for the Baton Rouge - New Orleans Industrial Corridor	Bulletin 12A	September 1980
A Change in the Course of the Lower Mississippi River: Description and Analysis of Some Economic Consequences	Bulletin 12B	September 1980

LWRRRI PUBLICATIONS: Technical Reports

The Recent Alluvium of Thomas and Duncan Points	Technical Report 1	June 1967
The Present and Future Ground Water Supply of the Baton Rouge Area	Technical Report 2	Sept 1967
A Summer Limnological Study of Lake Pontchartrain, Louisiana	Technical Report 3	Sept 1968
Physical, Chemical, Bacterial, and Plankton Dynamics of Lake Pontchartrain, Louisiana	Technical Report 4	Sept 1969
Epifaunal Invertebrates as Indicators of Water Quality in Southern Lake Pontchartrain, Louisiana	Technical Report 5	May 1975
Demonstration Project to Store Fresh Water in a Saline Water-bearing Formation: City of Houma, Louisiana	Technical Report 6	Feb 1979
Water Related Problems in the Coastal Zone of Louisiana	Technical Report 7	Nov 1980
Plan of Study for Evaluating the Effects of Lignite Mining in Louisiana on Water Resources	Technical Report 8	Aug 1981
Use of Twin Wells and Water-Source Heat Pumps for Energy Conservation in Louisiana	Technical Report 9	Dec 1981

LWRRRI PUBLICATIONS: GT Series

The Flood Control Capabilities of the Atchafalaya Basin Floodway	Bulletin GT-1	April 1967
Hydrology of Neogene Deposits in the Northern Gulf of Mexico Basin	Bulletin GT-2	April 1969
Economic Aspects of Ground- Water Basin Control	Bulletin GT-3	February 1970
Geohydrology of the Shallow Aquifers of Baton Rouge, Louisiana	Bulletin GT-4	October 1969
Possible Failure of the Low- Sill Control Structure at Old River, Louisiana: Economic and Physical Consequences	Bulletin GT-5	July 1976

PROJECT COMPLETION REPORTS

<u>TITLE</u>	<u>AUTHOR(S)</u>	<u>QUANTITY</u>
Algae Removal by Induced Air Flotation (May 1982)	Tittlebaum, Holtman	5
Application to the Principle of Maximum Entropy (POME) to Hydrologic Frequency Analysis (1984)	Singh, Rajagopal	18
Biodegradation of Hazardous Chemical Wastes (1984)	Pelon, Murray	28
Biological Removal of Chlorinated Hydrocarbons from Water (Oct 1985)	Templet	19
Chemical Quality of Surface and Sediment Pore Water in Louisiana and Mississippi Estuaries (Oct 1973)	Snowden, Otvos	1
Comparative Evaluation of Estimators of Some Flood Frequency Models Using Monte Carlo Simulation	Vijay P. Singh Kishore Arora	3
A Continuum Mechanics Approach to Streamflow Modeling (July 1983)	V. Singh, S. Prasad, L. Ubertini	2
Co-treatment of Water Softening and Wastewater Sludges (May 1982)	Bowie, Gautreaux	6
Design of Rainfall Networks Using Entropy (Oct. 1986)	Vijay P. Singh	3
Development of a Methodology for Evaluating Waste Disposal Sites (August 1982)	J. Hill, R. Malone,	14
Development of a Simplified Chlorinated Hydrocarbon Screening technique for Water and Sediment (August 1984)	Templet	8

PROJECT COMPLETION REPORTS

<u>TITLE</u>	<u>AUTHOR(S)</u>	<u>QUANTITY</u>
A Discrete Kernel Model for Simulation of Multilayered Aquifers (1984)	Illangasekare	17
The Dispersion of Continuously Injected Effluents in Open Channels (Feb 1973)	Harrison, Wehe	3
Effect of Diverting Mississippi River Water To Texas on Sedimentation in the River (March 1974)	Alawady	2
Effect of Viscosity Ratio on the Recovery of Fresh Water Stored in Saline Aquifers (April 1977)	Kimble, Whitehead	10
Evaluation of Parameter Estimation Methods for Flood Frequency Analysis: Computer Programs	Vijay P. Singh, Kishore Arora	3
Evaluation of Some Empirical Methods for Flood Frequency Analysis 2. Data and Computer Programs (March 1987)	Vijay P. Singh, Deepak Jain	3
Fate of PCB and Dioxin in Louisiana's Aquatic Environment (Sept 1983)	Pardue, DeLaune,	6
Floodwater Nutrient Processing in a Louisiana Swamp Forest Receiving Agriculture Runoff (Dec 1981)	Kemp, Day	1
A Geomorphic Approach to Hydrograph Synthesis, with Potential for Application to Ungaged Watersheds (June 1983)	V. Singh	4

PROJECT COMPLETION REPORTS

<u>TITLE</u>	<u>AUTHOR(S)</u>	<u>QUANTITY</u>
Hydraulic Conductivity of I Rockfill (July 1983)	A. A. Hannoura,	35 Vol
II	K. McManis	5 Vol
Information Dissemination for a Better Understanding of Louisiana's Water Resources (Sept 1984)	Worm	7
An Investigation Into the Removal of Algae by Fine Sand/Silt Filtration (Nov 1981)	Naghavi, Malone	8
Mathematical Models for Ungaged Watersheds with Potential for Quantifying the Effect of Land Use Changes on Streamflow (Oct 1984)	Singh	3
A Method of Determining the Quality of Irrigation Water to Achieve Optimum Growth of Bottomland Hardwoods in North Louisiana (Feb 1970)	Wilson, Miller, Banks	1
A Multivariate Approach to the Investigation of Nutrient Interaction in Barataria Basin, Louisiana (April 1983)	A. Witzig, J. Day	10
Nutrient Assimilation Capacity of Shallow Coastal Lakes (1983)	DeLaune, Smith, Patrick, Sarafyan	8
Optimum Treatment for Coal Pile Runoff in Louisiana (August 1984)	Hendershot, Tittlebaum	5
Oxidation of Trace Contami- nants in Drinking Water (Dec 1985)	F. Groves	20

PROJECT COMPLETION REPORTS

<u>TITLE</u>	<u>AUTHOR(S)</u>	<u>QUANTITY</u>
Prediction of Hydrothermal Regimes in the Proposed Darlington Reservoir (Sept 1986)	Field	5
Prediction of Hydrothermal Regimes in the Proposed Darlington Reservoir <u>Volume Supplement</u> (Sept 1986)	Field	4
Radioactivity in Mississippi River Water (April 1977)	Iddings, Knaus	5
Reaeration Rate Estimation Using the LAG in Dissolved Oxygen Concentration (Jan 1983)	M. Waldon	4
Reclamation of Polluted Farm Ponds (July 1977)	Robbins, Nelson	19
Reliability Analysis of BOD Kinetics in a Small Southern Stream Governed by the Discharge of an Oxidation Pond (1981)	Crane, Malone	3
Role of Mycorrhizae in Land Application of Municipal Wastewaters (August 1983)	J. Robbins	5
Sucrose Removal From Cane Sugar Mill Waste Streams by Ion Exchange (Oct 1976)	F. Groves	12
THM Precursors Removal From Surface Waters Using Ozone-Hydrogen Peroxide Oxidation (July 1982)	Fernandes	10
A Trophic State Index for the Louisiana Coastal Zone (April 1983)	A. Witzig, J. Day	4

PROJECT COMPLETION REPORTS

<u>TITLE</u>	<u>AUTHORS</u>	<u>QUANTITY</u>
Wastewater Treatment by Ligand Exchange (June 1983)	F. Groves	5
Water Quality Variation in the Potable Water of Grand Isle, Louisiana During Periods of Water Shortage (Feb 1983)	M. B. Walsh,	5
A Multivariate Stochastic Flood Analysis Using Entropy (October 1986)	Vijay P. Singh, P. K. Krstanovic	3
Reduction of Trihalomethane and Other Chlorinated Hydrocarbons in Drinking Water	B. Boyden J.B. Fernandes	10
Use of Stable Nitrogen Isotopes in Determining Nitrogen Sources Entering Louisiana Surface Waters	R. D. DeLaune C. W. Lindau W. H. Patrick	10
Rock-Reed Filters for Treatment of Small Domestic Wastewater Flows	R. F. Malone	10
Identification of High-Risk Atmospheric and Surface Conditions for Urban Flash Flooding in Louisiana (Dec 1989)	K. Hirschboeck	10
Pathways, Mechanisms, and Rates of Solute Transport Across the Base of the Fresh Water Zone, South Louisiana (October 1989)	J. Hanor	10
Determination of Rock-Reed Filter Volume Requirements for Small Domestic Wastewater Flows (October 1989)	M. Tittlebaum	10
A Water Quality Training Program for the Louisiana Cooperative Extension Service (Oct 1989)	B. Kelly B. Branch	10

PROJECT COMPLETION REPORTS

<u>TITLE</u>	<u>AUTHORS</u>	<u>QUANTITY</u>
Nature and Rates of Bacterial Metabolism in the Aquifer of Southeastern Louisiana	P. Aharon	10
Aquaculture/Marine Fisheries Process Wastewaters	J. Bankston	10
The Importance of Denitrification Efficiency of Wastewater Treatment in Forested Wetlands	R. Twilley	10
Field Testing of Rock/Reed Filters for Small Domestic Wastewater Flows	M. Tittlebaum	10
Technique for the Development of Management Oriented Groundwater Models for Multi-layered Aquifers (1984)	F. Groves	
Assessment of Uncertainty in Hydrologic Models for Flood Frequency Analysis (1984)	V. Singh	
Biological Removal of Chlorinated Hydrocarbons from Water (1984)	P. Templet B. Carr	
Transport of Chlorinated Hydrocarbons in Saturated Cohesive Deposits of Southern Louisiana (1985)	Y. Acar	
Simplified Extreme Value Method of Flood Frequency Prediction for Louisiana Streams (1986)	J. Cruise	
Evaluation of Factors Influencing Migration and Transport of Biocidal Agents to Groundwater and Surface Water Resources (1986)	D. Roy	
Determination of Rock-Reed Filter Volume Requirements for Small Domestic Wastewater Flows (1988)	W. Zachritz	

PROJECT COMPLETION REPORTS

<u>TITLES</u>	<u>AUTHOR(S)</u>	<u>QUANTITY</u>
Use of Soil Biofilter Beds for Treating High Organic, Low Toxicity Wastewater (1990)	R.D. DeLaune J.H. Pardue W.H. Patrick	
Studies on Uptake Accumulation and Metabolism of 2, 4-dichlorophenol and pentachlorophenol by Lemna gibba (1990)	H.E. Ensley J. Barber	
Application of Colloidal Gas Aphrons for Soil Washing and Groundwater Remediation (1990)	D. Roy	

LWRRRI THESES

<u>TITLE</u>	<u>AUTHOR</u>	<u>QUANTITY</u>
Analog Simulation of Anisotropic Permeability (May 1974)	Ronald E. Rinard	1
Black Willow (Salix Nigra Marsh) as a Bioaccumulator of Radioactive Pollutants in Fresh Water Ecosystem (Dec 1976)	Lynn R. Curry	1
The Design, Construction, and Testing of Consolidated Anisotropic Sand Models (May 1972)	D. L. Hinners	1
Dispersion & Gravity Segregation of Miscible Fluids in Porous Media for Stratified Radial Flow Systems (Jan 1968)	Anil Kumar	2
Effect of Dip on the Subsurface Storage or Disposal of Fluids in Saline Aquifers (August 1975)	Joseph A. D'Amico	1
Effect of Failure of the Old River Control Structure on Municipal and Industrial Water Supplies (May 1977)	Howard J. Redmond	1
The Effect of Flux & Gravitational Forces on Miscible Displacement in a Thin Homogeneous Bed (August 1973)	Walid J. Esmail	1
The Effect of Mixed Zone Length on the Growth of viscous Fingers During a Miscible Displacement (August 1977)	Calvin C. Barnhill	1
Effect of Viscosity Ratio on the Recovery of Fresh Water Stored in Saline Aquifers (December 1975)	Bipin K. Agrawal	1

LWRRRI THESES (cont.)

<u>TITLE</u>	<u>AUTHOR</u>	<u>QUANTITY</u>
Environmental Factors Affecting the Properties & Precipitation of Coloring Colloids in Aquatic Habitats (August 1973)	Billy R. Bordelon	1
Enzyme Process Design for Water Treatment (December 1976)	Steven W. Johnson	1
An Evaluation of Twin Wells for Use with Water Source Heat Pumps (May 1981)	Joseph R. Buller	1
Experimental Study of Multi-Cation Diffusion in an Artificial Quartz Sandstone (December 1974)	Ronald K. Stoessell	2
Geological Factors Influencing Recharge to the Baton Rouge Ground-water System, with Emphasis on the Citronelle Formation (August 1967)	Brian E. Parsons	2
The Influence of Brackish-Water Intrusion on Macro-invertebrate Associations of the Lower tchefuncte River, Louisiana (August 1975)	Maureen M. Mulino	2
Investigation of the Technical Feasibility of Storing Fresh Water in Saline Aquifers (August 1966)	Omar J. Esmail	1
Measurement of & Calibration for Gamma Spectroscopy of Mississippi River Water (August 1976)	Orren W. Williams	1
The Relationship Between the Presence of Dissolution Features at the Salt-Caprock Interface & Saline Plumes in Aquifers Surrounding Salt Domes (December 1982)	Martin L. Wouch	2

LWRRRI THESES (cont.)

<u>TITLE</u>	<u>AUTHOR</u>	<u>QUANTITY</u>
The Simulation of Whole Core Permeameter Flow Geometry (August 1974)	Louis O. Chemin, Jr.	1
A Study of the Technical and Economic Feasibility of Using Sewage Effluent for Irrigation in Ouachita Parish (Nov 1968)	Robert P. Cantrell	5
A Technique for Irrigating Bottomland Hardwood Trees with Papermill Effluent in North Louisiana (May 1970)	Ishtiaq Ahmed	6
The Transport of Chlorinated Hydrocarbons in Dilute Aqueous Solution Through Saturated Cohesive Deposits of Souther Louisiana (August 1987)	Laqique Haider	1
Unequal Density Miscible Displacement in Thin Homogeneous Tilted Beds (December 1971)	Thomas R. Painter	1
The Use of Bounding Wells to Control Flux in Underground Water Storage Projects (August 1974)	Edmond J. Langhete	1
The Use of Bounding Wells to Counteract the Effects of Gravity in Dipping Aquifers (May 1978)	Thomas E. Williams	1
Use of Bounding Wells to Negate the Effects of Gravity and Pre-Existing Groundwater Movement in Dipping Aquifers Used for Storage (August 1979)	Paul J. Abadie	1
Zonation of Lake Pontchartrain Invertebrates in a Polluted New Orleans Outfall Canal (August 1978)	Michael F. Rayle	2

LWRRRI THESES (cont.)

<u>TITLE</u>	<u>AUTHOR</u>	<u>QUANTITY</u>
Comparative Performance of the Estimators of Commonly Use Flood Frequency Models using Monte Carlo Simulation (1988)	K. Arora	
Spatial Variations in Subsurface Fluid Properties in a Portion of Southeast Louisiana: Implications for Regional Fluid Flow and Solute Transport (1989)	R. B. Bray	

CONFERENCE PROCEEDINGS 1984-1990

<u>TITLE</u>	<u>AUTHOR(S)</u>
Energy Dissipation in Tidal Waterways (1985)	P. D. Scarlatos
Some Recent Advances in the Application of the Principle of Maximum Entropy (POME) in Hydrology (1987)	V. P. Singh A. K. Rajagopal
A Low Maintenance Wastewater Treatment Plant Upgrade Alternative (1989)	J. W. Fuller R. F. Malone W. H. Zachritz

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JOURNAL PUBLICATIONS 1984-1990

<u>TITLE</u>	<u>AUTHOR</u>
Growth of Mixed Microbial Populations in Ground Water Containing Highly Chlorinated Organic Wastes (1987)	William Pelon John A. Mayo
Groundwater sources and Flow patterns derived from Stable Isotopes and Elemental Chemistry of the Southeast Louisiana Freshwater Aquifers (1990)	G. Gonthier P. Aharon
An Improved Microextraction Technique for for Measuring Dissolve Inorganic Carbon (DIC), ¹³ C (DIC), and ¹⁸ O (H ₂ O) from Milliliter-size Water Samples (1991)	E.R. Graber P. Aharon
Comparing Some Methods of Estimating Mean Areal Rainfall (1986)	V.P. Singh P.K. Chowdhury
On Fitting Gamma Distribution to Synthetic Runoff Hydrographs (1985)	V.P. Singh P.K. Chowdhury
Estimating Harmonic Parameters for Damped Co-Oscillating Tides (1987)	P.D. Scarlatos V.P. Singh
An Empirical Relation Between Volume and Peak of Direct Runoff (1996)	V.P. Singh H. Aminian
Derivation of the Gamma Distribution by Using the Principle of Maximum Entropy (1985)	V.P. Singh K. Singh
Derivation of the Pearson type (PT) III Distribution Using the Principle of Maximum Entropy (POME) (1985)	V.P. Singh K. Singh
Analysis of Nonlinear Muskingum Flood Routing (1987)	V.P. Singh P.D. Scarlatos
Estimating Parameters of EVI Distribution for Flood Frequency Analysis (1987)	D. Jain V.P. Singh
A Comparison of Transformation Methods for Flood Frequency Analysis (1986)	D. Jain V.P. Singh

JOURNAL PUBLICATIONS 1984-1990 (Cont.)

<u>TITLE</u>	<u>AUTHOR</u>
Parameter Estimation for Log-Pearson Type III Distribution by POME (1988)	V.P. Singh K. Singh
On Statistical Intercomparison of EVI Estimators by monte Carlo Simulation (1987)	K. Arora V.P. Singh
A New Method of Parameter Estimation for Hydrologic Frequency Analysis (1986)	V.P. Singh A.K. Rajagopal
A Stochastic Model for Sediment Yield Using the Principle of Maximum Entropy (1987)	V.P. Singh P.F. Krstanovic
On Derivation of the Extreme Value (EV) type III Distribution for Low Flows Using Entropy	V.P. Singh
A Comparative Eevaluation of the Estimators of the Log-Pearson Type (LP) 3 Distribution (1989)	K. Arora V.P. Singh
A Note on Mixed Moment Estimation for log-Pearson Type 3 Distribution (1989)	K. Arora V.P. Singh
Hydrologic Modeling Using Entropy (1989)	V.P. Singh
Fate of Nitrogen and Phosporus Entering A Gulf Coast Freshwater Lake: A Case Study (1990)	R.D. DeLaune C.W. Lindau R.S. Knox C.J. Smith
Spatial Variations in Subsurface Fluid Properties in a Portion of Southeast Louisiana: Implications for Regional Fluid Flow and Solute Transport (1990)	R.B. Bray J.S. Hanor
Assessment of Stable Nitrogen Isotopes in Fingerprinting Surface Water Inorganic Nitrogen Sources (1989)	C.W. Lindau R.D. DeLaune W.H. Patrick, Jr. E.N. Lambremont
Effect of Sediment ph and Oxidation-Reduction Potential on PCB Mineralization	J.H. Pardue R.D. DeLaune W.H. Patrick, Jr.