

# Water Resources Research Institute

## Annual Technical Report

**FY 1999**

### Introduction

The Puerto Rico Water Resources and Environmental Research Institute (PRWRERI) was established in 1965 by virtue of the Water Resources Research Act of 1964. Located at the Mayagüez Campus of the University of Puerto Rico (UPRM), the PRWRERI has served the water professional community of the beautiful island of Puerto Rico for over 34 years. Being a Caribbean island, Puerto Rico exhibits unique and exciting hydroclimatic characteristics, which produce a diversified array of hydrologic responses in very short aerial extensions. These conditions provide an excellent setting for research in the tropical and Caribbean water resources field. The PRWRERI serves all higher education institutions in Puerto Rico and contribute to the solution of local and island-wide water related problems.

### Research Program

The program goals of the Puerto Rico Water Resources Research Institute are three folded. First, to train student scientists and engineers through hands-on participation in research; secondly, to facilitate, through outreach and technology transfer activities, the incorporation of research results into the knowledge base of water resources professionals in Puerto Rico and the U.S.; and third, to conduct research aimed at resolving local and national water resources problems, working with the complexity of the geological and hydrologic situation of the Island and the Puerto Rico's unique cultural, social, and political circumstances. To accomplish these objectives, the Institute used to identifies Puerto Rico's most important water resources research needs, funds the most relevant and meritorious research projects proposed by faculty from universities of the Island, encourages and supports the participation of students in funded projects, and disseminates research results to scientists, engineers, and the general public. The PRWRERI selects proposals under the FY 1999 base grant. Under the direction of Dr. Jorge Rivera-Santos, the Institute issued a Request for Proposals and coordinated an evaluation process of the proposals by the External Advisory Committee (EAC). This Committee is composed by water resources professionals and officials in industry and government.

#### Basic Project Information

Basic Project Information	
Category	Data
Title	Monitoring Land Use and Land Cover in the Jobos Bay National Estuarine Research Reserve Watershed
Project Number	S-02
Start Date	07/01/1997
End Date	04/30/1999
Research Category	Engineering

<b>Focus Category #1</b>	Conservation
<b>Focus Category #2</b>	Management and Planning
<b>Focus Category #3</b>	Wetlands
<b>Lead Institution</b>	Water Resources Research Institute

### Principal Investigators

Principal Investigators			
Name	Title During Project Period	Affiliated Organization	Order
Linda L. Velez-Rodriguez	Associate Professor	University of Puerto Rico	01

### Problem and Research Objectives

Jobos Bay National Estuarine Research Reserve (JBNERR) is located on the southeastern coastal plain of Puerto Rico, within the subtropical dry forest life zone of Puerto Rico's tidal and submerged wetlands. Important wildlife habitats within the reserve limits include coral reef, extensive seagrass beds, sand beaches, 15 small mangrove cays and the mangrove forest and lagoon areas of Mar Negro. Endangered species such as the West Indian Manatee, hawksbill and green sea turtles, the brown pelican and yellow shouldered blackbird live within the reserve. Jobos Bay Watershed is subjected to different land uses and land cover, which could be impacting its unique environmental characteristics. A sample of these include extensive and intensive agricultural activities, thermoelectric power generation, sanitary landfill, residential areas, golf courses, and marinas. The objective of this project was to establish a digital database of the land use and land cover for the JBNERR watershed using a Geographic Information System and remote sensing technology.

### Methodology

The project was divided in two phases. Phase I consisted on identifying current land use and land cover in the vicinity of the Jobos Bay Research using photointerpretation techniques, one of the basic forms of remote sensing. To define the study area and for purposes of georeferencing it, the USGS topographic quadrangles series of 7.5 minutes of Coamo, Cayey, Patillas, Salinas, Central Aguirre and Guayama at scale 1:20,000 were used. Phase II consisted of building the Jobos Bay Reserve remote sensing database and relating it with a GIS. The conversion of the remote sensing data from the aerial photographs to digital form are the foundation of the digital database.

### Principal Findings and Significance

The prevailing land use and land cover classification of the study area was agricultural land followed by forestland closed. Each land use and land cover classification was established with their total area and percentage of coverage. A color map entitled Jobos Bay Watershed 1999 was produced. The map shows the study area and the main product of this research. With the data generated by this research the JBNERR ended with adequate information about its nearby land use and coverage. The digital data base generated in this project provides baseline information that will serve to compare land use trends

through time. The information provided by this project is a valuable tool in the development of priorities for the management of the reserve resources which are under natural and man induced stress. The generated database will be usefull for the development of land use dependent models such as BASINS.

### **Descriptors**

Bays, Estuaries, GIS, Land Use

### **Articles in Refereed Scientific Journals**

### **Book Chapters**

### **Dissertations**

### **Water Resources Research Institute Reports**

Velez-Rodriguez, Linda, 1999, The Use of a Geographic Information System and Remote Sensing Technology for Monitoring Land Use and Land Cover of the Jobos Bay National Estuarine Research Reserve Watershed of Puerto Rico, Puerto Rico Water Resources Research Institute, University of Puerto Rico, Mayaguez, Puerto Rico, p. 35.

### **Conference Proceedings**

### **Other Publications**

### **Basic Project Information**

<b>Basic Project Information</b>	
<b>Category</b>	<b>Data</b>
<b>Title</b>	Recirculation of Leachate within the Landfill for the Leachate Treatment
<b>Project Number</b>	C-01
<b>Start Date</b>	09/01/1997
<b>End Date</b>	08/01/1998
<b>Research Category</b>	Water Quality
<b>Focus Category #1</b>	Groundwater
<b>Focus Category #2</b>	Non Point Pollution
<b>Focus Category #3</b>	Water Quality
<b>Lead Institution</b>	Water Resources Research Institute

### **Principal Investigators**

<b>Principal Investigators</b>			
<b>Name</b>	<b>Title During Project Period</b>	<b>Affiliated Organization</b>	<b>Order</b>
Ning Hsi-Tang	Professor	University of Puerto Rico	01
Arturo Massol-Deya	Assistant Professor	University of Puerto Rico	02
Elba Diaz	Research Associate	University of Puerto Rico	03

## **Problem and Research Objectives**

Most of the treatment processes for water and wastewater treatment are used for leachate treatment. However, the aerobic treatment for the reduction of high concentration of organics in the leachate, will be too expensive. Anaerobic treatment technology will be more suitable for leachate treatment. The other leachate treatment technology is the recirculation of leachate over the landfill. This technology is attractive because it is simple and economical. Essentially, the landfill itself is used as a giant anaerobic reactor for the treatment of the leachate. This project examined the suitability of the leachate treatment recirculation. Gas production, COD and other variables were monitored during the recirculation process in the Cabo Rojo municipal landfill in the west part of Puerto Rico. The specific objectives of the project were: 1. To characterize the organic matters (COD), the inorganic matters (heavy metals) in leachate during the recirculation. 2. To monitor the gas production rate during the recirculation.

## **Methodology**

Cabo Rojo landfill is a relatively new facility of just three years old. This facility is divided into 20 cells. Each cell is a square entity with an area of 9,000 ft<sup>2</sup> and a depth of solid wastes of 90 ft. It is sufficient for receiving the city solid wastes for a period of two years. At present, the first cell is completed. In each cell there are two specially constructed gas vents and a manhole with a depth of 90 ft located near the center of the cell. Cabo Rojo landfill is located in a dry area of Puerto Rico. There is about 20 ft of leachate accumulated over the past two years in the bottom of the cell. The following procedures have been used for achieving the project objectives: 1. To install the recirculation facilities and the gas meter at the gas vents. 2. To analyze the leachate sample from the recirculation flow twice a week 3. To monitor the gas production rate on a daily basis.

## **Principal Findings and Significance**

The principal findings and conclusions of this project are: 1) Gas production increases after each recirculation. The principal cause seem to be the microorganisms feeding on the organics in the recirculated leachate. Also, the recirculated water wets the buried solids wastes and may speed up the decomposition process of the organics within the landfill. 2) The recirculation water does wash down the organics within the landfill. This results in the increase of the COD concentration in the recirculation leachate. However, the COD in the leachate will be eventually reduced if the application of the recirculation continues for a long time (one or two years). Further research is needed to verify this hypothesis. 3) The surface of the landfill needs to be sealed to prevent the rainwater entering as the new leachate. Otherwise, it is difficult to evaluate the experimental data. 4) The process offers an alternative route for leachate treatment because it is simple and economical. The cost for the recirculation facilities was approximately \$2,000. The cost of energy for the operation is minimum because only one hour per week is needed.

## Descriptors

Waste Disposal, Water Quality Control, Wastewater Treatment

## Articles in Refereed Scientific Journals

## Book Chapters

## Dissertations

Tarafa-Velez, P., 1999. "Leachate Treatment by Recirculation Within the Landfill" MS thesis, Department of Civil Engineering, University of Puerto Rico, Mayagüez Campus, Mayaguez, PR.

## Water Resources Research Institute Reports

Tang, Ning-Hsi; Massol, Arturo and Diaz, Elba. "Leachate Treatment by Recirculation Within the Landfill", Final Report, Puerto Rico Water Resources Research Institute, University of Puerto Rico, Mayaguez, Puerto Rico, 84 pp.

## Conference Proceedings

## Other Publications

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## Basic Project Information

Basic Project Information	
Category	Data
Title	Comprehensive Integrated Management Plan for the Mayaguez Bay Watershed
Project Number	S-01
Start Date	06/01/1998
End Date	05/31/1999
Research Category	Engineering
Focus Category #1	Management and Planning
Focus Category #2	Conservation
Focus Category #3	Education
Lead Institution	Water Resources Research Institute

## Principal Investigators

<b>Principal Investigators</b>			
<b>Name</b>	<b>Title During Project Period</b>	<b>Affiliated Organization</b>	<b>Order</b>
Jorge Rivera-Santos	Associate Professor	University of Puerto Rico	01
Jorge I Velez-Arocho	Professor	University of Puerto Rico	02
Walter F Silva-Araya	Associate Professor	University of Puerto Rico	03
Jose Norat	Professor	University of Puerto Rico	04
Felix Aponte	Professor	University of Puerto Rico	05

## **Problem and Research Objectives**

The Río Grande de Añasco watershed, located in the western coast of Puerto Rico, represents a valuable natural resource for the region, offering a diversity of uses to the inhabitants and the surrounding areas. The River discharges into the north part of the Mayaguez Bay. The increasing urban development and poor agricultural practices are affecting the intrinsic value of the natural resources of the watershed. In addition to the urban waste products and agricultural chemical products, the basin is also vulnerable to pollution deriving from chemical industries and wastewater treatment plant discharges. Also, the dismantling of land for development and the lack of management of agricultural practices promote excessive erosion that contributes to an increase the sediment load into the rivers and the Mayaguez Bay. Being the region traditionally agricultural, recent city and community expansions and the development of infrastructure, have deteriorated the quality and quantity of natural resources in the Añasco watershed, particularly in the lower parts of the basin. These changes have a direct impact in the estuarine resources and the Bay of Mayagüez. The increasing pollution in the watershed and its effects on the Bay have been of concern for many local, state, and federal government agencies, as well as for private groups and citizens. Several efforts to research and control the pollution have been attempted by various entities; however, the effects on the solution of the problem is not significant. The lack of integration and coordination of efforts among the interested parties is a major cause of the limited impact of these initiatives. The objective of this proposal is to develop a comprehensive integrated management plan for the Mayaguez Bay watershed that permits the restoration, conservation and protection of the quantity and quality of its natural resources, and that establishes a balance within the system uses and its ecological integrity. This project will lead to improved quality of life for all the inhabitants within the Bay and the watershed, as well as, the surrounding areas. The establishment of the Management Plan will allow the best utilization of the resources, ensuring the integrity of the ecosystem. Integration and communication between the different stakeholders will be greatly promoted.

## **Methodology**

The project was divided into several phases and funding was requested to the EPA for Phase I and Phase II as described next: Phase I. Investigation of previous works and existing information This part of the project consist of a search and evaluation of literature related to the natural resources of the Río Grande de Añasco Watershed, as well as, the acquisition and presentation of existing remotely sensed and Geographic Information Systems data. Phase II. Organization of the Stakeholder Forum The Vital Issues Process (VIP) methodology was used to organize the stakeholders of the watershed. This strategic planning tool identifies a group of programmatic activities for an organization, aimed at satisfying high-level goals and objectives. The methodology is implemented by a series of one-day long intensive workshops with active participation of the private sector, stakeholder communities, state and federal government and academy.

## **Principal Findings and Significance**

Phase I of this project was successfully completed. A literature review of hydrologic and environmental data available for this region is available as a database. Almost all libraries in Puerto Rico were searched and all found material relevant to the Río Grande de Añasco watershed was collected. Reports, technical papers, dissertations, and other printed material like maps and photographs were studied and summarized, when applicable, and included in the database. The database is searchable using MS Access or other suitable database manager program. Aerial photographs, satellite and remotely sensed images were also collected. Also, several maps and images were created by using the remotely sensed data and included in a Geographic Information System. Phase II of this project was also completed and the stakeholder forum for the watershed was formed. The VIP methodology proved to be very successful for use in watershed related problems. The process included a series of one-day long meetings or panels (a total of four meetings), which resulted in a forum of representatives from the government, industry, academia, and community. The first meeting established the goals of the Comprehensive Integrated Watershed Plan (CIMP) for the Mayaguez Bay Watershed. The second meeting ended with a list of prioritized issues concerning the quantity, quality and management of natural resources and ecosystems within the watershed. In the third panel, information required by each of the prioritized issues was identified. The results of the first year were so overwhelming that EPA solicited the Institute to submit a proposal for the continuation of the project into the second year. This proposal was approved and the second year of the project is about to be completed with very promising results. Details of the project can be found in the web site <http://www.ece.uprm.edu/cohemis/vip/> either in Spanish or English.

## **Descriptors**

Watershed Management, Bay, Stakeholders, Vital Issues Process

## **Articles in Refereed Scientific Journals**

## **Book Chapters**

## **Dissertations**

## **Water Resources Research Institute Reports**

Rivera-Santos, Jorge, 1999 "Comprehensive Integrated Management Plan for the Mayaguez Bay Watershed", Puerto Rico Water Resources Research Institute, University of Puerto Rico, Mayaguez, Puerto Rico.

## **Conference Proceedings**

## **Other Publications**

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## Basic Project Information

Basic Project Information	
Category	Data
Title	PROGRAM MANAGEMENT
Project Number	B-01
Start Date	03/01/1999
End Date	02/28/2000
Research Category	Not Applicable
Focus Category #1	Management and Planning
Focus Category #2	None
Focus Category #3	None
Lead Institution	Water Resources Research Institute

## Principal Investigators

Principal Investigators			
Name	Title During Project Period	Affiliated Organization	Order
Jorge Rivera-Santos	Associate Professor	University of Puerto Rico	01
Walter F Silva-Araya	Associate Professor	University of Puerto Rico	02

## Problem and Research Objectives

The objectives of the Puerto Rico Water Resources Research Institute (PRWRI) are 1. To conduct, direct, and promote research activities oriented toward the solution of local and national water resources and environmental problems, 2. To offer training to scientists, engineers, and technical personnel through research and technology transfer activities, and 3. To transfer research results to the water resources and environmental professionals of Puerto Rico and the United States. As part of its mission, during 1999, the Institute's research program continues focusing on the need for good management practices for watersheds in Puerto Rico. Also, the Institute continued to promote research for a better understanding of the water demand needs in the Island and the improvement of modeling techniques in this area. The EPA funded watershed management project for the Mayagüez Bay was a complete success in its first year. A proposal for a second year was submitted to the Environmental Protection Agency. This proposal was approved and the second year's work is well underway with very promising results. The project titled "Technical and Academic Cooperation in Water Resources between the University of Puerto Rico at Mayagüez (UPRM) and the Technologic Institute of Santo Domingo (INTEC) in Dominican Republic" was successfully completed and the results presented in a local conference. This project promoted the interrelationship between faculty members of the INTEC and faculty members of the Mayagüez Campus of the University of Puerto Rico. The Institute prepared and submitted the proposal "Hydraulic Characterization of Goodwin Creek." The US Corps of Engineers' Waterways Experimental Station at Mississippi approved this proposal, for the amount of \$100,000. Goodwin Creek is a tributary of Long Creek, which flows into one of the tributaries of Yazoo River in Mississippi. As part of this project, an intensive course in river mechanics was scheduled and offered in March 2000, at the Civil Engineering Department of the UPRM by a faculty member from Colorado

State University. The Institute also sponsored two short courses and workshops on watershed hydrology and river hydraulics offered in June 1999. The courses and workshops emphasized on the use of hydrologic and hydraulic computer models and was assisted by professional engineers and water technicians from all over the Island. The project "Determination and Mapping of the Land Use for the Jobos Bay National Estuarine Research Reserve (JBNERR) Watershed" was successfully finished. The maps and GIS database produced by the project has been incorporated to the JBNERR research facilities and is being used by other researchers. As result of the excellent performance in this project, the Institute was solicited to submit a proposal for the construction of land cover maps for the Southwest Coast of Puerto Rico. This proposal will take advantage of the Memorandum of Understanding (MOU) already signed with the DNER. Conversations with former Executive Director of the Puerto Rico Aqueduct and Sewer Authority (PRASA) lead to the preparation of a MOU for research, consulting, and training services. Unfortunately, PRASA was privatized before the MOU was signed and negotiations had to be started again with the new administration. The MOU is still under negotiation, but constant changes in administration at the new Water Company had precluded the formalization of this document. The Institute has continued its participation in the government's umbrella committee. This committee consists of representatives from all government agencies and offices that are related to water and environmental resources in the Island. The committee meets twice, or more, a year and establishes the research and consulting needs for these agencies. Proposals are then submitted by the USGS district office (the sole participant) and evaluated by the committee. Successful proposals are funded and administered by the President of the Environmental Quality Board of Puerto Rico (the local counterpart of EPA).

## **Methodology**

To accomplish its objectives, the PRWRRI identifies the most important environmental and water resources research needs in Puerto Rico, encourages scientists and professionals from the higher education institutions of Puerto Rico to write proposals for competitive grants, promotes the participation and support of students in funded projects; and disseminates research results to all the interested public. Problems related to watershed management, technology transfer, water distribution and demand, and GIS applications were given priority during this year. Those research projects developed during this year are described separately in this report.

## **Principal Findings and Significance**

The constant submission of research proposals resulted in several projects funded by various federal and non-federal institutions. One particular project - "Comprehensive Integrated Management Plan for the Mayagüez Bay Watershed" - attracted interest in countries from Central America, as well as from universities in Mexico and Michigan. The Institute's Director was invited to present the results of this project at the University of Michigan and helped to develop a similar project using the "Vital Issues" management methodology. El Salvador and Guatemala are also interested in developing similar projects using this technique. The Director was invited to collaborate in the watershed management project "Ríos Dos Novillos Basin Management Plan" at the Costa Rica's Tropic-Humid Region Agricultural College (EARTH in Spanish). Three universities in Mexico demonstrated interest in developing similar projects and made contact with the Institute. The exposure given by this project resulted in many new contacts abroad. The Institute has been contacted by Central and South American countries to discuss the possibilities of having technologic transfer activities conducted by our researchers in their countries. A proposal is being develop to assist the city of San Jose, Costa Rica, in solving their flood problems in downtown. The Institute exposure has resulted in invitations to participate in international research projects sponsored by the United Nations. The Director was invited to participate as a member of a

steering committee for a project that looks for the reduction of pesticide runoff to the Caribbean Sea.

## Descriptors

Project Management

## Articles in Refereed Scientific Journals

## Book Chapters

## Dissertations

## Water Resources Research Institute Reports

Rivera-Santos, Jorge, 1999, Water Resources Research Institute Annual Technical Report: FY 1998, Puerto Rico Water Resources and Environmental Research Institute, University of Puerto Rico, Mayagüez, Puerto Rico

## Conference Proceedings

## Other Publications

PRWRRRI Newsletter, Volume 9, Issue 1 & 2, January-July, 1999 PRWRRRI Newsletter, Volume 9, Issue 3 & 4, July-December, 1999 Institute's WEB Site at <http://www.ece.uprm.edu/rumhp/prwrrri/> CIMP Mayagüez Bay Watershed project Web Site at <http://www.ece.uprm.edu/cohemis/vip/>

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## Basic Project Information

<b>Basic Project Information</b>	
<b>Category</b>	<b>Data</b>
<b>Title</b>	Dynamic Simulation of Water Distribution Systems with Instantaneous Demands
<b>Project Number</b>	B-02
<b>Start Date</b>	03/01/1999
<b>End Date</b>	05/01/2001
<b>Research Category</b>	Engineering
<b>Focus Category #1</b>	Water Supply
<b>Focus Category #2</b>	Water Use
<b>Focus Category #3</b>	Water Quantity
<b>Lead Institution</b>	University of Puerto Rico

## Principal Investigators

<b>Principal Investigators</b>			
<b>Name</b>	<b>Title During Project Period</b>	<b>Affiliated Organization</b>	<b>Order</b>
Walter F Silva-Araya	Associate Professor	University of Puerto Rico	01
Noel Artilés	Associate Professor	University of Puerto Rico	02

## **Problem and Research Objectives**

Accurate predictions of water quantities are needed for efficient city planning in regions where land is limited for an ever increasing population. The competition for water is intense and the water availability problems are complex. Puerto Rico is suffering a water crisis caused by inappropriate management of the water infrastructure which has revealed as serious water allocation and distribution problems. These problems are aggravated by frequent shut downs of water treatment facilities due to poor quality of the effluents. Moreover, water quality in residential distribution networks deteriorates between the treatment plant and the consumer's tap. This fact has deep consequences for the drinking-water utilities because the new regulations proposed by the Safe Drinking Water Act (SDWA) require the fulfillment of drinking water standards at the household entrance. Therefore, efficient urban planning and development; as well as, the challenge posed by the SDWA motivate the creation of a new generation of promising methodologies which combine a detailed representation of water demand scenarios with time-dependent hydraulic models for reliable predictions of water quantity and quality in distribution systems. **OBJECTIVES** The principal objectives of this project are to develop a methodology to model instantaneous residential water demands in a neighborhood and to provide a micro-scale simulation algorithm that combines an unsteady flow model and the instantaneous demand model. The instantaneous demand model will be constructed from statistical simulation by combining probability distributions for the duration and time of apertures of faucets inside a house.

## **Methodology**

The project involves three phases: 1) Collecting neighborhood data related to water consumption and field measurements. A part of the neighborhood Alturas de Algarrobo, located in the Municipality of Mayagüez, in the west part of Puerto Rico, was selected for this study. The site is representative of a typical middle-class, homogeneous residential neighborhood. A questionnaire about resident habits associated to water consumption was distributed in a section of 360 households during the month of November 1999. The information requested included number of persons in the house throughout the day, frequency of use of water consumption devices such as washing machines, habits related to car washing, use of garden sprinklers and the availability of water storage tanks. A total of 136 questionnaires were answered and sent by mail to the Puerto Rico Water Resources Institute. The information was analyzed using statistical tools and the major findings are presented in this report. The field measurement program consists of recording discharge and pressures at the entrance of several households. The period of data collection was determined by the results of the statistical analysis of the questionnaire data. Even though the periods are already defined, the data collection program has not been implemented yet. However, the instrumentation is available and the program will begin in July 2000. Due to limitations in the number of instruments (one pressure transducer with datalogger and one ultrasonic flow meter), the sampling program will have to go slow and might be extended for several months. Flow data from several houses in the neighborhood will be analyzed statistically to determine the best combination of probability distributions and their parameters, to simulate the consumption pattern inside the study area. Pressure data will be used to calibrate the unsteady flow model and to run the simulations. By combining the instantaneous demand model with the hydraulic model, a micro-scale

simulation of the water consumption in the neighborhood will be obtained. 2) Experimental runs in a laboratory model A total of eight experiments with duration of three hours were conducted in the laboratory. The experiments reproduce the sequence of apertures and closure of faucets in a water distribution line. The pipe system consists of 94.94 feet long and 2.0 inches nominal diameter, PVC-SCH 40 pipe. Gluing uniform sand to the pipe wall using epoxy created the roughness effect. Ten "household" connections represented by  $\frac{3}{4}$  inch branch pipes are equally spaced along the pipe system. The connections are separated 8.2 m and each represents a house along a distribution line. A flow meter before the faucet was used to measure the water volumes consumed at each "house". One pressure transducer was located at the upstream end of the pipe, and the pressure was recorded during the experimental run. This data was collected using a Data Acquisition System (DAS) and a sample frequency of 10 Hz. An ultrasonic flow meter was installed at the downstream end of the pipe to measure the outflow from the 2 inches pipe. Discrete demand models were constructed from probability distributions to generate a sequence of apertures and closures of valves at each household. The sequences of closure and openings of faucets were created using different probabilistic distributions and random generation techniques. The time interval between the opening of each faucet was simulated using the exponential probability distribution. The duration of each opening was simulated using the exponential and the Weibull distribution with mean duration times of 20 and 40 seconds. Two types of experiments were performed. Four of them used five (5) valves; the other four were done with nine (9) valves. The total volume of water was read directly of the "household" water meter at the end of the experiment. The experiments were finished in May 2000. 3) Development and verification of the computer algorithm A computer simulation is been prepared to predict the water consumption in the households located in the water distribution line. The measured and computed demand volumes will be compared to determine the capability of the model for realistic micro-scale computer simulations. Experience with laboratory experiments was useful to foresee and prevent possible difficulties during full-scale field measurements in a real neighborhood.

## **Principal Findings and Significance**

The statistical analysis of the questionnaire information revealed that the occupation pattern in the neighborhood is different during the weekdays and during the weekends. The average number of persons is approximately constant during the weekdays; however, significant differences occur during the hours of the day. Based on the number of persons inside the house, three periods of time could be considered as homogeneous: 9 am to 5 pm, 5pm to 7 pm and, 7 pm to 9 am. This information will be useful during the field measurements. The first period corresponds to an average of 1.2 persons in the house with a standard deviation is 1.23. The second period has 2.2 persons with a standard deviation of 1.56. The third period has 2.82 persons with a standard deviation of 1.51. A water consumption pattern do not necessarily follows this tendency; however, a significant consumption period exists between 5:00 pm and 7:00 pm. By the end of the project, water consumption as a function of time will be available to supplement and expand these findings . There are no results from computer simulations at this time. However, the discrepancies obtained between the measured water volumes from the households water meters and those computed by multiplying the constant outflow expected from each faucet, obtained after calibration of the number of turns of the faucet key, by the time of opening varies between 0.4% and 14%. At present a review of the reasons for this discrepancy is undergoing. Possible reasons for these differences are that the outflow is not constant during the time of aperture and the time of closure of the valves. On the other hand, the discharge at each faucet changes by the opening or closing of other valves in the same line. This effect seems to be important under laboratory conditions because the water pressure is relatively small. The significance of this factor under field conditions will be studied. The final results and detailed analysis will be done when the computer algorithm is finished.

## Descriptors

Water Demand, Water Distribution Systems, Water Use, Monitoring, Dynamic Simulation, Unsteady Flow

## Articles in Refereed Scientific Journals

## Book Chapters

## Dissertations

## Water Resources Research Institute Reports

## Conference Proceedings

## Other Publications

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## Basic Project Information

Basic Project Information	
Category	Data
Title	Hydrologic Characterization of Goodwin Creek
Project Number	N-01
Start Date	10/01/1999
End Date	12/01/2000
Research Category	Climate and Hydrologic Processes
Focus Category #1	Hydrology
Focus Category #2	Surface Water
Focus Category #3	Sediments
Lead Institution	Water Resources Research Institute

## Principal Investigators

Principal Investigators			
Name	Title During Project Period	Affiliated Organization	Order
Walter F Silva-Araya	Associate Professor	University of Puerto Rico	01
Rafael Segarra	Professor	University of Puerto Rico	02

## Problem and Research Objectives

The Demonstration Erosion Control (DEC) Project is a comprehensive program that provides for the development of a system for control of sediment, erosion, and flooding in the hill areas of the Yazoo

River Basin, Mississippi. Goodwin Creek is a tributary of Long Creek that flows into one of the primary tributaries of the Yazoo River. Goodwin Creek is extensively gauged by the U.S. Army Corps of Engineers (USACOE) and the Agricultural Research Service (ARS) as a facility for research of upland erosion, instream sediment transport, and watershed hydrology. The watershed is divided into 14 subcatchments with a flow-measuring flume at each of the drainage outlets. The Puerto Rico Water and Environmental Resources Research Institute received a grant from the USACOE to prepare and calibrate a hydrologic model for Goodwin Creek. The model will use the existing gage information at sixteen locations inside the watershed and develop a detailed examination of the stage/flow frequency and duration relationships for the watershed data. This is the first phase of a comprehensive study that includes sediment yield analysis and development of hydraulic structures and other methods for practical sediment yield reduction.

## **Methodology**

Three researchers and one graduate student visited the Goodwin Creek basin in Mississippi with the goals of getting familiarized with the basin and all of the instruments installed in it. In addition, during this trip, the team visited the Sedimentology Research National Laboratory of the Agricultural Research Service of the U.S. Department of Agriculture (SRNL-ARS-USDA). The purpose of this visit was to meet with personnel from SRNL-ARA to discuss the possibility of obtaining information previously collected by them in relation to the Goodwin Creek Basin. Hydrologic, hydraulic, sediment and geographical data was collected to be used as basic information for the development of hydrologic models for Goodwin Creek. Several hydrologic models, including WMS and HEC-HMS are being considered at present as candidates. The final product will be a practical model that provides data to be used in hydraulic and sediment transport models for the same watershed. This project provided the opportunity for faculty members and students to receive an intensive 30 hrs course in River Mechanics offered by an expert from Colorado State University.

## **Principal Findings and Significance**

The project is in the phase of data acquisition and selection of hydrologic models. Information was retrieved from the Waterways Experimental Station and the Sedimentology Laboratory. Data processing and selection is undergoing now. The research potential of the Goodwin Creek watershed, and the capacity to investigate the temporal characteristics of the water sediment transported throughout the basin provide an excellent opportunity to conduct research in this area. This project served to establish new contacts with personnel from the US Corp of Engineers and the Agricultural Research Laboratory. It opened new horizons to strengthen the collaborative relations with these institutions.

## **Descriptors**

Hydrologic Processes, Hydrologic Models

## **Articles in Refereed Scientific Journals**

## **Book Chapters**

## **Dissertations**

## **Water Resources Research Institute Reports**

## Conference Proceedings

## Other Publications

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# Information Transfer Program

Information and Technology Transfer (ITT) is a vital component of the PRWRERI. ITT activities at the Institute consist of the Professional Development Center (PDC), short courses in collaboration with faculty from US and local universities, and conferences and talks to schools, interested groups, and general public. The PDC issues continuing education credits for in-training and professional engineers.

### Basic Project Information

Basic Project Information	
Category	Data
<b>Title</b>	Technical and Academic Cooperation in Water Resources Between the UPRM and the INTEC (Dominican Republic)
<b>Description</b>	S-02
<b>Start Date</b>	07/01/1998
<b>End Date</b>	12/01/1999
<b>Type</b>	Conferences
<b>Lead Institution</b>	University of Puerto Rico

### Principal Investigators

Principal Investigators			
Name	Title During Project Period	Affiliated Organization	Order
Walter F Silva-Araya	Associate Professor	University of Puerto Rico	01

### Problem and Research Objectives

Floods in Dominican Republic killed more than 10,000 persons during the last 50 years. Floods in this country produced losses to the economy for more than \$30,000 million dollars during the last 10 years. Floodway Delineation Maps are a useful tool to reduce these disasters because, if used as regulatory maps, they help to establish flood protection measures for structures in the flood zones or even, prohibit any construction in high risk areas. The PRWRERI took a first step in providing this Caribbean Island the basic knowledge and techniques for the development of Floodway Delineation Maps.

### Methodology

The project consisted of an intensive technology transfer program to establish the basis for teaching the techniques and methodology to create floodway maps for the Dominican Republic. The project also

strengthened the relations between researcher from both institutions in the area of water resources. The directors of the PRWRERI were the principal investigators and coordinators of the activities in Puerto Rico and, Prof. Alfredo Abel was the project responsible in Dominican Republic. Three faculty members from INTEC visited the UPRM in February, 1999 and shared ideas and possible collaborative projects with faculty member at the UPRM. Professors' Alfredo Abel from the Department of Civil Engineering, and Caterine Catafesta from the Social Sciences Department offered a conference on the effects of Hurricane Georges on the Dominican Republic. The Conference focused on the magnitude of the damage caused to this strong hurricane during its pass by this Caribbean Island. Students and faculty members of the UPRM attended the Conference. Several meetings with colleagues interested in developing collaborative projects were also programmed. The project also provided the opportunity to four faculty members from the UPRM to offer a sequence of intensive courses to professionals and students from the Dominican Republic to provide them with the essential skill to create Floodway Delineation Maps. Floodway maps are commonly available in Puerto Rico from FEMA Flood Insurance Studies. The Puerto Rico Planning Board uses then as the regulatory maps for Hydrologic and Hydraulic studies in the Island. The Dominican Republic is moving towards the development of a regulation for construction and the creation of a building code. A classification of flood zones is essential to determine the flood protection measures for buildings inside these zones; as well as, to establish regulations for these areas. Courses in hydrologic statistics, hydrologic modeling, hydraulic modeling and geographic information systems applied to water resources completed the training offered by the UPRM experts, coordinated by the PRWRERI, in Dominican Republic. Engineers, students and other professionals attended the activities offered from September to December, 1999.

### **Principal Findings and Significance**

This project provided experience in international collaboration between the PRWRERI and other caribbean country. As a consequence of this project, the PRWRERI was invited to participate in a joint consulting project to develop hydrologic studies for one major river in the Dominican Republic. A letter of intention was submmitted. Also, the directors of the PRWRERI were invited to offer a Conference on the importance of Floodway Delineation Maps in front of an international group assembled by the Dominican Government for the creation of a Building Code for this country. This project deserved a Special Recognition Award from the Atlantea Project Evaluation Committee in May, 2000.

### **Articles in Refereed Scientific Journals**

### **Book Chapters**

### **Dissertations**

### **Water Resources Research Institute Reports**

### **Conference Proceedings**

### **Other Publications**

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## Basic Project Information

Basic Project Information	
Category	Data
Title	River Mechanics (Intensive Course)
Description	N-01
Start Date	03/01/1999
End Date	03/11/1999
Type	Conferences
Lead Institution	University of Puerto Rico

## Principal Investigators

Principal Investigators			
Name	Title During Project Period	Affiliated Organization	Order
Walter F Silva-Araya	Associate Professor	University of Puerto Rico	01
Johannes Gessler	Associate Professor	Colorado State University	02

## Problem and Research Objectives

Motivated by further research related to the Goodwin Creek watershed, the project title "Hydraulic Characterization of Goodwin Creek" provided support to offer a course in River Mechanics at the Mayaguez Campus of the University of Puerto Rico. Dr. Johannes Gessler from Colorado State University was the instructor for this 11 days course. The course provided basic material, as well as, updated information on the field of river mechanics, erosion and sedimentation theories.

## Methodology

Dr. Johannes Gessler, from Colorado State University offered a 30 hours short course in River Mechanics. The classes were offered at the Department of Civil Engineering of the University of Puerto Rico, Mayaguez Campus. Three hours, during 11 days (from May 1 to May 11) a group of 10 students and two faculty member attended the conferences. The topics covered the areas of erosion, sedimentation and geomorphology, among others. Two credits were granted to those students enrolled in the course.

## Principal Findings and Significance

Many rivers in Puerto Rico has serious erosion problems. Sediment transport rates are very high during high stage flows. Sediment deposition is also a major concern in the most important reservoir of the Island. This training provided new information to the researchers and advanced students in the field of river mechanics. It will serve as a basis for continuing penetration into this field and, eventually, start developing applied research to reduce the accelerated degradation of the river channels.

## Articles in Refereed Scientific Journals

## Book Chapters

## Dissertations

## Water Resources Research Institute Reports

## Conference Proceedings

## Other Publications

Gessler, J., 1999. "A Short Course in River Mechanics", University of Puerto Rico Mayaguez. Class Handout

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## Basic Project Information

Basic Project Information	
Category	Data
Title	Professional Development Center
Description	N-04
Start Date	06/01/1999
End Date	06/30/2000
Type	Conferences
Lead Institution	Water Resources Research Institute

## Principal Investigators

Principal Investigators			
Name	Title During Project Period	Affiliated Organization	Order
Jorge Rivera-Santos	Associate Professor	University of Puerto Rico	01
Walter F Silva-Araya	Associate Professor	University of Puerto Rico	02

## Problem and Research Objectives

The Puerto Rico Water Resources Research Center established the Professional Development Center with to objective of organizing and offering short courses, seminars and workshops in the water resources and environmental engineering fields.

## Methodology

Two short courses and workshops were offered during summer 1999. The courses were titled Hydrologic Modeling Using HMS and River Hydraulics and Hydraulic Modeling Using HEC-RAS. Hand-on experience was given in the use of the computer programs by given a personal computer to each participant. The courses lasted three days each and 2.0 Continuing Education Units were granted to the participants. Co-sponsors of this project were the College of Engineers and Land Surveyors of

Puerto Rico and the General Engineering Department of the University of Puerto Rico.

### **Principal Findings and Significance**

The courses provided a comprehensive introduction to the theory and practice of the river hydraulics and hydrology using well-known computer models.

### **Articles in Refereed Scientific Journals**

### **Book Chapters**

### **Dissertations**

### **Water Resources Research Institute Reports**

### **Conference Proceedings**

### **Other Publications**

Silva-Araya, W. 1999, "River Hydraulics and Hydraulic Modeling Using HEC-RAS", Class Handout.  
Rivera-Santos, J. 1999. "Hydrologic Modeling Using HEC-HMS", Class Handout.

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## **USGS Internship Program**

### **Student Support**

<b>Student Support</b>					
<b>Category</b>	<b>Section 104 Base Grant</b>	<b>Section 104 RCGP Award</b>	<b>NIWR-USGS Internship</b>	<b>Supplemental Awards</b>	<b>Total</b>
<b>Undergraduate</b>	4	2	N/A	N/A	6
<b>Masters</b>	1	2	N/A	4	7
<b>Ph.D.</b>	N/A	N/A	N/A	N/A	N/A
<b>Post-Doc.</b>	N/A	N/A	N/A	N/A	N/A
<b>Total</b>	5	4	N/A	4	13

### **Awards & Achievements**

The international collaboration project "Technical and Academic Collaboration: INTEC-UPR-PRWRERI" was granted a SPECIAL RECOGNITION AWARD by the ATLANTEA Project Evaluation Committee, Central Administration, University of Puerto Rico, in May 2000.

### **Publications from Prior Projects**

**Articles in Refereed Scientific Journals**

None

**Book Chapters**

**Dissertations**

**Water Resources Research Institute Reports**

**Conference Proceedings**

**Other Publications**