SELECTION OF SEDIMENT TRANSPORT FUNCTIONS FOR ST. THOMAS ISLAND GUTS

Proposal submitted to

THE VIRGIN ISLANDS WATER RESOURCES RESEARCH INSTITUTE

Prepared by:

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November 2006

1. Title: **Selection of Sediment Transport Functions for St. Thomas Island Guts**

2. **Focus Categories**: G&G, SED, HYDROL

3. **Keywords**. Erosion, Sedimentation, Geomorphology, Flood Control

4. **Duration (month/year to month/year).** February/2007 to February/2008

5. **Federal funds requested:**

6. **Non-Federal (matching) funds pledged:**

7. **Principal Investigator(s) :** Walter F. Silva, Dept. of Engineering Sciences and Materials, University of Puerto Rico, Mayaguez, Puerto Rico.

8. **Congressional District : N/A**

9) STATEMENT OF THE PROBLEM

Very little is known about sediment transport processes in the Caribbean Islands. Although there are not perennial streams in the Virgin Islands, *guts* become the main channel for transporting water and sediments during runoff conditions. Suspended and bed sediment discharge into the coastal areas impacting the coral reefs and marine life. Same as in perennial streams, aggradation in guts changes the channel capacity and reduce the effective area for flow conveyance, increasing the probability for flooding conditions. Conversely, guts degradation increases bed erosion and deepens the channel. The net effect in both cases is channel instability.

Sediment transport during flow discharge periods is usually estimated by using *sediment transport functions*. The common approach to select the most appropriate sediment load equation for a particular stream is to analyze a series of measured values of suspended and/or bed load in order to find the function that best fit the field data. This approach requires a long period of historic measurements and usually this information is not available; therefore, this methodology cannot be applied in many streams.

This research will select sediment transport functions for two watersheds in Saint Thomas, V.I., using a methodology which does not require long periods of sediment discharge measurements. Instead, it uses grain size distributions, geometric and hydraulic parameters of the water course to identify those sediment transport functions more appropriate for the existing conditions. An urbanized and a more natural-state watershed will be selected in order to compare geomorphic impacts in guts do to urban development.

10) Statement of the results or benefits.

This project will provide knowledge about the capacity of sediment transport in guts in St. Thomas Island; as well as, help to identify potential degradation or aggradation problems due to erosion and deposition. Possible causes of these problems could be addressed; however, those will not be studied in detail.

The study will provide the basis for future solution of sediment transport and erosion control problems. The selected sediment transport functions could be used in other sediment transport studies, including geomorphic studies or environmental effects on coastal areas. It is expected to provide estimates of sediment discharges for rainfall events

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5. **Federal funds requested:** $18,488

6. **Non-Federal (matching) funds pledged:**

7. **Principal Investigator(s) :** Walter F. Silva, Dept. of Engineering Sciences and Materials, University of Puerto Rico, Mayaguez, Puerto Rico.

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of different return periods and durations. Frequency estimates from the recently published NOAA Atlas 14 (http://hdsc.nws.noaa.gov/hdsc/pfds/pr/vi_pfds.html) will be used.

11) Nature, scope, and objectives of the research

Changes in hydrologic variables, such as changes in land use, urbanization growth or deforestation are causes of instability in water courses. Guts are the main runoff water conveyance channels during rainfall events in the U.S. Virgin Islands and other small islands in the tropics. Sediment is moved through them from the high zones toward the coastal areas causing channel aggradation or degradation along its length.

This research points toward the estimation of the amount of sediment moved along the guts in two selected watersheds during rainfall events of different return periods and duration. One proposed study area is the basin discharging in Dorothea Bay and the other is a more developed watershed in the south east part of the Island. As discussed in the next section, the fulfillment of the project objectives requires hydrologic analysis to estimate the discharges along the guts, hydraulic analysis to estimate the water levels during rainfall events and sediment transport analysis to compute the sediment load during events.

12) Methods, Procedures and Facilities

The project involves the following three steps:

a) Data Collection and Processing
b) Hydrologic Analysis
c) Hydraulic Analysis
d) Sediment Transport Analysis

The following data will be collected:

a) Data Collection and Processing

Cross sections and longitudinal profile:

Cross sections and longitudinal profile of each gut will be surveyed. The separation between each cross section will be dictated by the geographic conditions; however, they will be close enough to obtain an accurate geometric description of the gut.

Sediment samples:

Sediment samples at the main channel and the banks will be collected at each cross section. Sediment samples will be processed to obtain the grain size distribution.

Maps and Aerial Photos

Soil maps, land use maps, topographic maps and aerial photographs for each watershed will be requested to complete the data collection for the project.

b) Hydrologic Analysis

Historic precipitation and discharge data will be searched and analyzed to determine its possible use as input for the computer simulation. If this is not satisfactory, a frequency analysis, based on the NOAA Atlas 14 data, will be used to generate rainfall events for different durations and return periods. A hydrologic simulation, using the U.S.

Army Corps of Engineers software HEC-HMS, will be used to convert the rainfall distributions into corresponding discharges for different durations and return periods.

c) Hydraulic Analysis

A hydraulic model will be used to determine water levels and flow velocities for different storm events. The selected model is HEC-RAS developed by the U.S. Army Corps of Engineers. Recent versions of HEC-RAS include sediment transport functions for analysis at particular cross sections; however, this is not a movable boundary model.

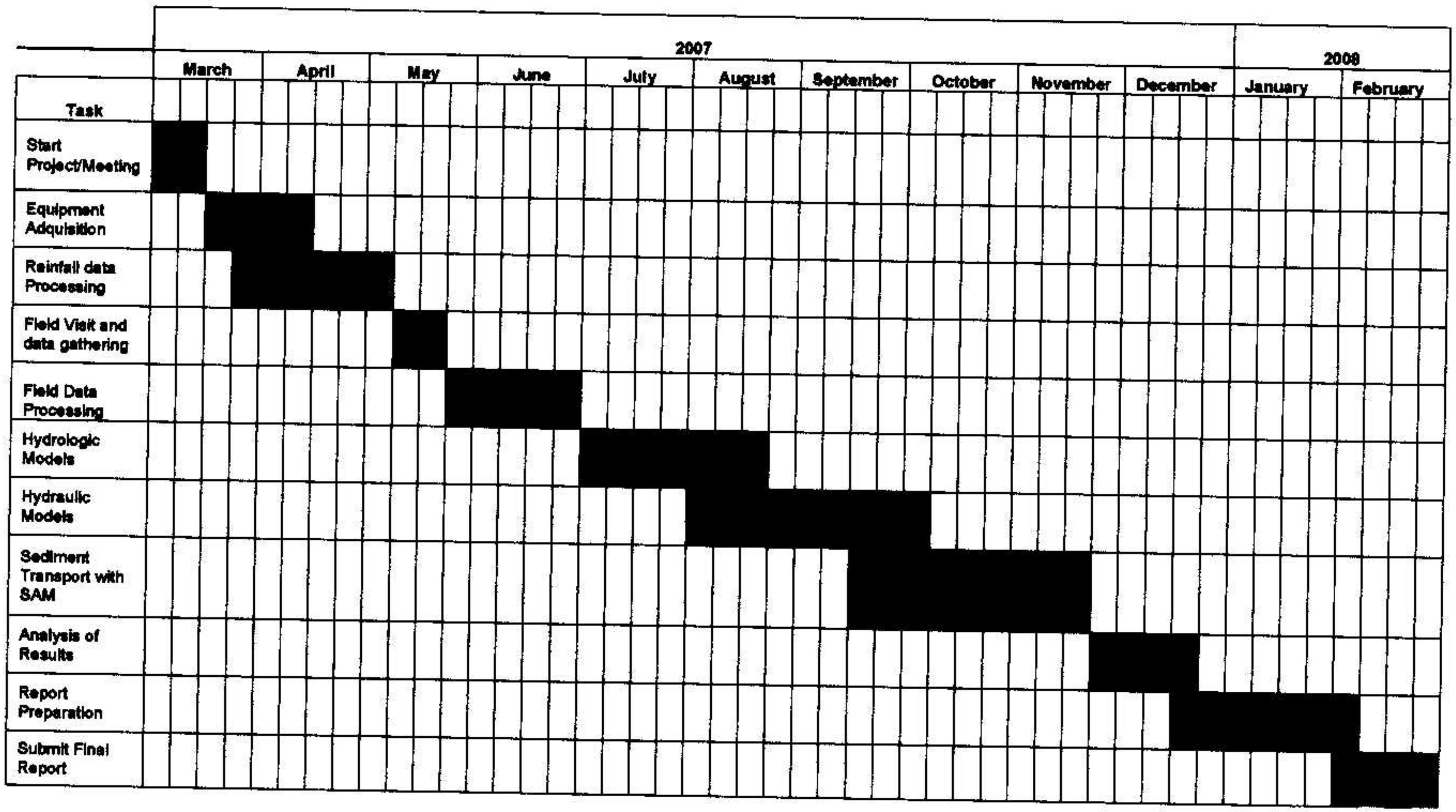
d) Sediment Transport Analysis

The selection of the sediment transport functions will be done using a database included in SAM. This software is an integration of several modules developed by the "Flood Dam Reduction and Stream Restoration Program" of the U.S. Army Corps of Engineers. SAM compares five parameters of the stream or gut with those coming from a database of rivers that have sufficient sediment data to determine an appropriate sediment transport function. A match is identified when a parameter falls within the range of data for a river in the database. The three best sediment transport functions for each database river is then listed, along with the type of parameter(s) that matched and the name of the data set matched. The screening parameters are: velocity, depth, slope, width and median diameter.

The grain size analysis will be done using standard sieve analysis C-136 ASTM. The computer simulations will be done at the Puerto Rico Water Resources Research Institute located at the University of Puerto Rico, Mayaguez Campus.

The geographic location, geometric, grain size distribution and photographs of the surveyed sections will be included in a Geographic Information System (GIS) using Arc GIS. The following next page presents a time table for the project, which is expected to be finished in one year.

TIME SCHEDULE FOR THE PROJECT
(12 months)



13) Related Research

Sediment transport studies in the United States started seriously in the decade of 1930. From that year until the 1970's the main interest was focused on bed load movement. Studies on suspended sediment came later. From those days until today, several sediment transport functions have been proposed.

A typical approach to estimate the amount of sediment passing by a channel cross section is to fit sediment discharges and water discharges, taken at that location, to empirical equations. A power function is commonly used (Bhallamudy and Chaudhry, 1991, Morris and Fan, 1997). This approach does not use grain size information, hydraulic or geometric parameters explicitly. Another alternative is to sample suspended and/or bed load material, obtain a representative grain size diameter (usually d_{50}, d_{30} or d_{84}) and select a sediment transport function to estimate the sediment discharge (Yang, 1996). Some sediment transport functions are for bed load, others are for suspended load and others for total load. Sediment transport functions are empirical relations developed by fitting experimental or/and field data to an equation in terms of the grain size, the geometric and the hydraulic parameters of the river. The equation pretends to predict the amount of sediment passing through a river cross section.

These functions are used nowadays for the solution of engineering problems, including degradation of streams due to construction of dams or increase in discharge due to urban development, design of earth channels, improvement to the geometry and meandering of channels to increase capacity or reduce bed aggradation or degradation, and others (Vanoni, 1984).

Both traditional approaches mentioned so far require field measurements for a relatively large range of flows. Most projects are on ungaged sites with small and possible intermitent streams; therefore, data are very limited to apply those methods in real situations.

Recently Silva-Araya and Villalta (2004) applied a methodology for the selection of sediment transport functions using a data base developed by Brownlie (1981) and incorporated into the computer program SAM (Copeland, McComas, Raphelt and Thomas, 1998) developed by the U.S. Army Corps of Engineers. This method only requires bed material gradations and hydraulic parameters to select, among 19 functions, those that matches, from one to five criteria, those conditions used for the development of a particular sediment transport function. The method was applied to three rivers of the Mayaguez Bay in Puerto Rico (Villalta, 2004). The selected functions for the Grande de Añasco, Mayaguez and Guanajibo rivers were Yang (1973) and Ackers-White (1973) Additional research for developing sediment transport models using the selected function for these rivers is being carried on presently. Recently, a new version of SAM, called SAMWIN was prepared for the US Army Corp of Engineers by Aires Associates.

References:

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Bhallamudi, S. M. and Chaudhry, M.H., 1991. "Numerical Modeling of Aggradation and Degradation in Alluvial Channels", Jour. Hyd. Engrn., ASCE, Vol 117, No. 9, pp 1145-1164.

Brownlie, W.R., 1981. "Prediction of Flow Depth and Sediment Discharge in Open Channels", California Institute of Technology, W. M. Keck Laboratory of Hydraulics and Water Resources, Pasadena, California.

Copeland, R., McComas, D., Raphelt, N. and Thomas, W., "User's Manual for the SAM Hydraulic Design Package for Channels", U.S. Army Corps of Engineers, 1998.

Silva-Araya, W.F., Villalta, C., *"Sediment Transport Functions for the Mayaguez Bay Rivers"*, 24th Puerto Rico Interdisciplinary Scientific Meeting, (in Spanish), March, 2004.

Vanoni, V., 1975, "Sedimentation Engineering", Manual 54. ASCE, New York.

Villalta, C., "Selection of Sediment Transport Functions for the Mayaguez Bay Using SAM" (in Spanish), MSCE Thesis, 2004.

Yang, C.T., 1996, "Sediment Transport :Theory and Practice", Mc Graw Hill, New York.

14. Training Potential

One graduate student from the Department of Civil Engineering of the University of Puerto Rico will benefit from this project. He will help the Principal Investigator during the project, including collecting, processing and analyzing the field data and doing the computations. The University of Virgin Islands will provide students to collaborate with UPR personnel in the field data collection and information gathering. The students will learn about instrumentation, data collection, management, processing and interpretation under the guidance of the Principal Investigator. Beyond that, the graduate student will benefit from learning the use of specialized software related to hydrology, hydraulics and sediment transport.

15. Investigator's Qualifications

a. Professional Preparation

B.S. Degree, Civil Engineering., 1982, University of Costa Rica, Costa Rica

M.S. Degree, Water Resources Engineering, 1984, University of Puerto Rico-Mayaguez

Ph.D. Degree, Hydraulic Engineering, 1993, Washington State University

b. Appointments

Interin Director, Department of Engineering Science and Materials, University of Puerto Rico, Mayaguez. August 2006 to present.

Associate Director, Puerto Rico Water Resources Research Institute, 1998 to present

Director, Fluid Mechanics Laboratory, University of Puerto Rico, 1996 to present

Professor, Dept. of General Engr., Univ. of Puerto Rico -- Mayagüez, July 2001 to present

Associate Professor, Dept. of General Engr., Univ. of Puerto Rico–Mayagüez, Jul. 1997–Jun 2001

Assistant Professor, Dept. of Gen. Engr., Univ. of P. Rico – Mayagüez, Jan. 1994-June 1997

Research Assistant, Dept. of Civil Engr., Washington State University [1989 - 1993]

c. Recent Publications

- Silva-Araya, W.F., Villalta, C., *"Sediment Transport Functions for the Mayaguez Bay Rivers"*, 24th Puerto Rico Interdisciplinary Scientific Meeting, (in Spanish), March, 2004.
- W. Silva-Araya, W. F., Rojas, A., *"Two Dimensional Model for Grande de Añasco River"*, 24th Puerto Rico Interdisciplinary Scientific Meeting, (in Spanish), March, 2004.
- Silva-Araya, W.F., *"Procedimiento de Diseño para Armadura de RipRap"* (Design Manual), Published by the Puerto Rico Water Resources Research Institute, 2003.
- Silva-Araya, W.F, Artiles-Leon, N., and Romero, M. *"Dynamic Simulation of Water Distribution Systems with Instantaneous Demands"*, Ninth International Conference on Hydraulic Information Management: HYDROSOFT IX, Montreal, Canada, WIT Press, May, 2002.
- Romero, M.; Silva-Araya, W.F. and Artiles, N., *"Dynamic Simulation of Water Distribution Systems"* , Sixth Caribbean Islands Water Resources Congress, Mayagüez, Puerto Rico, Feb. 22-23, 2001.
- Silva-Araya, W., "*Manual de Laboratorio de Mecánica de los Fluidos: Teoría y Procedimientos"*, John Wiley and Sons, 1st Ed, 2003.

d. Synergistic Activities

• Puerto Rico Acueducts and Sewer Authority. "Operacional Water Distribution Model for the West Side of Puerto Rico", W. F. Silva-Araya, (P.I.), J. Rivera-Santos,$418,840 [March 2005 – June 2006].

- Puerto Rico Acueducts and Sewer Authority. "Wells Inventory for the Island of Puerto Rico" W. F. Silva-Araya, (P.I.), J. Rivera-Santos, $198,000 [May 2003 – May 2005].

- USACE, ERDC, "Training in Hydraulics, Hydrology and Sediment Transport Processes in Latin America", $98,400, June 2004.

- USACE, ERDC, "Curso Internacional Sobre Control del Erosión y Estabilización de Riberas de Ríos",(International Course in Erosion Control and Streambank Stabilization in River Banks), Guatemala, $90,000, June, 2001.

- Reviewer for the *Journal of Hydraulic Engineering*, ASCE, since 1996.

e. Collaborators and Other Affiliations

(I) Collaborators.

- Dr. Jorge Rivera Santos, Hydrologist, Dept. of Civil Engr., Univ. of Puerto Rico-Mayagüez.
- Dr. Noel Artiles, Industrial Eng., Dept. of Industrial Engr., Univ. of Puerto Rico, Mayaguez
- Dr. David Biedenham, Geomorphologist, ERDC, USACE, Vickburg, Virginia.
- Dr. Chester Watson, Geomorphologist, Dept. of Civil Engr., Colorado State University.
- Dr. Colin Thorne, Geomorphologist, Dept. of Geography, Nottingham University, England.
- Dr. Hernán Solís, Hydraulic Eng., Dept. of Agricultural Engr., University of Costa Rica.
- Prof. Luis Olivieri, GIS Specialist, Puerto Rico Water Resources Reseach Institute

(II) Doctoral Advisors

- PhD Thesis, Dr. M. H. Chaudhry, Dept. of Civil Engr., Washington State University.
- PhD Thesis, Dr. Clayton Crowe, Dept. of Mechanical Engr. Washington State University.

(III) Thesis and Dissertation Sponsor

- MS Thesis, Marcela Durán, Dept. of Civil Eng., Univ. of Puerto Rico-Mayagüez (1997).
- MS Thesis, Laura Carbó, Dept. of Civil Eng., Univ. of Puerto Rico-Mayagüez (1998).
- MSThesis, Leydy Collazos, Dept. of Civil Eng., Univ. of Puerto Rico-Mayagüez (1999).
- MSThesis,Victor Arangoitia, Dept. of Civil Eng.,Univ. of Puerto Rico-Mayagüez (2000).
- MS Thesis, Eddy Peralta, Dept. of Mech. Eng., Univ. of Puerto Rico-Mayagüez (2001).
- MSThesis,Christian Villalta, Dept. of Civil Eng., Univ. of Puerto Rico-Mayagüez (2002).
- MSThesis,Alejandra Rojas, Dept. of Civil Eng., Univ. of Puerto Rico-Mayagüez (2003).
- MSThesis,Eduard García, Dept.of Mech. Eng., Univ. of Puerto Rico-Mayagüez (2003).
- MS Thesis, Luz E. Torres, Dept. of Civil Eng., Univ. of Puerto Rico-Mayagüez (2004).
- MS Thesis, Jaime Suarez, Dept of Mech. Eng., Univ. of Puerto Rico.-Mayaguez (2005)
- MSThesis, Julio Coaquira,Dept. of Civil Eng., Univ. of Puerto Rico-Mayagüez (2006)
- MSThesis,Federico García, Dept. of Civil Eng., Univ. of Puerto Rico-Mayagüez (ex2007).
- PhD Dissertation, Eduard García, Dept. of Civil Eng., Univ. of Puerto Rico-Mayagüez (ex 2008).