

CRC 4<sup>nd</sup> Annual Meeting: March 27-28, 2019  
Chapel Hill, NC

## Education for Improving Resilience of Coastal Infrastructure

**Ismael Pagán-Trinidad (PI)<sup>1</sup>, Ricardo R. López (Co-PI)<sup>2</sup>,  
Carla López del Puerto<sup>3</sup>**



**Civil Infrastructure Research Center (CIRC)  
Department of Civil Engineering and Surveying  
University of Puerto Rico at Mayagüez, Mayagüez, Puerto Rico  
(MSI-HSI)**



*1- Department Director; 2- CIRC Director/Dept. Associate Director; 3- Senior Personnel  
University of Puerto Rico. Mayagüez*

# Outline

- **Engagement with Users**
- **Activities and Outcomes**
- **Anticipated Impact**
- **Plans to Institutionalize and Sustain**

## HSE Educational Gap Resiliency of Coastal Infrastructure (RCI)

### Goal

Help educate the community by **transferring state of education and practice** knowledge and experiences to stakeholders

### Motivation

**Engage stakeholders** in advancing state of knowledge in coastal resilient infrastructure

### Target Stake Holders

Students, faculty, professionals, first responders, work force (**FEMA, municipalities, government**)

### Formal Education

**New Courses, internships, projects** (MS theses, undergraduate research, special professional projects)

### Informal Education

Conferences, workshops, seminars, lectures, short courses, "Conversatories"

**Help develop Education Culture in Resilient Coastal Infrastructure (RCI)**

**Provide Education**

**Engage Stakeholders**

**Attract Labor Force**

## END USERS ENGAGEMENT

**Students:** Trainees (Theses, Projects, Internships, Presentations, Articles, Posters, Essays)

**Faculty:** Trainers/Trainee/Mentors:/Researchers; Courses, Invited speakers, Independent Research, Interviews, Field inspections, Field studies, External funding proposals, Institutional services

**Sponsors:** Funding, Advise, Support, Opportunities, Partnerships

**Professionals:** Lecturers, Trainees, Certificates

**University Administrators:** Trainees, Certificates, Supporters

**PR-FEMA** – Partners, Planning, Trainers, Trainees, Certificates

**Community organizations/individuals: Participants:** Audience, Trainees, Certificates, Leadership, Feedback

## END USERS ENGAGEMENT –cont.

**Government:** Speakers, Certificates Federal, Local and Municipal Agencies Officials, Trainees, Trainers, Certificates

**ERDC- Coastal and Hydraulic Lab:** Sponsors and Mentors, 2 Internships, 4 Projects, 2 Theses; **Environmental Lab**

**PR Dept. of Natural and Environ. Res.-Coastal Management Program and PR Climate Change Council-PRCCC (Ernesto Díaz):** Instructor-Conference Collaborator, Coauthor

**PR College of Engineers and Surveyors** Faculty participation on special commissions to review construction codes and regulations (L. Aponte, J. Martínez, R. López); Continuing Education

**NOAA Tsunami Center:** Training and Drills; **Seismic Network/PRSMF:** Earthquakes, Tsunamis

**Transportation Technology Transfer Center:** FHWA, PRDTPW, PRHTA (B. Colucci) – Co-sponsor, Lecturer, Mentor

**PR Sea Grant and CARICOOS (NOAA) Programs:** Collaborators, Co-sponsors

# Education Work and Accomplishments

## Activities and Outcomes to Date

- **SUMREX**
- **Students' Research**
- **Sponsored Conferences and Presentations**
- **ReTALK**
- **Courses**
- **Expected Activities**

# Education Work and Accomplishments

## 2018 SUMREX INTERNSHIP

**2 students @ OSU**

**Bryan Acevedo, BSCE**

**Jorge Santiago, BSCE**

**Advisor: Dr. Dan Cox , Oregon State University, Corvallis OR**

**Title: Modelling Structural Response of Coastal Residences Under Wave Loads**

**Outcome: PPT Oral Presentation, Proposal, Paper, Poster, Essay, 3 crds.)**



**Second Prize Winners  
Creative Open Capstone  
UPRM, Dec. 2018**

# Education Work and Accomplishments

## 2018 SUMREX INTERNSHIP

### Follow-up on SUMREX Students

**Bryan Acevedo**, still working on BSCE, participates as undergraduate assistant on NSF project RISE-UP, A Collaborative Undergraduate STEM Program in Resilient and Sustainable Infrastructure. **He also participates in the Earthquake Engineering Institute Seismic Design Competition.**

**Jorge Santiago**, completed his BSCE at UPRM and is currently working on his PhD in Civil Engineering with specialty on structural and coastal engineering at University of Florida – Gainesville. He holds an NSF IGERT grant led by Dr. Forest Masters with the participation of Dr. Luis Aponte from CE Department at UPRM.

# Education Work and Accomplishments

## 2016 SUMREX INTERNSHIP

### Follow up on SUMREX Students

**Diego Delgado**, SUMREX 2016 and 2017, completed his BSCE at UPRM and is currently working on his PhD in Civil Engineering in Spain.

**Kevin Cueto**, SUMREX 2016 and ERDC 2017, completed his BSCE at UPRM and is currently working on his MSCE in Civil Engineering in UPRM, working on Computational Fluid Dynamics modelling of effects of storm surge and tsunami loads on structures.

**Félix Santiago**, SUMREX 2016, completed his BSCE and MSCE at UPRM and is currently working on his PhD in Civil Engineering at LSU, working under the guidance of Dr. Scott Hagen.

# Education Work and Accomplishments

## 2017 SUMREX INTERNSHIP

### Follow up on SUMREX Students

**Peter Rivera**, SUMREX 2017, completed his BSCE at UPRM and is currently working on his Master in Mechanical Engineering at UPRM.

**Hector Colón**, SUMREX 2017, is close to finishing his BSCE at UPRM. He plans to continue graduate studies.

## Education Work and Accomplishments - cont.

### CHL-ERDC Internships/Projects

Ismael Pagán -Trinidad (Academic Mentor/PI) – Proposal/Paper/Poster/Presentation/Essay

- **Nelson Cordero (Graduate Student): June 2018 to May 2019**

Assessment of Hurricane Vortex Models and Boundary Layer Models for the Development of Wind and Pressure Profiles and Fields – Coastal Hydraulic Laboratory

Advisor: Dr. Norberto Nadal, CHL-ERDC

Nelson has been working on CHL projects since 2017.

## Education Work and Accomplishments - cont.

### NSF – PIRE Summer Intern Proposals (Partnership with JSU/TAMG)

Ismael Pagán -Trinidad (Academic Mentor/PI)

Acknowledgement to Dr. Robert Whalin and Dr. Tom Richardson

- **5 Proposals by UPRM students were submitted**
- **Project is sponsored by NSF and managed by Texas A&M-Galveston and Jackson University**
- **One student, [Sofia N. Rivera-Soto](#) was selected to attend the internship and travel to Netherlands in Summer of 2019. Will spend 2 weeks in the Netherlands in May and 10 weeks at UPRM completing her research project during Summer.**
- **[Assessing changes in pH, temperature and salinity in the Eastern Scheldt estuary](#) :**

**The topic was based on trying to answer two proposed research questions: How have pH, temperature, and salinity levels in the Eastern Scheldt estuary changed since the creation of the barrier in 1986? Additionally, how have these variables impacted the estuary's water and the surrounding land's soil through processes of saltwater intrusion and CO2 absorption?**

## Education Work and Accomplishments - cont.

### Research Theses and Projects at UPRM

- **Angel Alicea (PhD):** “Dynamic Identification and Nonlinear Modeling for the Structural Health Assessment of Aged Coastal Infrastructure in Puerto Rico”, PhD dissertation completed in December 2018, also worked in educational activities for the project, has been co-sponsored by FHWA Eisenhower Fellowships.
- **Kevin Cueto (MSCE):** “Modeling considering Computational Fluid Dynamics of hydraulic pressure exerted on coastal structures”, MS thesis in progress, also works in educational activities for the project.
- **Alexander Molano (MSCE):** “Education and Awareness in Resilience of Coastal Transportation Infrastructure”, MS thesis in progress, also works in educational activities for the project, prepared several presentations and participated in Special Topics courses, FHWA Eisenhower Fellow.
- **Jorge Romeu (MECE):** “Structural Analysis of Common Coastal Structures Found on the West Coast of PR using FEMA P-646”, ME project in progress, also works in educational activities for the project, serves as instructor for Capstone course.



**Dr. Angel Alicea (PhD-Dec 2018)**  
**Advisor: Dr. Ricardo López**

# Education Work and Accomplishments - cont.

## Research Theses and Projects at UPRM

- **Juan Rodríguez (PhD):** 1. “Variation of the nonlinear dynamic response of three-dimensional buildings of reinforced concrete considering the directionality of seismic accelerations”, PhD dissertation in progress. 2. Also works in educational activities for the project preparing presentations, certificates and collecting information.
- **Johnny Rosario (PhD):** “Resistance to Tsunami Loads of Critical Structures in Puerto Rico”, PhD dissertation in progress.
- **Nelson Cordero (MSCE):** “ Configuration and Validation of the Weather Research and Forecasting Model (WRF) for Tropical and Extratropical Cyclones with Applications in Hydrodynamic Modeling” , MS thesis in progress.
- **Efraín Ramos (MSCE):** “Stochastic Simulation of Tropical Cyclones for Quantification of Uncertainty associated with Strong Recurrence and Intensity”, MS thesis in progress. Currently working on his thesis at CHL-ERDC.

# Sponsored Conferences and Seminars

- [Re-Imagine Puerto Rico](#) a discussion panel on solutions to rebuild PR, co-sponsored with Resilient Puerto Rico Advisory Commission, 11 speakers including **Prof. Ismael Pagán**, ample audience participation, UPRM, August 14, 2018
- [Coastal Resiliency Building, Mainstreaming Adaptation](#), Ernesto Díaz, Director, Coastal Management Program of Dept. Natural Environment Resources and of PR, offered at Capstone course, UPRM, October 4, 2018
- [Digital Coast Tools Applications-1 day Seminar](#), Sponsor: PR Sea Grant, NOAA, CRC; Two NOAA instructors, UPRM, December 5, 2018
- [NOAA Coastal Inundation Mapping Workshop](#), Sponsors Sea Grant, NOAA, CRC; two NOAA instructors, UPRM, December 6-7, 2018



**GIS Training for Coastal Resource Professionals**

**NOAA Coastal Inundation Mapping**

**On-site Regional GIS Training**  
To help address the need for building technical capacity within research reserves, regulatory programs, emergency preparedness offices, Sea Grant programs, and other organizations who manage coastal resources the National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management has partnered with Sea Grant Puerto Rico to offer two days of free geospatial training.

**Course Content**  
The two-day intermediate level course offers a combination of lectures and hands-on exercises designed to give students a better understanding of coastal inundation issues and inundation mapping methods using GIS. Topics include the different types of coastal inundation, elevation datasets and datums, spatial methodologies used to map flood areas in a coastal environment, the applications and limitations of various types of inundation products, and mapping sea level rise including uncertainty.

For questions about course content please contact Matt Pendleton at [Matt.Pendleton@noaa.gov](mailto:Matt.Pendleton@noaa.gov).

**Training Logistics**

**Location:** CAIRel. Computer Lab. (CI-019)  
Civil Engineering and Surveying Department  
University of Puerto Rico @ Mayaguez.

**Dates:** December 6-7, 2018. Time both days: 8:30 am - 4:30 pm  
Lunch will not be provided, local options area available.  
Only 25 spaces available.

**Requirements:** The intended audience for this two-day course is certified floodplain managers, National Weather Service personnel, and county, state, and municipal officials (including planners, emergency managers, and coastal resource managers). **Class participants should have basic GIS skills (6 months to 1 year).**

**To Register:** Link: <https://open.gi/forms/0c9ah2ZYAEwdfes1>  
or contact Lillian Ramirez ([Lillian.Ramirez@upr.edu](mailto:Lillian.Ramirez@upr.edu))

The bottom of the flyer features logos for NOAA, Sea Grant, and the Coastal Resilience Center.

# Sponsored Conferences and Seminars, cont.

**Research in Coastal Engineering**, Sponsors with CARCI NSF planning grant with Dr. Dan Cox, Six speakers including three from Oregon State University, one from Rice University and two from UPR Mayagüez, UPRM, December 6, 2018

**NOAA – Introduction to Green Infrastructure for Coastal Resiliency**: Co-sponsored with NOAA, PR Sea Grant Program, UPRM-CRC, December 12, 2018

**Coastal Resiliency Building and Promoting Adaptation**: Ernesto Díaz of Dept Natural Resources and Environment of PR, offered at Capstone course UPRM, January 31, 2019

**Low Impact Development and Green Alternatives for Urban Projects**: Sponsors FEMA, CRC; Speaker Ismael Pagán Trinidad, Aguadilla FEMA Headquarters, February 8, 2019

**Seminar on the Integral Management of Hydrographic Watershed**: Sponsors with FEMA, UPRM, March 5, 2019



## Panels on Energy

- **Small Modular Reactors: A Feasible Option for Puerto Rico?**, a panel discussion, co-sponsored with Nuclear Alternative Project, UPRM, October 30, 2018
- **Public Forum: Energy Policy in Puerto Rico, What is Ongoing**, Co-sponsored with INESI, UPRM, November 29, 2018
- **Note:** A **proposal for the DoE** is under development to study the feasibility of nuclear plants in Puerto Rico with the participation of UPRM faculty

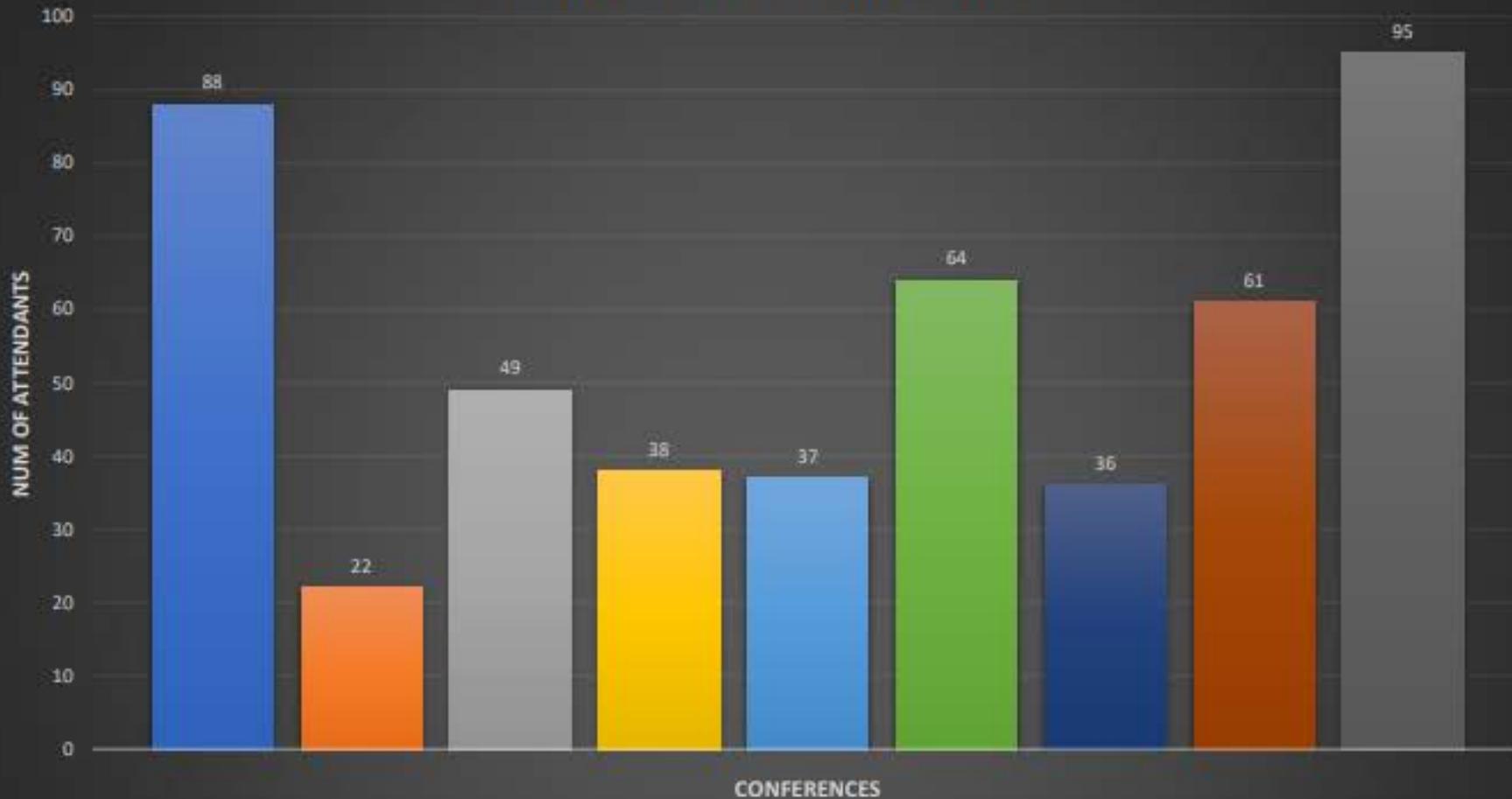
The poster features a background image of a coastal landscape with a road and a large white dome structure. At the top left is the University of Puerto Rico logo. The title 'PANEL DISCUSSION Small Modular Reactors: A feasible option for Puerto Rico?' is in bold green and black text. Below the title is a call to action: 'Come and engage directly with experts about the option of small modular reactors to transform Puerto Rico's energy infrastructure.' A white speech bubble on the left says 'LET'S TALK!'. The date and time 'OCT 30 2018 5PM-8PM' are in green. The location 'WHERE Auditorium Civil Engineering Department University of Puerto Rico - Mayagüez' is in black. A green box on the right says 'Sponsored by' with logos for 'THE NUCLEAR ALTERNATIVE PROJECT' and 'Nuclear Alternative Project'. Below that is a green box with white text: 'Puerto Rican Engineers working in the US energy sector committed to connect the people of Puerto Rico with the technological advances of nuclear power and its opportunities for the island.' The 'WHO will be there?' section lists speakers with their photos and affiliations: Jesabel Rivera (Community Impact & Engagement Consultant, Nuclear Alternative Project), Eddie Guerra (Senior Structural Engineer, ARUP), Carlos Fernandez (Chair of Environmental, Energy and Land Use Practice Group, McConnell Valdes), Donald Hoffman (President and CEO, EXCEL), Jose Reyes (Cofounder & Chief Technology Officer, NUSCALE), Angel Reyes (Senior Programs Engineer Plant Operations, Exelon), Jeffrey Harper (Vice President, Strategy & Business Development, Xenergy), Abdul Dulloo (Director, Plant Technology & Product Development, Westinghouse), Scott Singer (Chief Security & Information Officer, PAR SYSTEMS), David Sledzik (Senior Vice President Nuclear, HITACHI). A box titled 'Topics include:' lists: Nuclear waste management, Technological safety advances, Earthquakes and tsunamis, Environmental impact, Operation and management, Energy and Transportation Systems, Financing, Public perception & social responsibility, Cyber-security, Federal regulations, Economic development, Solar + Wind + Nuclear.

## Seminar on the Integral Management of Hydrographic Watershed

Sponsors: FEMA, UPRM-CRC, March 5, 2019 (audience=95)



# CONFERENCE ATTENDANCE



■ Relmagina Puerto Rico

■ NOAA Digital Coast Tools Seminar

■ NOAA Coastal Inundation Mapping Workshop

■ Coastal Resiliency Building, Mainstreaming Adaptation

■ Seminar on the Integral Management of Hydrographic Watershed

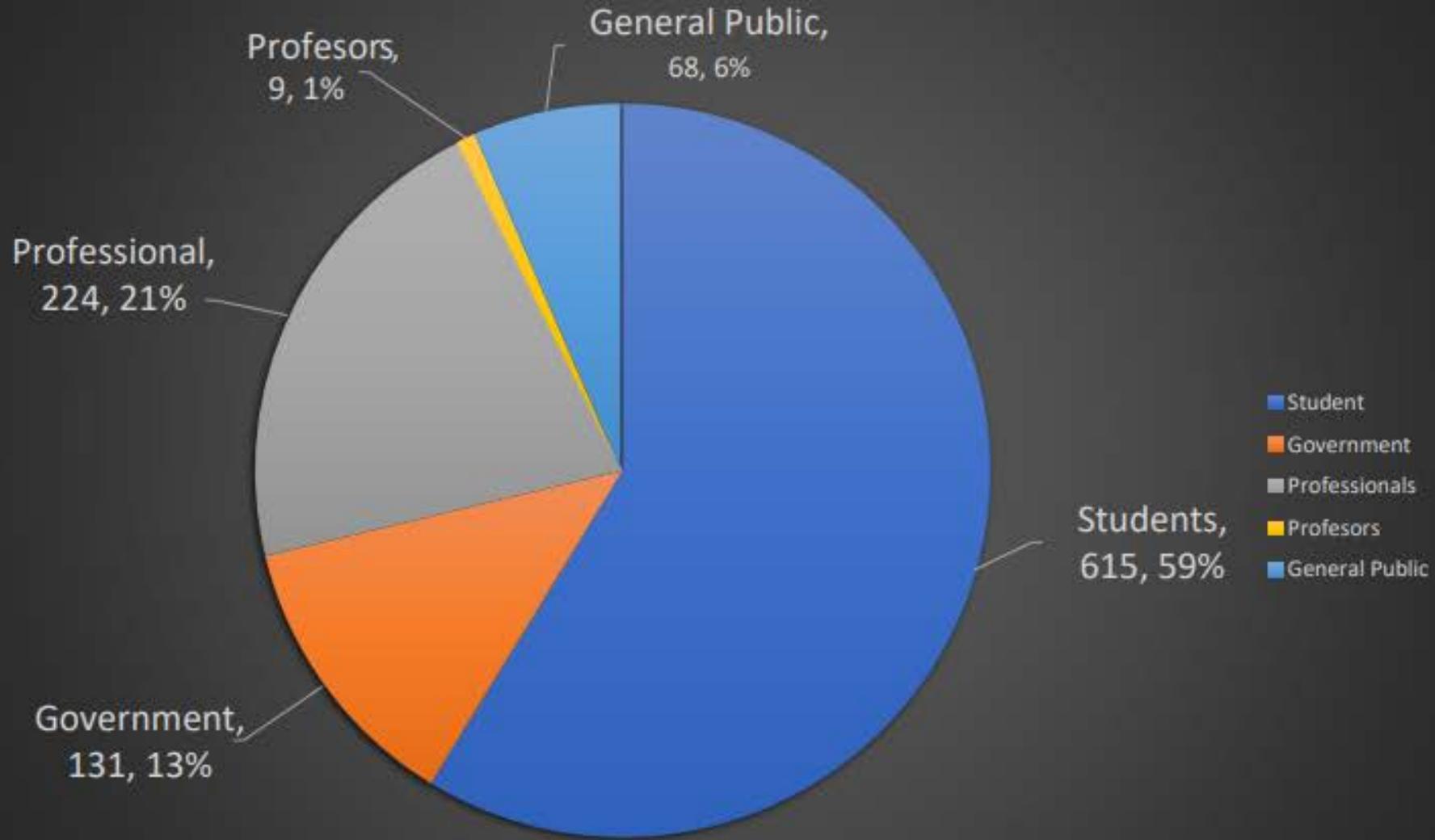
■ Coastal Resiliency Building, Mainstreaming Adaptation

■ Presentation on Research in Coastal Engineering

■ NOAA: Introducción a la Infraestructura Verde para la Resiliencia Costera

■ Low Impact Development (LID) and Green Alternatives for Urban Projects

# ATTENDANCE BY CATEGORY



# Presentations/Meetings by Researchers

- **Ismael Pagán Trinidad and Ricardo López** at Re-Imagine PR, Mayaguez, August 2018
- **Ismael Pagán Trinidad and Ricardo López** at Rincón, December 12, 2018
- **Ismael Pagán Trinidad, Ricardo López and Raúl Zapata**, at Aguadilla, February 8, 2019
- **Carla López del Puerto, Ismael Pagán Trinidad and Ricardo López** at ASCE Construction Summit in Atlanta, March 7 to 9, 2019
- **Ismael Pagán Trinidad and Ricardo López**, at Gavin Smith's Seminar at UNC, February 27, 2019, remote.
- **Ismael Pagán Trinidad and Ricardo López**, at Gavin Smith's Seminar at NCSU, February 27, 2019, remote.
- **Ismael Pagán Trinidad and Ricardo López** were invited and participated in Coastal Engineering Workshop, sponsored by NSF, held in Arlington, Virginia, November 13 and 14, 2018.



## Puerto Rico Beach Recovery Post-Maria 2017: Erosion Assessment, Control and Management

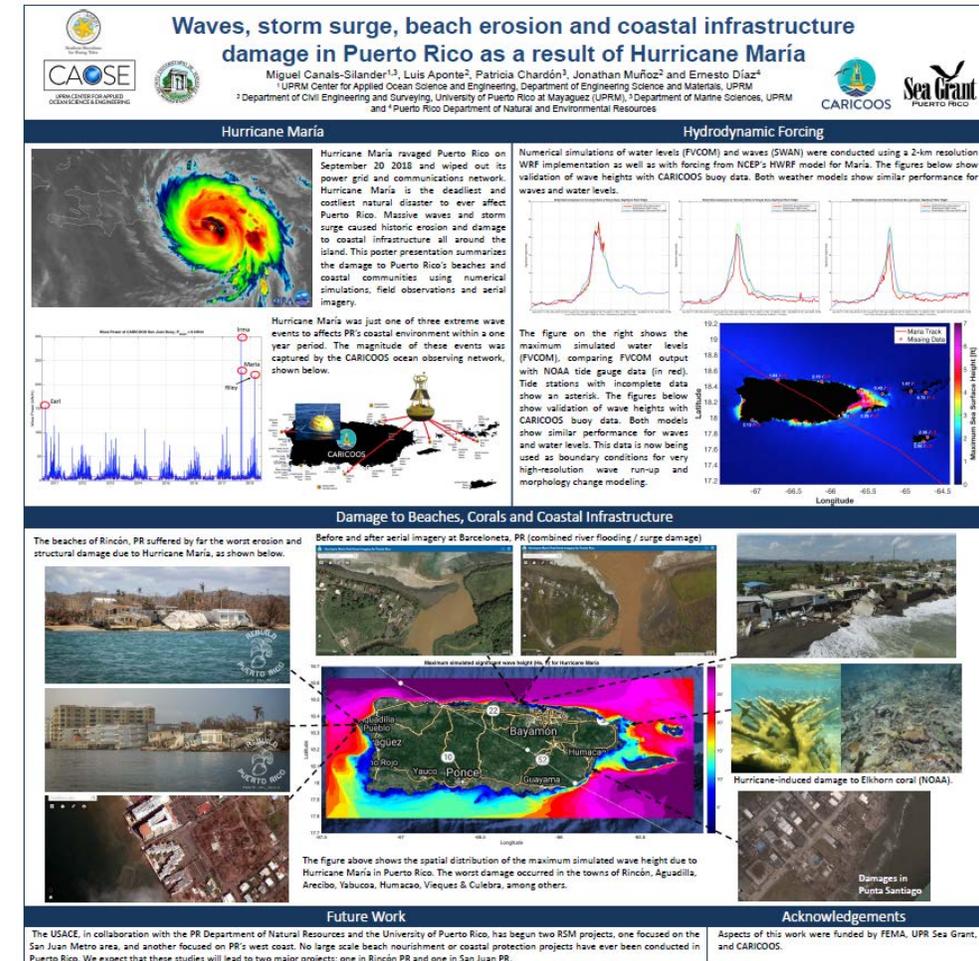
Dr. Luis D. Aponte-Bermúdez, Professor; Dr. Miguel Canals, Professor UPRM; Dr. Jonathan Muñoz Associate Professor, UPRM, Dra. Patricia Chardon, UPRM Researcher & Mr. Ernesto Diaz, Director of DRNA Coastal Management Program Office

### Purpose:

Provide support to decision making for the Department of Interior Puerto Rico Hurricane Maria recovery efforts. Specifically, addressing the need for science support to assess shoreline changes and identify beach erosion amelioration strategies, including recommendation to protect, adapt or retreat. The findings presented on this poster were funded by the US Dept. of Interior Fish and Wildlife Service Award No.

F18AC00144

Poster presented at: American Shore & Beach Preservation Association; Resilient Shorelines for rising Tides; Galveston October 30 – November 2, 2019



## Life Cycle Coast Analysis of Beach Restoration: Rincón, PR Testbed

Dr. Luis D. Aponte-Bermúdez, Professor; Dr. Miguel Canals, Professor UPRM; Graduate Student: Francisco Villafañe

### Abstract:

A tool for determining oceanfront property cost from updated public records and sand volume using UAV and exiting bathymetry and elevation data was developed for the Rincón shoreline located at the northwest corner of Puerto Rico. Rincón has one of the most rapidly eroding coastlines in Puerto Rico and was severely affected by hurricane Maria on September 20, 2017. In order to protect life and property beach restoration in many areas has been the method of choice. This method remains controversial due to its high cost and requires an adequate cost-benefit analysis. Two major obstacles were identified and addressed in this analysis. The first was the creation of a method for updating oceanfront property values from existing public records. The second was to estimate the volume of sand needed to extend the life of the beach and protect coastal infrastructure. During the study, the value of oceanfront properties was successfully updated to present values, and the sand volume was determined using UAV and existing bathymetry and elevation records. The value of coastal infrastructure was compared with the cost of protecting that property using beach restoration. The findings presented on this poster were funded by the University of Puerto Rico Sea Grant College Program under project No. R/75-1-14.

Poster presented at: American Shore & Beach Preservation Association; Resilient Shorelines for rising Tides; Galveston October 30 – November 2, 2019

**A benefit-cost analysis of using beach nourishment to protect Rincón Puerto Rico shoreline**

Luis D. Aponte Bermúdez, P.E., Ph.D.<sup>1,3</sup>, Francisco J. Villafañe Rosa, S.I.T., M.S.<sup>1,3</sup>, Miguel Canals, Ph.D.<sup>2,4</sup> and Brian Aponte Ramos<sup>1,4</sup>  
[luis.aponte@upr.edu](mailto:luis.aponte@upr.edu)

<sup>1</sup>Department of Civil Engineering and Surveying, University of Puerto Rico at Mayagüez  
<sup>2</sup>Department of Engineering Science and Materials, Center for Applied Ocean Sciences and Engineering  
<sup>3</sup>University of Puerto Rico at Mayagüez  
<sup>4</sup>University of Puerto Rico at Mayagüez

**Abstract**

A tool for determining oceanfront property cost from updated public records and sand volume using UAV and exiting bathymetry and elevation data was developed for the Rincón shoreline located at the northwest corner of Puerto Rico. Rincón has one of the most rapidly eroding coastlines in Puerto Rico and was severely affected by hurricane Maria on September 20, 2017. In order to protect life and property beach restoration in many areas has been the method of choice. This method remains controversial due to its high cost and requires an adequate cost-benefit analysis. Two major obstacles were identified and addressed in this analysis. The first was the creation of a method for updating oceanfront property values from existing public records. The second was to estimate the volume of sand needed to extend the life of the beach and protect coastal infrastructure. During the study, the value of oceanfront properties was successfully updated to present values, and the sand volume was determined using UAV and existing bathymetry and elevation records. The value of coastal infrastructure was compared with the cost of protecting that property using beach restoration. A conservative Benefit-Cost Ratio for the Rincón area ranges from 4 to 2, for site conditions prior to Hurricane Maria. The findings presented on this poster were funded by University of Puerto Rico Sea Grant College Program under project No. R/75-1-14.

**Background and Motivation/Introduction**

The town of Rincón is located in the northwest corner of Puerto Rico and has a current population of about 15,000. Like other US American beach communities, Rincón's local economy thrives on the condition of its beaches and has been driven primarily by the tourist industry since the late 1950s: its seashfront hotels and the variety of small beaches along its shoreline are key to its prosperity. This project is intended to provide information to private and public planners to make the best decisions in coastal zone management. The research performed involved analysis and manipulation GIS data from the USGS, CHRM, USACE, SIME, PFRB, and ORNA. The alternatives available to mitigate economic issues related to coastal erosion are managed retreat, armoring, and beach nourishment. The USGS study prepared by Thielier et al. (2007) provides historical data of shoreline position for the region from 1936 to 2006. The database of the Center for Municipal Income Revenue Collection (CRIM), by its acronym in Spanish, includes parcels and property values and is used in the herein study to estimate the current value of oceanfront properties. A Lidar Digital Elevation Model (DEM) provided by USACE has been used to determine the required sand volume to provide a 33 m berm in the most critical region along the shoreline.

**Location Map/Site Location**

**Available Data**

The shoreline changes presented in Figure 1 shows the severe reduction for the area of Córcega, Rincón from 1936 to 2016. Rincón's CHRM database, illustrated in Figure 2, consists of 8,164 properties for the entire municipality. Table 1 indicated that 613 properties along Rincón's shoreline are considered first location, also known as waterfront properties by its geographical location. The CHRM's database provides a property appraisal value adjusted to the year 1975 (Job & Rodríguez, 2016). Only 1,506 parcels, approximately 30 %, contain data regarding sales including amount value and transaction date.

Location	# of properties
Ocean Front	613
Within 1km from	
Aerial	4,422
Total	8,166
Filtered data	
Criteria	Average growth (m/yr)
Ocean Front	5.76 %
Within 1 km from	
Aerial	5.81 %
Total	6.37 %

**Historical Shoreline Changes**

**Methodology**

The shoreline changes presented in Figure 1 shows the severe reduction for the area of Córcega, Rincón from 1936 to 2016. Rincón's CHRM database, illustrated in Figure 2, consists of 8,164 properties for the entire municipality. Table 1 indicated that 613 properties along Rincón's shoreline are considered first location, also known as waterfront properties by its geographical location. The CHRM's database provides a property appraisal value adjusted to the year 1975 (Job & Rodríguez, 2016). Only 1,506 parcels, approximately 30 %, contain data regarding sales including amount value and transaction date.

**Results**

Figure 3 summarizes the interest growth rate calculated for all the properties in the municipality of Rincón which is summed up in the color magenta subplot. All the properties within 1 km from the shoreline are represented in the green subplot and the oceanfront properties belong to the yellow subplot. Figure 4 shows the devastation cause by Hurricane Maria at various coastal residential properties in the Córcega Rincón area that include family dwelling and residential apartments complex. CARICOO's Rincón buoy (WDR-4112) recorded on September 20, 2017 at 19:30 AET a maximum wave height of 24-25 m from southwest.

**Nourishment Cost**

Typical unitary cost ranges from 59 to 548 per yd<sup>3</sup> in the east coast of the US. Bearing in mind these unitary costs, a preliminary cost to conduct the proposed beach nourishment in Rincón ranges from \$15,000,000 to \$80,000,000. Further cost analysis is needed, given that the mobilization cost of the equipment to the island might drive up the costs and the area have been severely impacted after Hurricane Maria.

**Armoring Cost**

A preliminary cost analysis to armor the beach placing solid structures, such as sheet piles or concrete modular gravity walls, to protect the coastal infrastructure was obtained from a tool from the manufacturer (Sheelife). The typical cost according to this resource for a sheet pile is \$1,500 per linear foot and for concrete modular gravity walls it is \$2,000 per linear foot.

**Acronyms**

ORNA: Global Metrics Engineering  
 CHRM: Municipios Revenue Collection Center  
 ORNA: "Departamento de Recursos Naturales y Ambientales"  
 PFRB: Puerto Rico Planning Board  
 TIN: Triangulated Irregular Network  
 USACE: United States Army Corps of Engineers  
 USGS: United States Geological Survey

**Acknowledgement**

Special thanks to the Sea Grant College Program of the University of Puerto Rico for the support and funding provided to conduct project number R/75-1-14 titled Life Cycle Cost Analysis of Beach Restoration: Rincón, PR Testbed, to the Office of the Puerto Rico. Also, many thanks to the Puerto Rico Digital Coastal Office (CRIM) and CARICOOs for providing the data.

## Instructor of FEMA Building Science Courses

Dr. Luis D. Aponte-Bermúdez, Professor UPRM and STARR II Consultant

- **Fundamentals of Building Science (L0312 – 4Day course)**
- **Coastal Construction course (L0386 – 2Day course)**
  - Multi-Hazard Mitigation Design Concepts
  - Audience: FEMA and Government of Puerto Rico personnel
  - Purpose: Building capacity among local government officials and FEMA personnel
  - Dr. Aponte in collaboration with other FEMA consultants customize the training with content, conclusions, and recommendations from the Mitigation Assessment Team Report: Hurricanes Irma and Maria in Puerto Rico (FEMA P-2020).

## Publications by Students

- **Hector Colón**, SUMREX 2017, Paper and Presentation, ASCE Coastal Engineering International Conference, **“NUMERICAL MODELLING OF TSUNAMI INUNDATION CONSIDERING THE PRESENCE OF OFFSHORE ISLANDS AND BARRIER REEFS”**, Baltimore, MD, July 2018
- **Alexander Molano**, Graduate student supported by the CRC project, Paper and Presentation, **“Impacts and Lessons Learned as a Result of the Passage of Hurricane Maria on the Transportation Infrastructure of the Caribbean Island of Puerto Rico”**, by Colucci, Figueroa and Molano, UPADI, August 2018.
- **Alexander Molano**, Graduate student supported by the CRC project, Paper and Presentation, **“Lessons Learned for the Puerto Rico Transportation Infrastructure after Hurricane María”**, by Colucci, Figueroa and Molano, ITE, October 2018.

## ReTALK

- **Research in Coastal Engineering** at UPRM, Dr. Dan Cox, OSU, 6 lectures, December 6, 2018
- Two lectures by Ismael Pagán and Ricardo López on Gavin Smith's courses in UNC and NCSU, February 27, 2019.



### Observations of the Impact and Recovery from Hurricane María on Puerto Rico : An Engineering Perspective

presented at course LAR 582 004: Dr. Gavin Smith  
Natural Hazards, Disasters and Climate Change Adaptation Lecture Series  
the University of North Carolina at Chapel Hill and North Carolina State University  
by

Ismael Pagán Trinidad, Ricardo R. López Rodríguez, Carla López del Puerto  
Department of Civil Engineering and Surveying, University of Puerto Rico at Mayagüez  
[ismael.pagan@upr.edu](mailto:ismael.pagan@upr.edu), [ri.lopez@upr.edu](mailto:ri.lopez@upr.edu), [carla.lopezdelpuerto@upr.edu](mailto:carla.lopezdelpuerto@upr.edu)

February 27, 2019

Collaborators and Sources: Ernesto Díaz-PRNER/PRCMP/PRCCC, Humberto Chaparro-PR Sea Grant Program, Benjamín Calucci-T2 Center, Luis Aponte, Alvin Rodríguez, Aurelio Mercado, Patricia Chardón, NOAA, NHC, USGS, COHEMIS-UPRM-CARICOOS, others

*The UPRM Coastal Research Center of Excellence at the Department of Civil Engineering, and the proposed Engineering Research Center for Adaptive and Resilient Coastal Infrastructure invites to the presentations on:*

## **RESEARCH IN COASTAL ENGINEERING**

✓ Lecture by: **Dr. Daniel Cox**

**Planning for an NSF Engineering Research Center for Adaptive and Resilient Coastal Infrastructure (CARCI)**

✓ Lecture by: **Dr. Jamie Padgett**

**Co-Evolution of Chemical Spill Risks and Social Vulnerability in Storm Surge Prone Regions**

✓ Lecture by: **Dr. Peter Rugiero**

**Envisioning Resilient Coastal Futures: Exploring alternative scenarios along the Oregon and Washington coastline**

✓ Lecture by: **Dr. Eduardo Cotilla Sánchez**

**Open access modeling and testbeds for inclusive research**

✓ Lecture by: **Dr. Sylvia Rodriguez**

**Coastal Bottom Boundary Layers Research and other Endeavors**

✓ Lecture by: **Dr. Miguel Canals**

**Geometric and hydrodynamic optimization of coral reef restoration projects to enhance wave power reduction and coastal protection**

✓ Place: **Auditorium-Civil Engineering & Surveying Department**

✓ Date: **Thursday, December 6**

✓ Time: **1:30 pm -3:30 pm**



## Education Work and Accomplishments - cont.

### Formal Courses: 5

- Resilience and Reliability : Ali Saffar, on line course to be offered 2019
- Rehabilitation of Coastal Infrastructure: José Guevara, offered 2018
- Solid Waste and Debris Impact on Coastal Environments - West Coast of Puerto Rico : Ismael Pagán Trinidad, ongoing Spring 2019
- Complex Project Management for Coastal Communities Carla López del Puerto, developed Spring 2019, to be offered Fall 2019
- Civil Engineering Capstone Course: 5 Professors, offered every semester with a different project related to coastal engineering



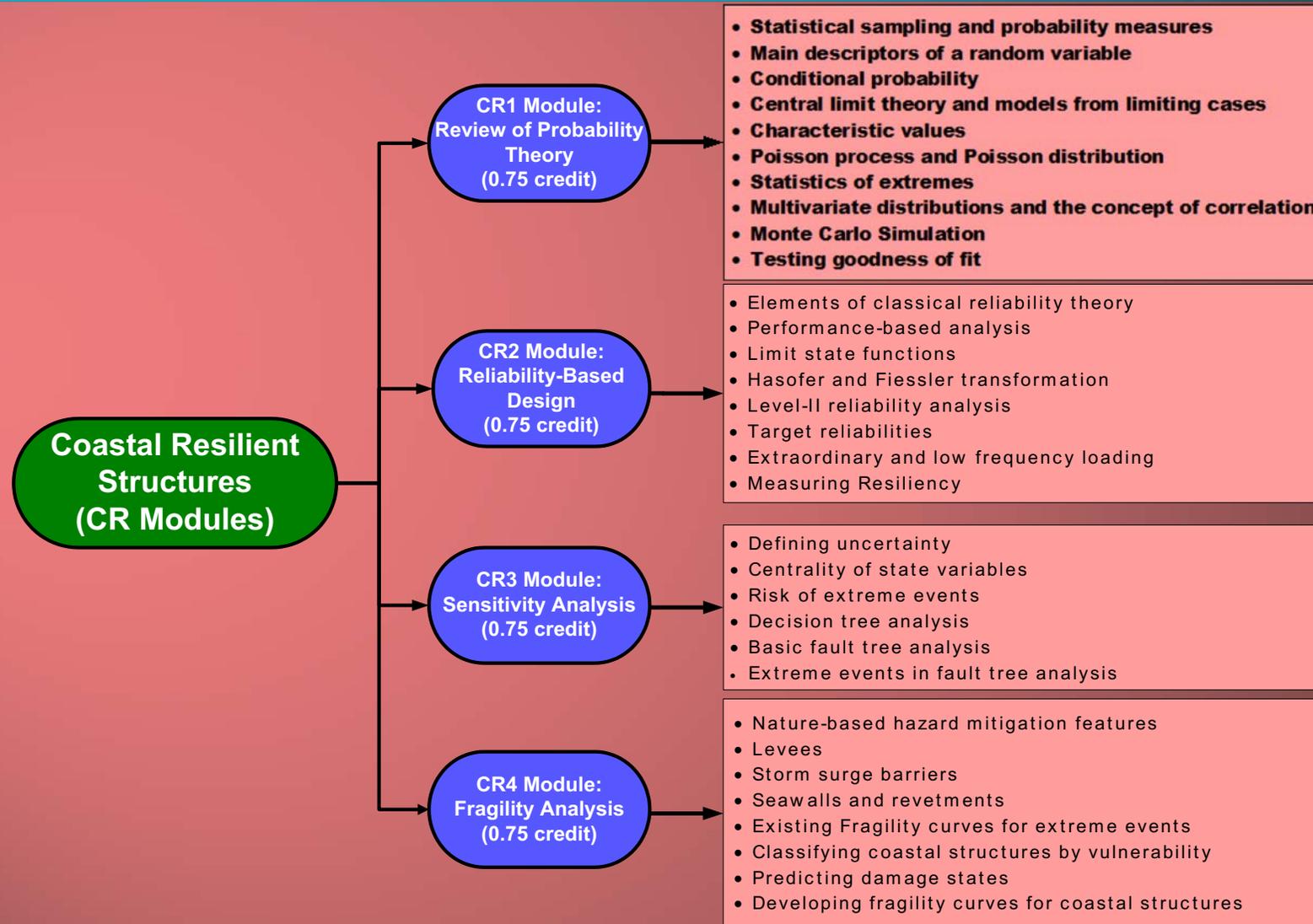
# A First Course on Coastal Resilient Structures

## Unit 1: Design Overview

Dr. Ali Saffar



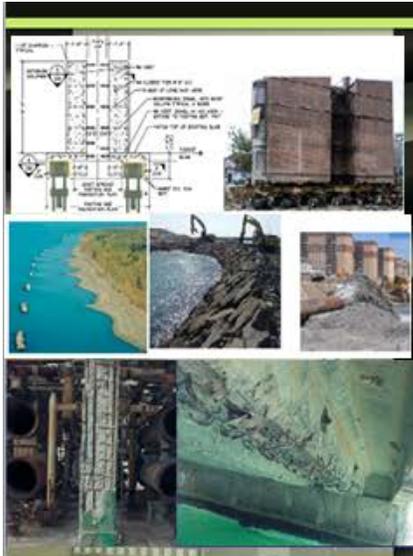
# Structure of the Course



# COASTAL RESILIENCE CENTER

A U.S. Department of Homeland Security Center of Excellence

## Education Work and Accomplishments - cont. Regular Courses –Rehabilitation



**ASSESSMENT AND REHABILITATION  
OF COASTAL STRUCTURES  
INCI 5996/INCI6997**

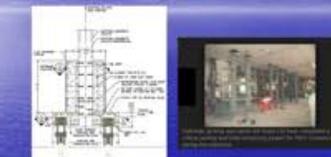
**JOSE O. GUEVARA, Ph.D., P.E.**

***MJ 12:00P.M. 1:15P.M.***

Estimating Loads for extreme events, estimate of the reserve capacity of the structure, criteria to determine the need for repair, quality control, defects in materials, construction, detailing, corrosion, temperature effects, fire effects, manifestation of distress, repair methods and retrofitting, repair of structures affected marine environment, repair of footings, seismic rehabilitation

### ADAPT

- It will require jacketing



REHABILITATION OF STRUCTURES AFFECTED BY MARINE ENVIRONMENT

- PILE ENCAPSULATION, CONCRETE REINFORCEMENT HAD WORK EFFECTIVELY.



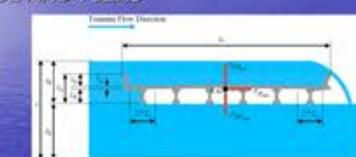
### RETREAT

- Will require move the structure



### TSUNAMIS

- BRIDGE AND PIERS



## Complex Project Management for Coastal Communities

**Dra. Carla López del Puerto, Associate Professor, UPRM**

**Purpose:** To provide participants with the skills necessary to assess the complexity of a project to manage the project effectively

**Emphasis:** Managing complex project in coastal communities to restore services after natural disasters.

**Focus:** Actions that can be taken to meet or exceed expectations for project time, cost, quality, stakeholder satisfaction, and financial feasibility. A five dimensional project management model will be used to manage complexity related to cost, technical, schedule, finance and context. Complexity maps will be plotted to quantify a project's complexity footprint.

**Collaboration:** The Department of Civil Engineering and Surveying has several initiatives that share the **goal of capacity building to increase readiness before, during and after natural events such as hurricanes, tsunamis and earthquakes**. In particular, the **collaboration between CRC, RISE-UP and NSF Rapid projects lead to a panel session titled "Hurricane Maria in Puerto Rico: Assessment of the Damages, Reconstruction Efforts and Beyond Recovery"**, that was presented at the Construction Industry Summit in Atlanta, Georgia.

### Case Study Projects PR and New Zealand

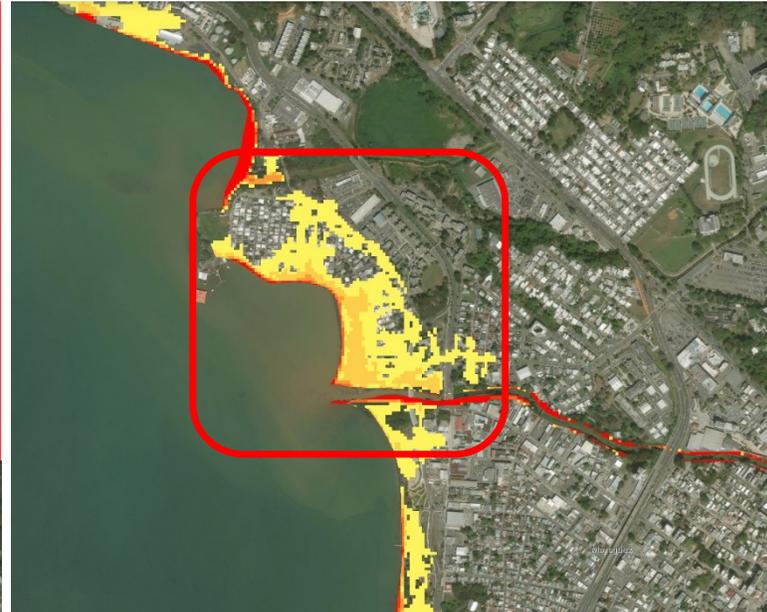
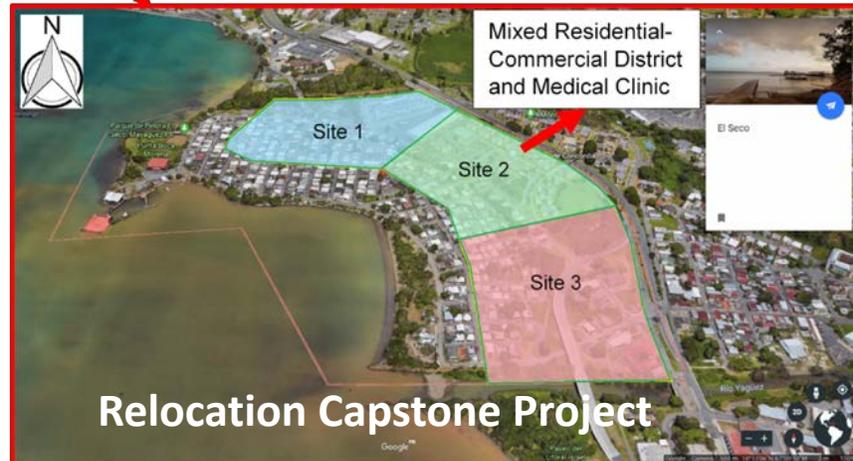


# Education Work and Accomplishments - cont.

## Regular Courses :The Senior CE Capstone Experience

### Incorporate Coastal Resilient Design





## CAPSTONE DESIGN PROJECT

**Site:** El Seco Community - Spring Semester

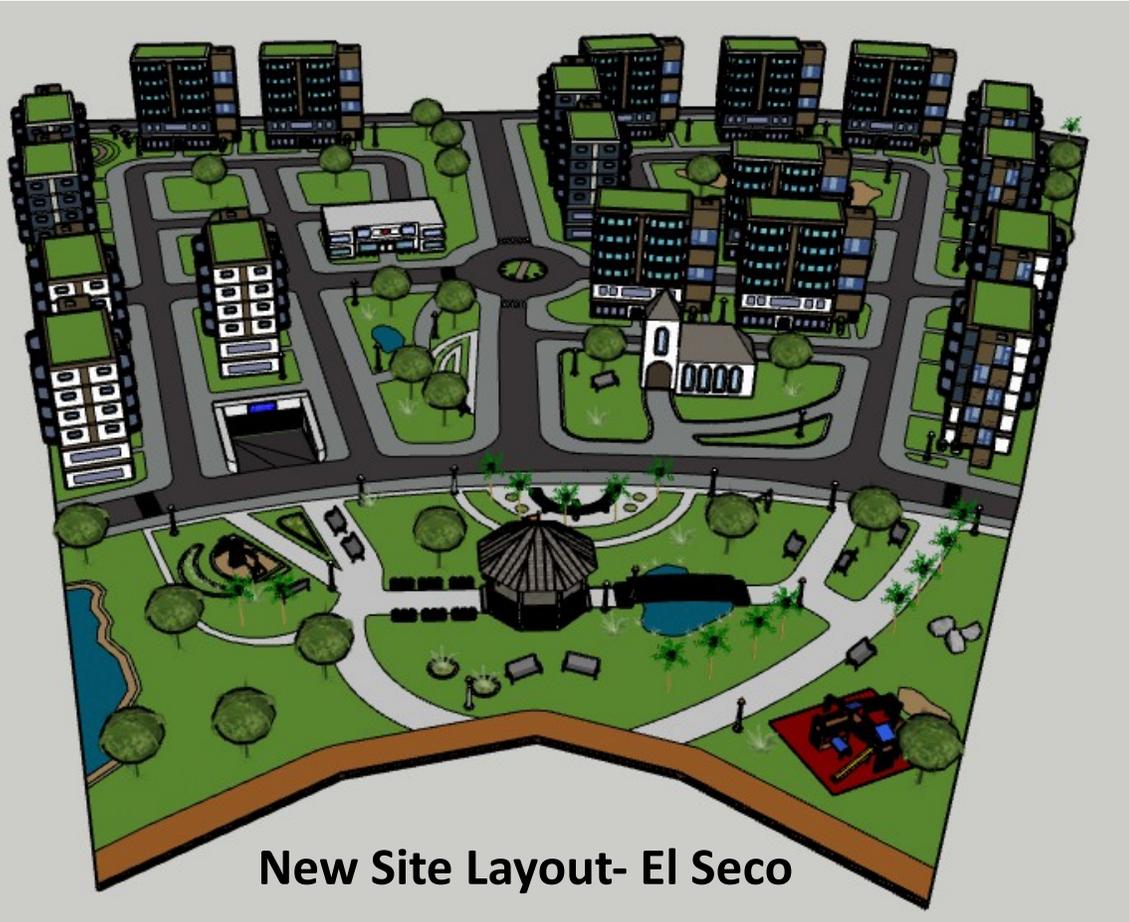
**Participants:** 31 Students, 5 Faculties, 2 Grad Students

**Purpose:** Mixed Use Project (Commercial, Offices, Housing)

**Hazards:** Coastal and riverine floods, wind, earthquake, soil instabilities

**Objective:** Flood Relocation Project (adjacent to the neighborhood)

## 3D view of overall alternative 3 project site Conceptual Plan-El Seco Community



Education Work and Accomplishments - cont.

Regular Courses :The Senior CE Capstone Experience

Incorporate Coastal Resilient Design



**Students from the CE Capstone Course won Third Prize in the Open Capstone Competition at UPRM, December 2018**

## Expected activities

- ReTALK by Dr. Gavin Smith, “ **Relocation of Coastal Communities**”, April 2019
- **Low Impact Development**, Two days Course/Workshop by ERDC, April 2019
- **NSF ERC proposal** participation
- **Consciousness of Tsunamis** (May 22, 2019); **Tsunami Awareness Training for the Disable** (July 31) with the help of FEMA and National Disaster Preparedness Training Center (NDPTC)-UPRM
- Paper submitted and approved for presentation and publication to ASEE Conference in Tampa, FL, June 2019 (“***Education and Building Capacity for Improving Resilience of Coastal Infrastructure***”)
- Course offering –Curricular option Certificate on Resiliency of Coastal Environments
- Curricular Sequence on Coastal and Ocean Engineering (College of Engineering)

## Anticipated Project Impact

- **Stakeholders:**
  - Orient/Train/Educate/Support university/government initiatives to help rise up PR
  - Provide expert resources from the department to our constituents.
  - Focus on collaboration, coordination, and partnerships to deal with mitigation and community preparedness .
  - Make our resources available to support Emergency Offices, First Responders, Faculty and Students
  - Provoke/Promote leadership
- **Pursue and Develop New Knowledge:**
  - **Creative/Research/Development Projects:** Students projects and theses, faculty as lecturers, and presentations:
    - Increase faculty and students participation in “**learned by doing experiences**”
    - Attract more faculty and students to pursue educational and research proposal and projects
    - Attract applications and retain undergraduate and graduate students in CE
    - Stimulate the faculty to work together and be available to continue helping “Rise Up PR”

## Anticipated Project Impact-cont.

- **SUMREX and Internships:** Motivate and maintain students pipeline and interest into RCI enterprise, help identify research and thesis topics, attract students into graduate programs and labor force
- **Curriculum Impacts:** Strengthen CE Curriculum and better prepared for professional practice considering resilient civil infrastructure
- **Reach a larger audience by research, publications and presentations**

## SUSTAINABILITY AND INSTITUTIONALIZATION

- **Department:** Proposed curricular option (certificate) on resilient coastal infrastructure – new and existing courses; engaged faculty, attract students
- **Deanship:** Partnering with other departments to create a multi-department curricular option (or minor)
- **Campus Committee of Emergencies (COE):** Active participation in trainings and emergency drills
- **Municipality:** Participation as members of the Community Advisory Board on Mayagüez Territorial Ordering Plan
- **Partnering:** Engage in active collaboration with DHS partners (**FEMA, NIST, RAND Corporation, NOAA, ERDC, NDPTC, PRDNR, ReImagine PR, The Nuclear Alternative, PRDNR, PR Sea Grant Program, NSF RISE-UP, Oregon NSF-ERC others**).

## SUSTAINABILITY AND INSTITUTIONALIZATION

- **Research/Education/Services**: Synergistic initiatives on research, curriculum development, and institutional services on the topic of resilient infrastructure
  - **Proposals and Projects**
    - **UPRM-NSF RISE-UP Project** : Multicampus-multidisciplinary educational project (CLDP-PI; RL,IPT- Senior Personnel)
    - **NSF CARCI Planning Grant**: Center for Adaptive and Resilient Coastal Infrastructure (RL- UPRM CoPI, a team of faculties from UPRM)
    - **ERDC BAA Projects and Summer Internships** (IPT, PI)
    - **“Expert Analysis of FEMA Cost Estimate Development process and validation for FEMA-4339-DR-PR and FEMA-4340-DR-VI (Hurricane Maria) Remediation / Reconstruction”**: project to assist RAND Co. Consultants to FEMA Center of Excellence (RL-PI, IPT-COPI)
    - **NIST Study of Hurricane Maria's effects on Puerto Rico** – Faculty participation
  - **Engage Faculty and Students**: Continue engaging faculty and researchers in the topic of resilience and sustainable coastal infrastructure
  - **Students pipeline**: Motivate and maintain the interest into RCI enterprise, help identify research and thesis topics, attract students into graduate programs and labor

# Acknowledgement

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*Thank You!*