



# **SUMMARY OF WERI'S ACTIVITIES**

by

**Shahram Khosrowpanah Ph.D., P.E.  
Director**

**February 2016**



# **WERI**

**WATER AND ENVIRONMENTAL RESEARCH INSTITUTE  
OF THE WESTERN PACIFIC  
UNIVERSITY OF GUAM**



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Water & Environmental Research Institute of the Western Pacific  
University of Guam





**WERI Graduate Research Assistants with USGS Hydrologist monitoring observation well in Northern Guam Lens Aquifer.**



**WERI researchers team with local chiefs of Ifalik atoll during their 2015 hydrological assessment of selected outlying islands in Yap State.**



**Leak detection training, Yap State, FSM, 2015.**



**Guam Advisory Council meeting, Hyatt, Guam, 2015.**



**Bill Whitman and Vivianna Bendixson testing water quality of rain catchment system in Ifalik atoll, Yap State, 2015.**



**Yap State Utilities completed leak detection training, Yap State, 2015.**



**Drs. Lander, Heitz, Jenson, Rouse, Senator Tom Ada, Drs. Enriquez, Khosrowpanah, Denton, and Yudin at the *Second Conference on Water Resource Sustainability Issues on Tropical Islands* at Hilton Hawaiian Village Hotel, Honolulu, Hawaii, December 1-3, 2015. The conference was sponsored by the Guam, Hawaii, Puerto Rico, and US Virgin Islands Water Research Institutes.**



# WERI

## Water & Environmental Research Institute of the Western Pacific University of Guam



The Water & Environmental Research Institute of the Western Pacific (WERI) is one of 54 water research institutes established by U.S. Congressional legislation at each Land Grant University in the U.S. and in several territories. The Institute is now in its 41<sup>st</sup> year of operation.

WERI's mission is to seek solutions through research, teaching, and outreach programs, to issues and problems associated with the location, production, distribution, and management of freshwater resources. The Institute provides its regional stakeholders with technical expertise in water resources related fields spanning the entire natural water cycle and spectrum of human water use, including tropical climatology, surface water hydrology, rainfall catchment systems, groundwater modeling and management, and various aspects of water quality. WERI administers and carries out research, training, and other information transfer programs under a variety of federal and local funding sources, but the institute was created specifically to administer Department of Interior (US Geological Survey) money under Section 104-B of the National Institute of Water Research (NIWR) 104-B Program. WERI has responsibility for 104-B monies on Guam, in the Commonwealth of the Northern Marianas islands (CNMI), and in the Federated States of Micronesia (FSM). The faculty and staff of WERI seek to improve economic conditions and quality of life for the citizens of Guam and its regional island partners.

In FY-2015 WERI faculty were involved as principal investigators and/or advisors on 24 research and training projects with a combined budget of approximately \$1,433,826. Of this, \$277,005 was awarded through the Water Resources Research, Institute Program administered by USGS under 104-B, while \$338,320 was received as a special appropriation from the Guam Legislature. The remainder came from other Federal and Private Sources awarded directly to the Institute, or indirectly through local Government Agencies.

Currently, WERI has seven fulltime research faculty, one of whom serves as Director on a rotational basis; one emeritus research faculty

member; a water analysis laboratory manager and technician; two office staff, as well as several graduate and undergraduate research assistants. WERI provides teaching and student advisement for the undergraduate Pre-Engineering and graduate Environmental Science Programs, and also provides community services to the university and public.

WERI runs a state-of-the-art water quality laboratory that supports research and provides public service for water testing.

Over the last ten years, WERI faculty members have collectively published 70 refereed journal articles, 51 technical reports, and over 100 conference proceedings. They have also given numerous professional presentations and training workshops. Following its most recent 3-year evaluation, WERI was once again congratulated by the evaluation panel for continuing to promote an exemplary program appropriately focused in a programmatically separate way on the water problems of Guam, the CNMI and the FSM.

For more information on WERI's research and academic programs please visit us on the web at: <http://www.weriguam.org> or contact:

### **Dr. Shahram Khosrowpanah**

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**Dr. Khosrowpanah with Governor Tony Ganngiyan, Yap State, FSM, August 7, 2015.**

# WERI FACULTY, STAFF & STUDENTS



## DIRECTOR



Dr. Shahram Khosrowpanah  
Prof. Civil Engineering

## FACULTY



Dr. Gary Denton  
Professor  
Environmental Toxicology



Dr. John Jenson  
Professor  
Hydrogeology



Dr. Nathan Habana  
Asst. Professor  
Groundwater Hydrology



Dr. Mark Lander  
Assist. Professor  
Meteorology



Dr. Joe Rouse  
Assoc. Professor  
Environmental Engineering



Dr. Yuming Wen  
Assoc. Professor  
GIS

## STAFF



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Administrative Assistant



Norma Blas  
Secretary



Jennifer Cruz  
Lab Manager



Cris Tagudin  
Lab Technician

## RESEARCH ASSISTANTS



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Graduate RA



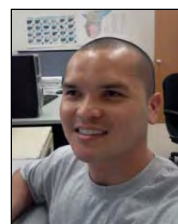
Bekah Dougher  
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Graduate RA



Lauren Swaddell  
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Bill Whitman  
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Daniel Superales  
Undergraduate RA

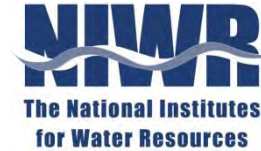




# ACTIVE RESEARCH PROJECTS



PROJECTS FUNDED BY:  
USGS 104B WATER INSTITUTE PROGRAM



## **GUAM:**

**Expansion of Baseline Data for the Northern Guam Lens Aquifer and Evaluation of Innovative Treatments to Reduce Contaminant Input to the Aquifer**

**Enhancing Predictions of Average Flow and Flow Duration Curves at Ungauged Stream Sites in Guam Using the USGS South Guam Streamflow Model**

**Exploring the Natural Limits of the Northern Guam Lens Aquifer: A Step Toward Optimum Sustainable Management, Phase 3 – Model Implementation: Determining Ultimate Yield**

## **COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS (CNMI):**

**Identification and Delineation of Land-Based Mercury Sources Impacting Fisheries in the Southern Central Coastal Region of Saipan Lagoon**

**Real-Time Investigation of the Impacts of the 2015-16 El Niño on Water Resources in the CNMI**

## **FEDERATED STATES OF MICRONESIA (FSM):**

**Digital Atlas of Pohnpei State – A Geospatial Map and Data Server for Resource Management**

**Beneficial Use of Piggery Waste with a Focus on Energy Production**

**Real-Time Investigation of the Impacts of the 2015-16 El Niño on Water Resources in the FSM**

**Building the Resilience of Communities and their Ecosystems to the Impacts of Climate Change through an Integrated Natural Resource Management, Education, and Outreach Campaign in Pohnpei, Federated States of Micronesia**

## **PROJECTS FUNDED BY: OTHER FEDERAL & LOCAL SOURCES**

### **US GEOLOGICAL SURVEY (USGS) Pacific Islands Climate Science Center**

**Potential Impacts of Adaptive Response to Climate Change for Department of Defense Installations in Guam**

**NATIONAL SCIENCE FOUNDATION  
Collaborative Research: What Hydrological Processes Control Weathering in the Deep Critical Zone of Unburied Karst Landscapes**

**NATIONAL WEATHER SERVICE  
Pacific ENSO Applications Center (2015-2016)**

**NATIONAL PARK SERVICE  
American Memorial Park Shoreline Infauna and Heavy Metals Assessment**

**GUAM BUREAU OF STATISTICS AND PLANS (BSP)  
Developing Hydrological Data for Toguan Watershed Management**

**GUAM WATERWORKS AUTHORITY  
(GWA)**

**A Study on Influence of Seawater on  
Biological Wastewater Treatment on Guam,  
CNMI, and FSM**

**Developing Hydrological Data “Stage to Flow  
Relationships” for the Toguan River**

**DIRECT LOCAL FUNDING FROM  
THE GUAM LEGISLATURE  
SUPPORTS:**

**A. COMPREHENSIVE WATER MONITORING  
PROGRAM (CWMP):**

**Stream-flow, Sediment Discharge,  
Rainfall and Groundwater  
Characteristics Data Collections in Guam**

**B. GUAM HYDROLOGIC SURVEY (GHS):**

**Hydrological Database for Northern Guam**

**Basement Map of the Northern Guam  
Lens Aquifer**

**Development of a Hydrologic Map Series  
for the Northern Guam Lens Aquifer**

**PCB Biomonitoring Strategy Development  
for Guam’s Coastal Waters, Part II**



## Expansion of Baseline Data for the Northern Guam Lens Aquifer and Evaluation of Innovative Treatments to Reduce Contaminant Input to the Aquifer



**Funded by:**  
**US Geological Survey, Water Institute Program**

**Principal Investigators:**  
**Joe Rouse, Nathan Habana, & John Jenson**

The Northern Guam Lens Aquifer (NGLA) is Guam's primary source of freshwater for potable use. This porous limestone formation currently provides approximately 80% of the island's municipal water supply. Aggressive production of groundwater has grown to 40 million gallons per day (mgd). With water demand rising and concerns over water quality increasing, proper management of this freshwater source has become critical to the welfare of the island's increasing population of residents and tourists. Preliminary inquiries have suggested that contaminants from anthropogenic sources are showing up in the NGLA. Much more baseline data of contaminant concentrations well-water samples is needed to determine if the problem is greater in zones with sewer collection lines, or in zones that rely on household septic tanks; furthermore, it is not known if contaminant levels are increasing, or not. It is essential that these issues be studied before actions are taken to extend sewer collection lines or even build new wastewater plants in Northern Guam. In addition, the effectiveness of septic tanks is also an issue of concern. As an alternative to traditional septic tanks, consideration is increasingly given to use of single-family prefabricated, packaged treatment units. It is considered that these units could serve to reduce the potential of contamination reaching the water table, though insufficient testing has been done to evaluate their potential.

Accordingly, we intend to conduct a study that will offer further enlightenment as to the transport and fate of contaminants of anthropogenic sources in the NGLA, and will evaluate methods for reducing contaminant input to the sub-surface. These results will strengthen modeling capabilities addressing the water quality, thus being of importance to human safety. The project will include fieldwork distributed over several months, consisting of setting up testing probes at well heads for onsite data collection and of transporting samples to the

lab for further testing and data assessment. The result of the proposed study would be an improved body of knowledge concerning the current state of water quality in the NGLA. In addition, treatment capabilities of packaged treatment units will be determined. Such information would be advantageous for a range of applications, including the development of planning strategies for installation of single-family package treatment units. It would also allow for more informed decision making regarding extension of collection networks. Results of this study would be presented at environmental conferences and published in a WERI Technical Report to be made available to authorized stakeholders.



**Installation of multiprobe meter at GWA well F-13.**



## Enhancing Predictions of Average Flow and Flow Duration Curves at Ungauged Stream Sites in Guam Using the USGS South Guam Streamflow Model



Funded by:  
US Geological Survey, Water Institute Program

### Principal Investigators:

Leroy Heitz, Shahram Khosrowpanah, Sarah Rosa, & Mark Lander

In order to properly manage a region's water resources, it is important for water managers to know the time variability of flow in the streams of that region. Not only what are the highest flows, such as what would be available from a flood frequency study, but also how the flows vary day to day, season to season, and year to year. Studies such as water supply studies, hydropower studies and those involving sediment transport depend on this kind of long term variability data in order to develop the best management practices for a region's water resources.

Guam is no different than other areas requiring water resources investigations. In order to properly carry out good water resources management, it is necessary to be able to define the variability of flows available in Guam's streams. This is normally done by direct analyses of streamflow data for the stream in question or by applying some sort of inferential techniques from a gauged to an ungauged stream or from a gauged location on a stream to an ungauged location on that same stream. Of course, the most reliable means is to use actual

stream flow data measured at the point of interest. The problem in Guam is that stream flow information is not available for all possible sites where information is required.

A recently completed USGS Water Institute Program funded study developed a means of predicting flow duration curves at ungauged sites in South Guam. This proposed study will use a streamflow model (PRMS-IV) recently developed for South Guam by the USGS Pacific Water Science Center to enhance the predictions made by the previous study. The synthetic flows generated by the PRMS-IV model will be analyzed to produce average flows and duration curves at key points along South Guam streams. These average flows and duration curves will be compared to those developed in the previous USGS funded study. It is expected that these comparisons might reveal changes to the PRMS-IV model that could improve model predictions. But more importantly, the vast amount of virtual streamflow data generated by the model should improve on average flows and duration curves generated in the previous study.



Taking crossflow measurements at Toguan River, Umatac.



## Exploring the Natural Limits of the Northern Guam Lens Aquifer: A Step Toward Optimum Sustainable Management, Phase 3 – Model Implementation: Determining Ultimate Yield



Funded by:  
US Geological Survey, Water Institute Program

**Principal Investigators:**  
**Nathan Habana & John Jenson**

The Northern Guam Lens Aquifer (NGLA) provides 80% of Guam’s drinking water. The anticipated addition of US Marine Corps activities will require additional production, while ongoing economic growth will increase demand as well. Policy-makers and water managers have begun asking “what is the absolute *maximum* volume of water that could be sustainably withdrawn from the aquifer?” Answering such a question requires identifying (1) the *natural limits* on aquifer recharge, storage, and water quality imposed by climatic and geologic conditions, (2) but doing it *for an ideal production system*, i.e., one that is constructed and operated so as to achieve the maximum possible production for a given standard of quality. This study is therefore directed at estimating the *maximum potential capacity* of the NGLA, i.e., the capacity that ultimately *could* be achieved by an ideal production system, given what we currently know or must assume about the natural limiting conditions. Recent modeling has incorporated the current state of knowledge regarding natural conditions and constraints. In the this third phase, estimates of maximum potential capacity can now be made by exploring scenarios in which hypothetical well depths, expansion by addition of basal wells, and pumping rates are distributed so as to maximize the capacity for given upper limits of chloride. This study will thus help provide some estimates of the absolute upper limits of production that could, in principle, be achieved by an optimum system. These will provide ultimate baselines against which to make economic evaluations of future options for holistic sustainable management of the aquifer.

The principal investigators will lead a research team composed of themselves, a WERI research associate trained in modeling, and WERI-based graduate and undergraduate research assistants (UOG environmental science MS candidate), working in collaboration with colleagues at the USGS Pacific Islands Water Science Center

(PIWSC) to assemble and prepare the data sets; identify climatic phenomena and geologic features that are most likely to exert significant control on rainfall amount and intensity, infiltration rates, aquifer storage, groundwater flow, and groundwater salinity on northern Guam; and apply statistical, geospatial, and other analytical tools to identify, characterize, and interpret past and present spatial patterns in rainfall, groundwater levels, specific conductivity, chloride concentrations, and production rates from existing wells within the NGLA. The team will develop scenarios to identify ideal configurations (i.e., configurations not limited by economic, social, legal, or other non-natural factors) of well distribution and spacing, depth, and pumping rates that could thus in principle maximize production from the aquifer for specified limits on saltwater content. Scenarios will also examine how the ideal configuration might also respond to different long term climatic conditions.



**WERI researchers with the drilling crew for an exploratory well in the NGLA.**



# Identification and Delineation of Land-Based Mercury Sources Impacting Fisheries in the Southern Central Coastal Region of Saipan Lagoon



Funded by:  
US Geological Survey, Water Institute Program

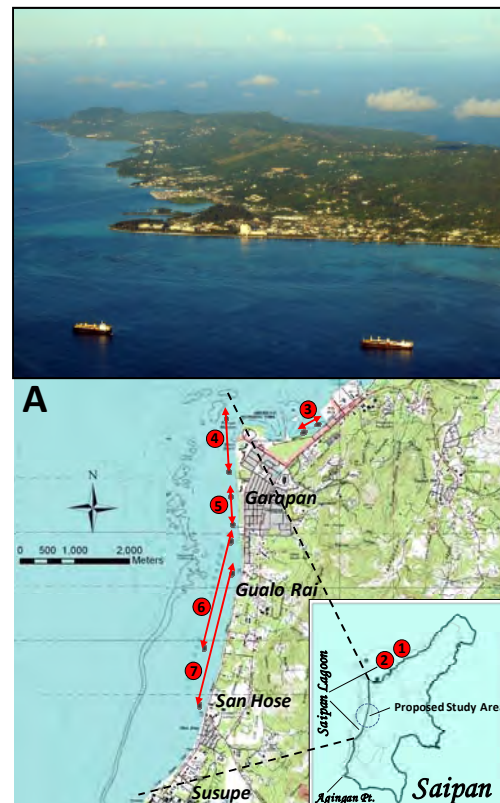
**Principal Investigators:**  
Gary Denton, Michael Trianni, Michael Tenorio, & Ray Masga

The southern half of Saipan Lagoon is heavily impacted by urban runoff that primarily flows from roads (paved and unpaved) and properties (residential and commercial) within 0.5 km of the coast. Frequent mercury detections have previously been reported in discharges from several stormdrains in this part of the lagoon (Environet Inc. 2007). Such findings are unusual because mercury is rarely detected in runoff outside of industrialized areas (USEPA 1983). The highest level recorded was 150 ng/L, which again is remarkable given that detectable levels in runoff seldom exceed 0.01 ng/L (Morace 2012). Denton *et al.* (2014) noted unusual mercury distribution patterns in sediments from the lagoon's southern waters and concluded that inputs washed into the ocean from land-based sources were superimposed upon a scattering of mercury contamination emanating from within the lagoon itself. They attributed their findings to the extensive use of mercury in artillery shells and other explosive devices manufactured during WWII, and to the heavy shelling of Japanese defenses positioned along the shoreline of the lagoon prior to the US invasion in 1944. Continuing mercury releases from corroding munitions left behind after the war most likely account for the Environet findings noted above.

The aftermath of these cataclysmic wartime events on fisheries in the lagoon is currently unknown although an earlier study revealed elevated mercury concentrations in a popular table fish (*Lethrinus atkinsoni*) from a 3-km stretch of coastline just north of the invasion beaches (Denton *et al.* 2010). Levels encountered here were higher than in the same species and a close relative (*L. harak*) from waters further north in the lagoon.

The study proposed here seeks funding to revisit the 3-km coastal strip from whence the earlier contaminated fish were captured and identify the

primary source or sources of mercury impacting them. The primary objectives of the study are to: a) determine mercury concentrations in surface deposits from stormwater drainage pathways servicing the Gualo Rai area; b) back-track along obviously enriched pathways to pinpoint sources of contamination within the watershed; c) delineate the extent of contamination in the lagoonal target area (via sediment analysis) and evaluate the impact on popular table fish with bioindicator potential; and d) weigh the fish data against established USEPA benchmarks to determine potential health risks and advisable maximum monthly consumption rates.



a) Aerial view of Saipan Lagoon.  
b) Map of the site locations of the study.



## Real-Time Investigation of the Impacts of the 2015-16 El Niño on Water Resources in the CNMI



Funded by:  
US Geological Survey, Water Institute Program

**Principal Investigators:**  
**Mark Lander & Shahram Khosrowpanah**

One of the primary concerns of water resource managers throughout the tropical Pacific islands is drought. Major drought is often a serious consequence of El Niño. However, the El Niño-related droughts, while severe, are short-lived (i.e., ~6 months), with normal rains thereafter. Two of the most severe El Niño-related droughts occurred in the latter decades of the 20<sup>th</sup> Century: The 1982-83 El Niño and the 1997-98 El Niño. The 1997-98 El Niño event is still regarded as the strongest in the historical record. El Niño developed during early 2015 and became strong by the end of the year, rivaling the intensity of the epic El Niño events of 1982-83 and 1997-98.

All the Mariana Islands from Guam through the Commonwealth of the Northern Mariana Islands (CNMI) are vulnerable to damaging extremes of weather during the roughly 18-month course of an El Niño event. The year 2015 indeed saw many weather extremes, including an unusual abundance of named tropical storms and typhoons passing through regional waters. A particularly severe typhoon (Typhoon Soudelor) heavily damaged Saipan during the night of August 2015. This typhoon was at the Category 4 level of intensity and caused severe damage on Saipan. Saipan is still recovering from Soudelor and other typhoons of 2015. To make matters worse, in the first few months of the calendar year that follow a strong El Niño (this will be the case for 2016), the rainfall on Saipan and the other islands of the CNMI tends to be well below normal. Streamflow is sharply reduced, forests and grasslands dry to the point that wildfires become a problem, and municipal wells see an increase in Chloride. Many of Saipan's wells have a sea salt concentration that severely degrades the taste and smell of the water supply, and may even pose a health risk. Major drought in 2016 would pose a threat to both water quality and water quantity on Saipan.

The overall objective of the proposed project will be to study the impact of the anticipated El Niño drought on Saipan, with a focus on the impacts to the municipal water system through the year. Physical properties of the wells, such as the well head and water quality measurements will be monitored. In partnership with local water system managers, this project will also document impacts to the extraction and distribution components of the municipal water system (e.g., pumping rates, storage, line pressures, and usage patterns) through the anticipated dry year. The physical data, water agency responses and the lessons learned over the course of the drought will undergo a comprehensive review at a workshop tailored for Saipan water system managers and other water resource managers and stakeholders.



**Drought conditions on Saipan, CNMI.**



# Digital Atlas of Pohnpei State – A Geospatial Map and Data Server for Resource Management



Funded by:  
US Geological Survey, Water Institute Program

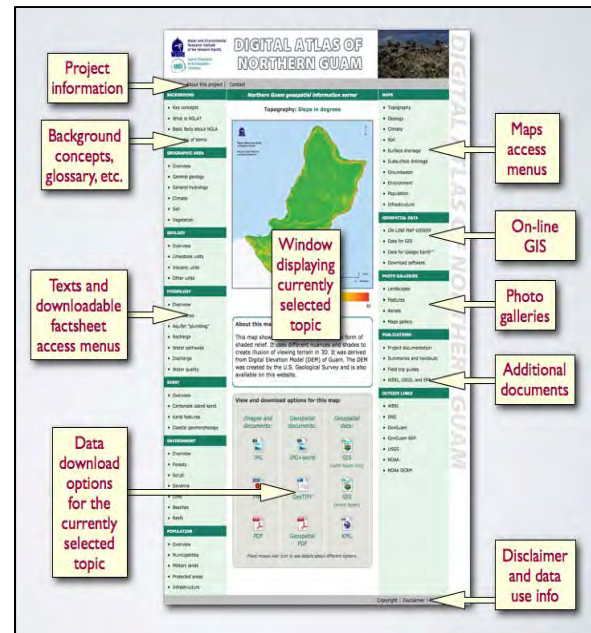
**Principal Investigators:**  
**Danko Taborosi & Shahram Khosrowpanah**

Pohnpei is the political and administrative center of the Federated States of Micronesia (FSM). It is home to over a third of the nation's population and represents the hub of commercial activity and economic development in the region. In addition, Pohnpei is a part of a Small Island Developing State (SIDS) whose many low-lying yet densely-populated areas are at great risk of natural disasters and effects of climate change and sea-level rise. Sustainable development and effective management of resources, especially in the context of improving resiliency to the effects of climate change and responding to the risk of natural disasters and ameliorating their effects, requires geospatial information of the physical, environmental, and anthropogenic components of the entire system. Such information must be accurate, up-to-date, mutually compatible, and readily available. Given the difficulties in locating and accessing such data on Pohnpei, let alone verifying their quality and actually applying them in decision making, Pohnpei has a great need for a unified, comprehensive, and user-friendly information management system for geospatial data. We propose to create a web-based digital repository and dissemination system for GIS and other geospatial data related to Pohnpei, to include all maps and significant aspects of its natural and man-made geography (see Appendix 1), as well as comparable data for all of Pohnpei State's outer islands (see Appendix 2).

The resultant geo-database will be established to incorporate all relevant physical, environmental, and infrastructural information and would include existing data (which would be inventoried and collected as part of this project) and any new data yet to be created, and become the mainstay for future collecting, digitizing, cataloguing, and distributing geospatial data on Pohnpei. Therefore, the overall objective of the project proposed here is to create a robust, comprehensive, and versatile geospatial data server to support all geospatial aspects of planning, disaster risk reduction and emergency

response, resource management, sustainable development, research and modeling, conservation, and education on Pohnpei. Based on experiences from Guam and results of comparable projects there, we plan to call the product proposed here the “Digital Atlas of Pohnpei” so that it can become a sister product to the intensively used and highly successful “Digital Atlas of Guam,” created in several stages between 2009 and 2013.

The Digital Atlas of Pohnpei will be web-based, permanently on-line, and act both as a repository of relevant GIS data and geospatial resources in other formats, as well as a digital point-of-contact and information-sharing hub for anyone involved in resource management, engineering, research, and decision-making in Pohnpei.



**Detail of Digital Atlas of Guam.**





## Beneficial use of Piggery Waste with a Focus on Energy Production



Funded by:  
US Geological Survey, Water Institute Program

**Principal Investigators:**  
**Joe Rouse & Hyun-Jong Hahm**

In the Federated States of Micronesia (FSM), pig farming is a common practice. Households may have one to three animals for personal use and sometimes up to as many as ten. In addition, on Pohnpei there are several pig farms with up to a hundred or more animals in each. Due to a lack of oversight, the actual density of the livestock is unknown and the impact on the environment is difficult to quantify, though it is known that runoff from all sizes of such operations does have a detrimental effect on coastal water quality. The greater the density of livestock, the greater the excess of manure becomes beyond that which can be usefully incorporated into the local environment. With proper management, though, manure can be used as a fertilizer or soil conditioner for enhanced crop production or remediation of badlands. This has the added benefit of abating air and water pollution, leading to improved human and animal health. Another value that can be drawn from the manure is that of energy production. This activity has often been written off as being too difficult for remote locations lacking technical support, or for small-scale operations where the capital investment would be inhibitive. However, under various scenarios advancements

have been made in extending this technology to effectively cover both relatively large-scale and smaller scale applications. The project proposed here consists of gathering, categorizing, and summarizing information pertaining to pig farming in the FSM; assessing the environmental impacts of these farming operations; developing solutions for converting waste to energy; and reporting viable, holistic methodologies of a practicable nature. The objective of the proposed project is to encourage and empower the local populations to further enhance their independence from petroleum based fuels for energy production, protect their water environment, enhance agricultural productivity, and improve their overall standard of living. The project timeline will include fieldwork distributed over several months, consisting of visits to two of the four states. Upon completion of the fieldwork portion of the project, all information will be processed and conclusion formulated. A technical workshop will be conducted near the end of the project to present the preliminary results to stakeholders. In addition, a WERI Technical Report will be produced and made available to all pertinent stakeholders.



**Free range pig in Pohnpei, FSM.**



## Real-Time Investigation of the Impacts of the 2015-16 El Niño on Water Resources in the FSM



Funded by:  
US Geological Survey, Water Institute Program

**Principal Investigators:**  
**Mark Lander & Shahram Khosrowpanah**

At the time of this writing (December 2015) a major El Niño is nearing its peak (Rasmussen and Carpenter 1982, Ropelewski and Halpert 1987, and PEAC 2015), with commonly used indices of El Niño rising to levels seen only two other times in the past 60 years: the epic El Niño events of 1982-83 and 1997-98. All states of the FSM are vulnerable to damaging extremes of weather during the roughly 18-month course of an El Niño event. Through the first year of a strong El Niño, the region typically experiences an abundance of typhoons, other extremes of heavy rainfall, and high surf raised by the typhoons and unusual monsoonal winds. The year 2015 indeed saw such conditions, with nearly all the islands of the FSM experiencing damaging effects from typhoons and other severe weather conditions. Two particularly intense typhoons caused severe damage: Typhoon Maysak destroyed much of Ulithi Atoll in April, and a month later, Typhoon Dolphin tracked across the Chuuk Lagoon, bringing destructive winds to most of the islands therein. In the first few months of the calendar year that follows a strong El Niño (this will be the case for 2016), the rainfall across all of Micronesia tends to be well below normal. Sharply reduced rainfall can quickly become a life-threatening emergency as reservoirs and rain catchment systems run dry, and agricultural plants are damaged. This is especially true on atolls where the water lenses are thin and rain catchment is a prominent source of drinking water. Micronesia-wide severe droughts in 1983, 1992 and 1998 required the deployment of U.S. military assets to the islands of the FSM to help transport and generate drinking water supplies.

Since widespread drought across the FSM typically follows a strong El Niño, it is therefore potentially foreseeable a few months in advance. Indeed, nearly all local and regional meteorological and hydrological service agencies (e.g., the Weather Forecast Offices of the FSM, the Guam Weather Service Forecast Office, the Pacific ENSO Applications Climate Center, and additional international agencies) anticipate a

Micronesia-wide severe drought during the first 6 months of 2016.

The objectives of this project are to: a) Travel to all four states of the FSM in May or June of 2016 to observe and gather data on the effects of the 2015-16 El Niño in the region, b) Visit with representatives of water resource management (e.g. water treatment facility operators) to get a detailed picture of the impacts in each state of the 2015-16 El Niño-related typhoons, extreme rains, sea inundations and drought, c) Determine the efficacy of practices taken (if any) to lessen the impacts of the 2015-16 El Niño, and d) Develop an outreach itinerary for group discussion of drought during FSM visits.



**Water supply reservoir in Yap State, FSM during 2009 drought.**



## Building the Resilience of Communities and their Ecosystems to the Impacts of Climate Change through an Integrated Natural Resource Management, Education, and Outreach Campaign in Pohnpei, Federated States of Micronesia



Funded by:  
US Geological Survey, Water Institute Program

**Principal Investigators:**  
Francisca Sohl Obispo & Eugene Joseph

The small island developing state of Pohnpei, in the Federated States of Micronesia (FSM), located in the north Pacific region, is directly facing challenges associated with climate variability and change. Notable climate change impacts are: extreme temperatures, sea level rise, drought, and heavy rainfall leading to flooding and landslides. Such impacts are threatening marine and terrestrial environments, and island water. Pohnpei has also experienced the cyclical effects of the EL Nino/Southern Oscillation (ENSO)-related weather anomalies. Such climate variability is associated with drought, which often leads to: water shortages, crop failures, food shortages and fires.

CSP hopes to further these goals via community outreach under the Building the Resilience of Communities and their Ecosystem to the impacts of Climate Change through and Integrated Natural Resources Management, Education, and Outreach on campaign in Pohnpei.

Despite the risks associated with climate change, there is a general lack of community awareness and preparedness for climate change and the natural hazards associated with it. This was confirmed in an International Organization for Migration (IOM) survey conducted in mid-2012, which revealed a general lack of public awareness. The results indicated that approximately half of the population had experienced a natural disaster in their lifetime; and that almost 50% of respondents had been forced to move during their lifetime as a result of a natural disaster. In the context of such results, CSP has tested a climate change toolkit created by the Micronesia Conservation Trust (MCT) that would help communities develop Local Early Action plans – detailing short and long term climate adaptation or disaster mitigation interventions to pursue. Community awareness of environmental and social

vulnerabilities is the basis of the successful implementation of a disaster risk management and climate change adaptation process that draws and builds on the knowledge and capacity of the local community. A participatory process establishes ownership of climate adaptation projects and improves the likelihood of sustainability over a long period of time, as this process requires “buy-in” from local governments, civil society actors, and community leaders. CSP is well positioned to lead sustainable resilience raising efforts in schools and communities in Pohnpei.

This project aims to build the resilience of vulnerable communities in Pohnpei to climate change and natural hazards. Utilizing an ad-hoc group called Pohnpei Climate Change Outreach Committee (PCCOC), which is comprised of local partners and key community champions led by CSP, this committee’s existing presence in Pohnpei and expertise in climate change adaptation and disaster preparedness is essential to ongoing efforts. CSP and partners will target at least two but not limited specific communities and school age children across Pohnpei under the proposed project.



Meeting with chiefs of FSM.



## Pacific Islands Climate Center



Funded by:  
US Geological Survey

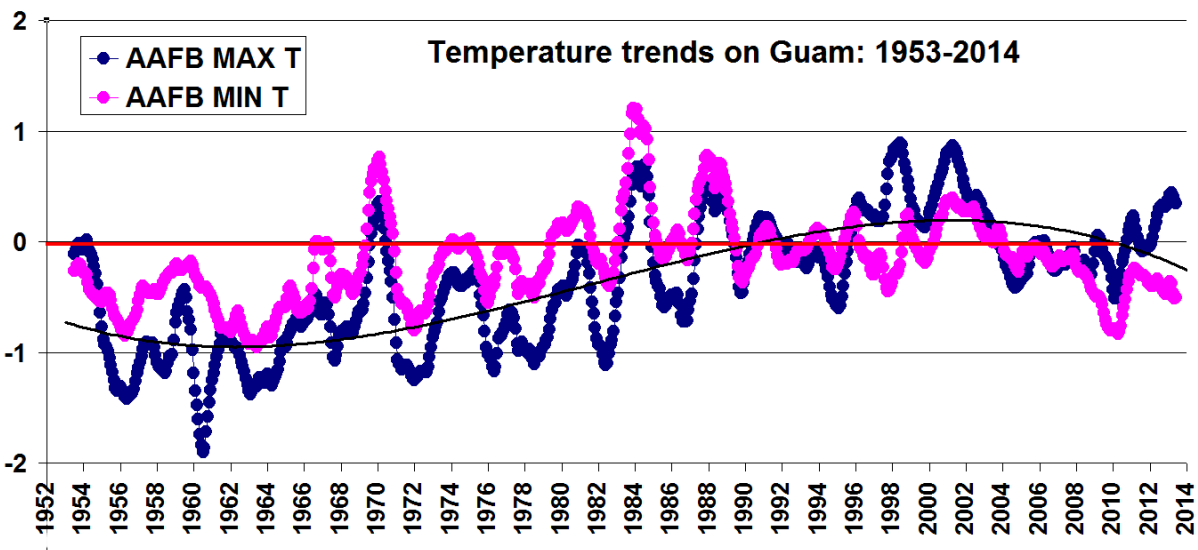
**Principal Investigator:**  
Mark Lander & John Jenson

In the year 2011, the US Department of Interior announced the formation of the Pacific Islands Climate Science Center (PICSC). The PICSC is a consortium led by the University of Hawai'i at Mānoa, the University of Hawai'i at Hilo, and the University of Guam. Together with two other new regional climate science centers, the Pacific Islands Climate Science Center is part of a network of eight regional centers established by the Department of the Interior. The centers serve to provide land managers in federal, state and local agencies access to the best science available regarding climate change and other landscape-scale stressors impacting the nation's natural and cultural resources.

The PICSC addresses regional climate change challenges such as:

- (1) Coral Reef Health
- (2) Fish and Wildlife Response to Climate Change
- (3) Invasive Species
- (4) Marine and Coastal Resilience
- (5) Protection of Trust Species
- (6) Sea-level Rise and Coastal Erosion
- (7) Wildlife Disease

The UOG is now in its second year of PICSC-sponsored ongoing efforts to understand the regional climate system, and to provide outreach, education activities and expert advice for local and regional climate, climate variability and climate change.





## Collaborative Research: What Hydrological Processes Control Weathering in the Deep Critical Zone of Unburied Karst Landscapes



Funded by:  
National Science Foundation

Principal Investigator:  
Mark Lander & John Jenson

Limestone provides 25 percent of the world's population with drinking water and contains more than 50 percent of the world's known hydrocarbon reserves. Limestone's high solubility allows for the formation of caves that control the flow of water and hydrocarbons below-ground. Understanding the processes that contribute to the formation of caves is thus necessary for improved characterization of water and hydrocarbon resources. In carbonate platform environments where limestones form (e.g. Bahamas, Yucatan and Florida), zones of unsaturated rock (vadose zone) that exceed 60 m in thickness have been proposed to limit movement of organic carbon from soil to the water table, where oxidation to carbon dioxide (CO<sub>2</sub>) would otherwise drive corrosion of limestone bedrock. In contrast to this interpretation, cave systems occur in carbonate platforms at depths of more than 100 m below modern sea level. These caves are thought to have formed in contact with fresh groundwater at times in the past when sea level was lower than it is today. Because vadose zones would have been much thicker than 60 m when these caves formed, the geochemical processes responsible for their formation are poorly understood. In this project, the movement of dissolved organic carbon (DOC) and CO<sub>2</sub> gas to the water table via vadose zone fast flow routes is

hypothesized to provide a mechanism for corroding limestone and create caves beneath thick vadose zones. This hypothesis will be tested on the island of Guam, where tectonic uplift has created vadose zones that are up to 180 m in thickness. Cave formation by CO<sub>2</sub> that is produced by biological processes in the deep vadose zone runs contrary to the paradigm that caves in carbonate platforms form as a result of mixing waters of different chemical composition. Concepts explored by this proposal thus have potential to transform understanding of the geomorphology and biogeochemistry of the vadose zone by challenging canonical views that mixing dissolution is the principal agent of dissolution and cave formation in carbonate platform landscapes.



Leena Muller, graduate research assistant collecting samples from Jinapsan Cave, Spring 2013.



## Pacific ENSO Applications Center

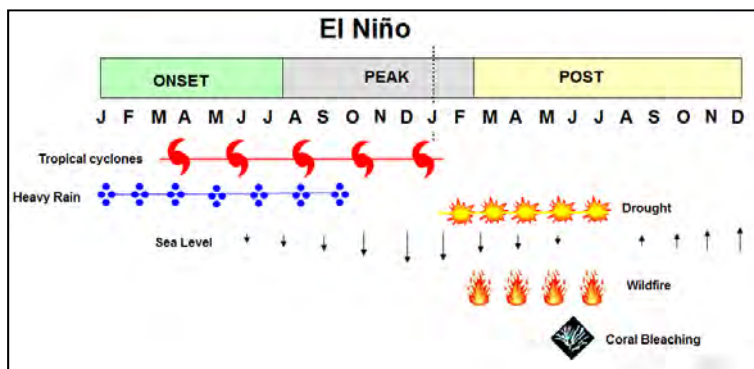
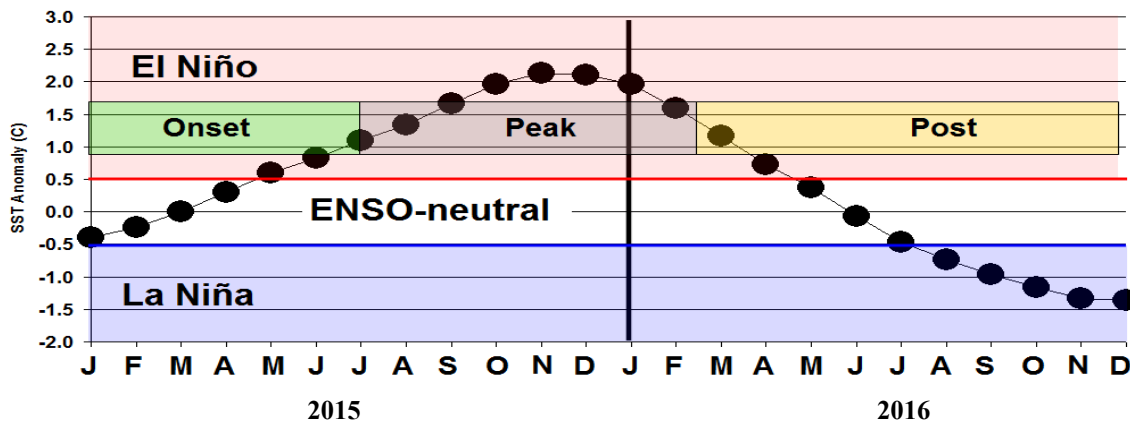


Funded by:  
National Weather Service

Principal Investigator:  
Mark Lander

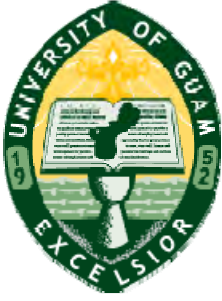
The Pacific ENSO Applications Climate Center (PEAC) was formally established in 1994 and funded by the National Oceanic and Atmospheric Administration (NOAA). It was among the first areas of the world to develop such a center. This Center is a collaborative effort between the University of Guam, the Pacific Basin Development Council, and the University of Hawaii. The goals of the PEAC Center are to tailor products of global El Niño/Southern Oscillation (ENSO) prediction models to the Pacific region, and to interpret and disseminate regional forecasts to public policy officials in the Pacific islands. To achieve these goals the activities of the Center revolve around two components:

research and outreach. The research component includes: 1) a study of the regional climatology; 2) development and publication of regional synoptic climatology; 3) development of rainfall and sea level forecast models; and, 4) evaluation of and feedback on the performance of climate models from other agencies and institutions. The outreach program includes: 1) providing tailored ENSO advisories; 2) publishing a quarterly bulletin which includes information on El Niño and climate predictions for the region; and, 3) presenting on-island workshops to interpret the predictions for decision makers, and to offer suggestions for local water resources management.



(Above) Typical evolution of the Niño 3.4 ENSO Index over the entire span of a strong El Niño event.

(Left) Timing of climatic hazards associated with El Niño.



## American Memorial Park Shoreline Infauna and Heavy Metals Assessment



Funded by:  
National Park Service (NPS)

**Principal Investigator:**  
Gary Denton & Maria Celia DeFrance Malay

The American Memorial Park (AMME) is a 133 acre parcel of land that borders the central region of Saipan Lagoon. The park has been under the administrative jurisdiction of the NPS since 1979. The AMME shoreline and adjacent waters, like the rest of the lagoon, are used for fishing and aesthetic enjoyment and are of great cultural significance to the people of Saipan. The AMME park shoreline is adjacent to the Puerto Rico dump site, and has documented enrichment of heavy metals in biota in the area of the dump. However, biota from the dump-adjacent AMME shoreline were not part of the study.

Like much of Saipan, the AMME area was occupied by the US military for several years after WWII, and parts of it were designated for the storage and disposal of bombs, shells and other munitions. Primary contaminants of concern associated with such activities include heavy metals, particularly lead and mercury. Both elements are accumulative poisons and can occur in relatively high concentrations in aquatic species from contaminated waters. The impact of WWII activities on heavy metal profiles in sediments from the southern half of Saipan Lagoon has recently been demonstrated, and studies are currently underway to determine the heavy metal concentration in biotic components living in shoreline sediments (i.e., infauna) traditionally harvested for food from AMME nearshore waters and evaluate any potential human health risks. The study is therefore seen as a useful extension of these

earlier works and as providing information specifically about the AMME shoreline.

Investigators from UOG-WERI and NPS staff will collaborate to accomplish the following specific goals.

- Determine the spatial distribution of the bivalves and other macro-infauna along the shoreline of AMME.
- Design a contaminants sampling plan based on the distribution of macro-infauna, runoff areas and potential contaminant sources.
- Collect and process biota samples based on the sampling plan and determine heavy metal concentrations in their edible body tissue.
- Provide detailed and summarized information on heavy metal concentrations, distribution, and discernible trends to park staff that can be used to determine if and what alternative shoreline management alternatives should be considered.



**Location of American Memorial Park, Saipan.**



## Developing Hydrological data for Toguan Watershed Management



Funded by:  
Guam Bureau of Statistics and Plans

### Principal Investigator:

Shahram Khosrowpanah, Mark Lander, Joseph Rouse, and Lauren Swaddell

The programmatic implementation of the Guam Coastal Nonpoint Pollution Control Program (GCNPCP), in accordance with the requirements of Section 6217 of the Coastal Zone Act Reauthorization Amendment (CZARA) of 1990, requires the development of a multi-year watershed restoration strategy. According to the guidance of Section 6217, the Watershed Restoration Action Strategies should include watershed assessment and identification of opportunities to reduce nonpoint sources pollution.

The Toguan watershed is comprised of dense forest, some savanna, some wetlands at the lower reaches, and a small amount of badlands along the surrounding ridges. The village of Merizo is situated along the coast south of the Toguan watershed and the village of Umatac is to the north. There is little development within this watershed, with the exception of residential coastal developments along the island's primary coastal road and the GWA wastewater treatment plant. As GWA continues to provide resources for upgrading the wastewater infrastructure and mitigate impacts to the environment, there is increasing interest concerning hydrology of the areas affected. The project goals are: (1) determine the physical condition of the watersheds prior to the "restoration", and (2) establish the nature of the pristine condition toward which the "restoration" aims. The Toguan watershed is a great place to establish the

physical conditions of a watershed that, while not necessarily pristine with respect to pre-human activity, the interior portion of the watershed among the most pristine areas now exists on Guam. A further benefit of the study would be to establish a baseline for the Toguan watershed for comparison to any future improvements in GWA operations or other significant developments within this watershed.



**Toguan Watershed with Mount Schroeder in the background.**





## A Study on Influence of Seawater on Biological Treatment on Guam, CNMI, and FSM



Funded by:  
Guam Waterworks Authority (GWA)

Principal Investigator:  
Joe Rouse

Management of fresh water resources has increasingly become an issue of concern in water-stressed islands of the western Pacific. With projected increases in Guam's population, the sustainable yield of the Northern Guam Lens Aquifer, which serves as a potable water source for over 80% of the residents and virtually all the tourists on Guam, may be surpassed in the near future. Accordingly, there is an urgent need to develop strategies for sustainable water use.

One option to conserve freshwater involves the use of seawater for toilet flushing, which would reduce the demand for potable water by over 100 L/capita/day, amounting to 30% of domestic demands. The use of seawater for flushing is a known practice (Leung et al. 2012); however, its influence on the biochemistry of wastewater treatment is yet a relatively new field of study with very few publications in the literature.

A key feature unique to seawater-based biological wastewater treatment, is the abundance of sulfate in seawater, which has the potential to serve as an electron acceptor, versus more commonly used dissolved oxygen or nitrate. Thus, as a first step, a waste stream consisting of seawater carrying organic contaminants could be treated effectively under anaerobic conditions. During this step, most of the organic compounds will be oxidized (eliminated) and some of the sulfate

reduced to sulfide. In the second step, the sulfide can then serve as an electron donor for reduction of nitrate and formation of nitrogen gas by autotrophic denitrification (van Loosdrecht 2012), versus more commonly observed heterotrophic denitrification. The third step would be ordinary aerobic nitrification of ammonium to nitrate, with return of the nitrate-rich wastewater to the second step (as internal recycle) for denitrification. Overall, this approach has been shown to have the potential to reduce excess sludge production by 90%, energy requirements by 35%, and greenhouse gas emissions by 36% as compared to a conventional treatment system for biological nutrient removal (Lu et al. 2011).

The objectives of this study will be to evaluate the influence of seawater on biological wastewater treatment processes and determine optimal conditions for design and operation of seawater-based systems. Attention will be given to monitoring key parameters (COD,  $\text{NH}_4^+$ ,  $\text{NO}_3^-$ , etc.) that will allow for determination of treatment efficiencies and rates. These objectives will be met by conducting continuous-flow treatment under various operational conditions using moving-bed unit processes. A porous biocarrier for immobilization and retention of biomass will be employed.



## Developing Hydrological Data “Stage to Flow Relationships” for the Toguan River



Funded by:  
Guam Waterworks Authority

**Principal Investigator:**  
**Shahram Khosrowpanah**

The Toguan watershed is of interest because it is affected by activities from the Guam Waterworks Authority (GWA) Merizo-Umatac Wastewater Treatment Plant (WWTP). The Toguan River discharges into the ocean between the minimally developed regions of Umatac and Merizo. The upper reaches of the Toguan River and tributaries are largely forested, grading to grasslands and some badlands on the surrounding high slopes.

Currently, GWA is required by Court Order to upgrade the WWTP to bring the facility into compliance with the existing NPDES permit and to meet the needs of the surrounding community for the next 20 years. In response, GWA has initiated an Action Plan that includes multiple improvement projects within the collection system and at the WWTP. The Action Plan includes additional data collection and analysis to better understand the characteristics of the effluent discharge and receiving water, as well as to support future regulatory discussions regarding modification of permit conditions and/or water quality standards to achieve compliance. The overall objective is to develop stage to flow curves and correlations between stream flow and the rainfall at the selected sites. The activities includes: a) Collect available information about the watershed’s current condition from previous studies as well as field visitations, b) To set up equipment to monitor rainfall, stream flow and stream level, and c) develop stage-to-flow

relationships (Stage Curves) and flow-rainfall relations for the two selected sites in the Toguan River.

The project will be completed in three phases. First, a watershed assessment will be completed using all available physical and environmental information from previous studies. Second, hydrologic data including rainfall, stream velocity, and stream level change, will be collected at the two selected sites to quantify and correlate baseline environmental conditions in comparison to the discharge from the treatment facility. Finally, all the data collected will be analyzed and the stage to flow curves for the selected sites and relationships between rainfall and stream flow changes will be developed.



**Map of the Toguan watershed within Umatac and Merizo, Guam.**



# Comprehensive Water Resources Monitoring Program



Funded by:  
Government of Guam

Principal Investigator:  
Shahram Khosrowpanah

The United States Geological Survey (USGS) has monitored our island's water resources since 1951. Unfortunately, during the 1990s they were forced to downsize this program because matching support from the Government of Guam was discontinued. This resulted in the abandonment of all deep monitoring wells needed to monitor saltwater intrusion in the north, and most of the stream gages in the south by the mid-1990s. In 1995, the USGS closed its field office at Naval Station, but continued to run a limited monitoring program (out of its Saipan and Honolulu offices).

In August, 1998 the CWMP was made a permanent part of WERI's program when Governor Gutierrez signed PL 24-247. This resulted in the refurbishment of the deep monitoring wells and a renewed program of water resource monitoring on Guam. The intent of PL 24-161 was to restore, and then to expand, as needed, the discontinued monitoring program in order to help Guam manage and safeguard all of its freshwater resources, now and in the future. Under PL 24-161, WERI/UOG and the USGS entered into a memorandum of understanding to administer and fund this program on a 50/50 cost-sharing basis. The CWMP is a permanent investment in Guam's future.

A well-designed long-term CWMP can save communities millions of dollars, and

even human lives, by providing critical information for water-supply, culvert and bridge design, delineating flood-hazard areas, and tracking effects of climate change. The USGS started a water-resource monitoring program in Guam in 1951 with installation of stream gages at Pago, Lonfit, and Tolaeyuus and a rain gage near Fena dam. At the same time, measurements of discharge from Almagosa Springs and water levels in Fena Reservoir started. Since 1951 about 22 continuous streamflow, 8 rain, and 16 groundwater monitoring stations have been operated, providing reliable information on the water resources and hydrologic hazards of Guam.



Locations of USGS Monitoring Stations on Guam



## Hydrological Database for Northern Guam

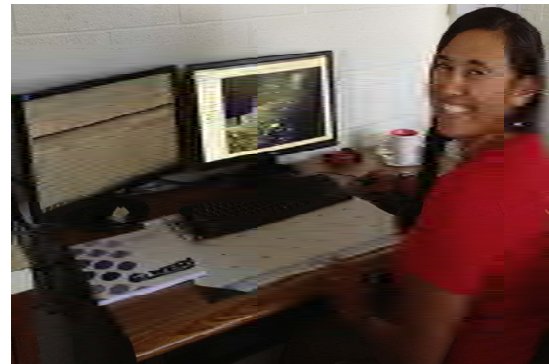


Funded by:  
Guam Hydrologic Survey (GHS)

**Principal Investigator:**  
**John Jenson, Mark Lander, & Shahram Khosrowpanah**

The Northern Guam Lens Aquifer supplies 80% of the island's drinking water. Anticipated growth in demand, including a possible surge to support expansion of military activities during the coming decade has elicited interest and support from both the federal and local governments for acquiring tools to support timely development and sustainable management of the aquifer.

The *Northern Guam Lens Aquifer Database*, is a comprehensive centralized database containing information on custodianship, function, operational status, and the geographical, hydrological, engineering, and geological attributes of each well installed in northern Guam for which records could be found. The database is integrated with current ArcGIS® geospatial information visualization tools. Developed in support of the 2010-2013 *Guam Groundwater Availability Study* led by the USGS's Pacific Islands Water Science Center, with funding by the US Marine Corps, and in conjunction with the 2010 NavFacPac Exploratory Drilling Program on northern Guam, its integration into WERI's Guam Hydrologic Survey Program will keep it up to date and make it permanently and readily accessible to professional and scientific users. The database is also the



**Graduate Research Assistant, Vивиanna Bendixson, working on the Northern Guam Lens Aquifer database.**

foundational component for WERI's topographic map of the basement rock beneath the aquifer. In preparing the database, over 4,000 pages of documents were digitally saved and organized into individual electronic folders for each of the 525 wells documented so far. These include 20 exploratory wells, 115 observation/monitoring wells, 212 drinking water wells, 39 agricultural/industrial wells, and 104 stormwater management wells. Each well folder is electronically linked to its corresponding record in a Microsoft Excel® spreadsheet, which contains key engineering and hydrogeological data. The project goal is to consolidate Guam's hydrological data gathered over the years by local and federal government agencies and consultants.



## Basement Map of the Northern Guam Lens Aquifer



Funded by:  
Guam Hydrologic Survey (GHS)

**Principal Investigator:**  
John Jenson, Mark Lander, & Nathan Habana

By far the single most important tool for successfully locating new wells that will deliver abundant high quality water from the Northern Guam Lens Aquifer is an accurate and precise map of the volcanic basement rock that forms the floor of the aquifer. The volcanic rock beneath the water-bearing limestone partitions the aquifer into semi-contiguous subterranean catchments, or *basins*. On the slopes of the basement rock standing above sea level, where the base of the aquifer thus lies above sea level, downward percolating fresh water becomes concentrated in basement valleys and at the base of the slopes, where it enters the lip of the fresh water lens. The rim of fresh water thus concentrated along the boundary of the volcanic basement and the water-table near sea level is underlain by volcanic rock rather than sea water. This *para-basal* water is thus fresher, thicker and much less vulnerable to salt-water contamination than the *basal* water downstream, which floats on the underlying sea water and becomes progressively thinner and saltier until it discharges at coastal springs and seeps. Water flowing down the flank of the volcanic slopes above sea level, designated *supra-basal* water, is the freshest of the water in the aquifer and is completely invulnerable to contamination by sea water.

The first detailed map of the basement topography was produced as part of the 1982 Northern Guam Lens Study.

Beginning in 1998, with the establishment of the Guam Hydrologic Survey by the 24<sup>th</sup> Legislature, WERI began updating and revising the 1982 map based on new data and insights acquired by exploratory drilling, the emplacement of new monitoring wells, and other data obtained incidental to ongoing local aquifer development and military installation environmental remediation projects. The new map will actually consist of a set of maps, which will show the basement topography in relation to aquifer geology, surface topography, and the locations of drinking water production wells and aquifer observation and monitoring wells. These maps will be available to other geologists and engineers in the public and private sectors, for which they will enhance the success and thereby reduce the cost of ongoing aquifer development.

They will also be essential tools to environmental scientists, regulators, and policy-makers seeking to develop appropriate regulations for aquifer protection and sustainable management.



**Outcrop of weathered basalt on the summit of Mt Alutom, which gives its name to the unit of basement rock beneath the northern limestone plateau.**



## Development of a Hydrologic Map Series for the Northern Guam Lens Aquifer



Funded by:  
Guam Hydrologic Survey (GHS)

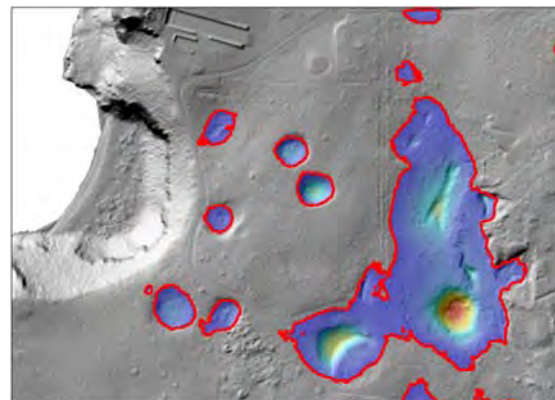
Principal Investigator:  
John Jensen

The Northern Guam Lens Aquifer is Guam's primary source of water, and if managed properly will continue to supply the island's daily water needs for generations to come. It is also a very complex hydrogeologic system. No simple technique or approach can characterize this aquifer. Rather, a multi-layer analysis is required to describe, model, and manage the groundwater system. The development of a series of hydrogeologic maps that captures each of the components—while also providing a means for showing their inter-relationships—is of basic and utmost importance for successful exploration, development, and management of the aquifer. These updates incorporate new insights gained from the 2010 Exploratory Drilling Program funded by *Naval Facilities Engineering Command Pacific*, and the 2013 *Guam Groundwater Availability Study*.

The new map specifically shows no-pumping simulation from the modeling study to estimate the water-table, hydraulic gradients, flow lines, and basin boundaries. The modeled lens geometry shows the estimated location of boundaries of the para-basal zone. Drill-logs and contours of supra-basal waters were also incorporated in the map. Occurrence of surface streams over the Hagåtña Basin and adjacent terrain were also included. Semi-transparent surface hill-shading provide a surface elevation perspective of the limestone plateau. Other hydrologic features that will be added to the current map or included in complementary maps in

the series, include hydraulic conductivities, geologic features, soils, porosities, pumping effects, groundwater locality of sustainable limit supply, land cover, and rainfall distribution.

The first complementary map, which will be published during the coming year, is a map of the sinkholes on the aquifer surface, which constitute its drainage system. Spatial analysis of LiDAR-based digital elevation model allows a precise determination of closed contour depressions on the limestone plateau.



Mapping these depressions and their relationships to other hydrologic and geologic features will be a major contribution to determining the distribution of recharge between fast vertical conduit flow channels and slow percolation through the bedrock. This is important to the refinement for accurately modeling aquifer recharge and potential contaminant entry and flow paths.



## PCB Biomonitoring Strategy Development for Guam's Coastal Waters, Part II



Funded by:  
Guam Hydrologic Survey (GHS)

**Principal Investigator:**  
Gary Denton

PCBs are a ubiquitous group of contaminants that were once widely used in industry. Considered by USEPA to be probable carcinogens, they accumulate within food chains, and are recognized endocrine disruptors. PCBs from land-based sources are transported into coastal waters via polluted rivers and streams, contaminated groundwater, urban runoff, seepage from landfills and wastewater discharges. Contaminated coastal sites on Guam exist at Apra Harbor, Orote Point and Cocos Island. The PCB status of other nearshore waters around the island is largely unknown.

Previously we examined the brown seaweed, *Padina boryana*, as a biomonitor for PCBs in Guam's coastal waters. Culturing techniques were explored and a simple, convenient and cost-effective way of transplanting the seaweed into coastal areas where it does not normally occur was developed (see FY 2013 Status Report). The work outlined here extends the scope of this research and examines the biomonitoring potential of another common and widespread resident of Guam's nearshore waters, namely the soft coral, *Sinularia polydactyla*.



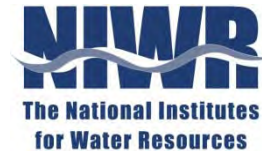
*Sinularia polydactyla* soft coral colony.



# PROJECTS COMPLETED: FY2015



FUNDED BY:  
US GEOLOGICAL SURVEY WATER INSTITUTE PROGRAM  
(Completed, February 2016)



## **GUAM:**

Exploring the Natural Limits of the Northern Guam Lens Aquifer: A Step Toward Optimum Sustainable Management, Phase 2– Implementation of a Numerical Model.

Second Conference on Water Resource Sustainability Issues on Tropical Islands

Workshop Series on Guam Groundwater Resources.

## **COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS (CNMI):**

Impact of Multiple Mercury Sources on Edible Quality of Fish from American Memorial Park Nearshore Waters, Saipan, CNMI.

Augment Saipan Daily Rainfall Measurements to Inform a Study of Well Head and Well Salinity Variations.

Review of Hydraulic Analysis Methods and Advanced Modeling Techniques Using the EPANET Water Distribution System Model.

Impacts of Land Cover Change on Groundwater Quality in Saipan.

## **FEDERATED STATES OF MICRONESIA (FSM):**

Sustainable Conjunctive Use of Groundwater and Rain Catchment Water under Variable Climatic Scenarios for Atoll Island Communities of Yap State: Ifalik, Eauripik, Satawal, Ulithi.

Continuation and Expansion of Data Collection for Sewage Treatment Pilot Study on Yap with Addition of a Composting Pilot Test for Reuse of Waste Sludge.

Water System Leak Detection Training for Yap State Public Services Corporation (YSPSC).

Enhance the Network of Community-based Engagement for Watershed Forest Reserve to Conserve and Protect Our Fresh Water Ecosystems in Pohnpei, Federated States of Micronesia-FSM.

## **OTHER FUNDED PROJECTS**

**US GEOLOGICAL SURVEY (USGS)  
through GUAM BUREAU OF  
STATISTICS AND PLANS**  
Update the Watershed Boundary Dataset (WBD) and National Hydrography Dataset (NHD) of Guam

**US GEOLOGICAL SURVEY (USGS)  
Pacific Islands Climate Center (2014-2015)**

**NATIONAL OCEANIC AND  
ATMOSPHERIC ADMINISTRATION  
(NOAA) through GUAM BUREAU OF  
STATISTICS AND PLANS**  
Digital Atlas of Southern Guam – a thorough overhaul and data upgrade

**NATIONAL WEATHER SERVICE  
Pacific ENSO Applications Center (2014-  
2015)**



**NATIONAL SCIENCE FOUNDATION**  
**Holocene Hydrological Variability across the**  
**Western Pacific Warm Pool**

**NATIONAL PARK SERVICE**  
**American Memorial Park Shoreline Infauna**  
**and Heavy Metals Assessment (2014-2015)**

**SECRETARIAT OF THE PACIFIC**  
**COMMUNITY**  
**Short-Term Consultancy to Conduct a**  
**Detailed Hydrological Assessment of Selected**  
**Outlying Islands Yap State, Federated States**  
**of Micronesia**

**GUAM WATERWORKS AUTHORITY**  
**(GWA)**  
**A Study on Influence of Seawater on**  
**Biological Wastewater Treatment on Guam,**  
**CNMI, and FSM**

**DIRECT LOCAL FUNDING FROM**  
**THE GUAM LEGISLATURE**  
**SUPPORTS:**

**A. COMPREHENSIVE WATER MONITORING**  
**PROGRAM (CWMP)**  
**Stream-flow, Sediment Discharge, Rainfall**  
**and Groundwater Characteristics Data**  
**Collections in Guam**

**B. GUAM HYDROLOGIC SURVEY (GHS)**  
**Assessment of Turbidity in the Geus River**  
**Watershed in Southern Guam**

**Hydrological Database for Northern Guam**

**Basement Map of the Northern Guam Lens**  
**Aquifer**

**Development of a Hydrologic Map Series for**  
**the Northern Guam Lens Aquifer**



## Environmental Science Graduate Program University of Guam



The Environmental Science Program is designed to provide students with an appreciation of the interdisciplinary nature of environmental problems that exist in the world today and prepare them for professional employment, teaching, or advanced studies in diverse areas of environmental science, or related disciplines. The program also serves working professionals in local schools, government agencies and the private sector who are seeking career advancement and/or professional enrichment, e.g., educators, regulators, administrators and planners.

The interdisciplinary focus of the program is intended to train students to identify and understand environmental problems and exercise sound judgment in effecting their remediation. This is accomplished through a careful blend of core courses and electives in an integrated teaching-research approach. Students are required to conduct a research project and document their study in thesis form. They are encouraged to present their findings in a variety of forums (e.g., society meetings, conferences, workshops, seminars, peer-reviewed journals, technical reports, newsletters and the local newspaper). Students also have the opportunity to serve out an internship with a local environmental or engineering firm, or an appropriate Government of Guam or Federal Government Agency. This permits them to gain professional problem solving skills in the environmental arena. Students who graduate from the MS program can, therefore, reasonably expect to enter professional employment in a variety of areas in the public and private sectors where an understanding of the complex interdisciplinary scientific, social, and political dimensions posed by environmental problems is increasingly necessary.



**Graduate students on a WERI Field Trip, after assessing the environmental impacts in and around Talofof Bay.**

The Environmental Science Program strives to promote educational and service projects within island communities of the Western Pacific, and attract a broadly based group of scholars committed to seeking answers to the many environmental questions that are arising in developing island nations of the tropical Pacific Basin. Areas of faculty expertise center around three broad areas of concentration namely, biology-ecology, geosciences and engineering, and management. Further information may be obtained from the Program Chair, **Dr. Mohammad Golabi**, phone: 671-735-2134, e-mail: [mgolabi@ugam.uog.edu](mailto:mgolabi@ugam.uog.edu).



## Pre Engineering Program University of Guam



Engineers are society's problem solvers. They take the theoretical ideas of the scientist and bring them into reality in today's world for the benefit of mankind. Engineers are involved with projects that vary from the design and construction of transportation systems to the planning of the space stations of the future. Nearly all aspects of our lives are touched by the projects worked on by people in the various engineering fields.

### WHAT IS PRE-ENGINEERING AT THE UNIVERSITY OF GUAM?

The Pre-Engineering Program at the University of Guam (UOG), which was established in 1989, parallels the curricula of the first two years of the engineering programs offered at major colleges and universities in the US and abroad. After completing the required coursework in this program, students transfer to other universities that offer degrees in engineering in order to complete their studies. In 2013, a cooperative agreement was signed with the Universities of Iowa, Mapua Institute of Technology (Manila, Philippines) for student and faculty exchange. The courses offered by the Pre-Engineering Program at UOG have been accepted by these institutes. Therefore, it provides for an easy transfer of students, thus enabling them to complete their degree.

On October 29, 2009, the President of the University of Guam expressed his vision for establishing a four-year accredited engineering degree program to help meet current and growing

demand for engineering expertise in Guam's private and public sectors. The anticipated rapid economic growth and development in our community and region over the next decade will produce an acute need for engineering talent to support new construction, repair and rehabilitation of aging infrastructure, development of natural resources, and environmental preservation and protection. It is therefore envisioned that the engineering curriculum will focus, at least initially, on civil and environmental engineering.



### Engineering students during the 2<sup>nd</sup> Annual Spaghetti Bridge Competition

### WHERE TO GET MORE INFORMATION?

For more information on the Pre-Engineering Program and the Upcoming School of Civil and Environmental Engineering, contact the Dean of the College of Natural and Applied Sciences, at the University of Guam, **Dr. Lee Yudin**, phone: 671-735-2002, e-mail: [lyudin@uguam.uog.edu](mailto:lyudin@uguam.uog.edu); or Program Chair, **Dr. Shahram Khosrowpanah**, phone: 671-735-2685, e-mail: [khosrow@triton.uog.edu](mailto:khosrow@triton.uog.edu).



## RECENT PUBLICATIONS BY WERI FACULTY AND ASSOCIATE INVESTIGATORS



(2006-2015)

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## CONFERENCE PROCEEDINGS, PRESENTATIONS AND ABSTRACTS

2015

**Denton, G.R.W., Sian-Denton, C.M., and Habana, N.C. (2015).** Dieltrin: An Unregulated Contaminant of Potential Concern in Guam's Groundwater. *Second Conference on Water Resource Sustainability Issues on Tropical Islands*. Abstracts. Hilton Hawaiian Village Hotel, Honolulu, Hawaii, December 1-3, 2015.

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**Lander, M., Guard, C., Khosrowpanah, S. (2015).** Damaging Typhoons and Major Drought: The Ongoing and Forecast Effects of the 2015 El Niño in the Tropical Pacific. *Second Conference on Water Resource Sustainability Issues on Tropical islands*. Abstracts. Hilton Hawaiian Village Hotel, Honolulu, Hawaii, December 1-3, 2015.

**Rouse, J.D. (2015).** Studies on Enhancement of Sewage Treatment and Composting of Sludge on Yap Island. *Second Conference on Water Resource Sustainability Issues on Tropical Islands*. Abstracts. Hilton Hawaiian Village Hotel, Honolulu, Hawaii, December 1-3, 2015.

**Rouse, J.D. (2015).** Wastewater Treatment Practices in the FSM with a Focus on Pilot Testing on Yap. *First Annual Conference, American Water Works Association, Hawaii Section, Western Pacific Sub-Section*. Tumon, Guam; April 13-14, 2015.

**Simard, C.A., Jenson, J.W. and Lander, M.A. (2015).** Analysis of Salinity in the Northern Guam Lens Aquifer, in *Proceedings Proceedings of the 16th Symposium on the Geology of the Bahamas and other Carbonate Regions*, Gerace Research Center, San Salvador Island, Bahamas, June 14-18, 2012.

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**Denton, G.R.W. and Denton, C.M. (2014).** Regulatory Framework and Monitoring Strategies Adopted by GWA for the Sustainable Production of Safe Drinking Water from the Northern Guam Lens Aquifer. *Regional Islands Sustainability Conference*, Hyatt Regency, Tumon, Guam, April 15-16 2014.

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**Denton, G.R.W. and Namazi, S. (2014).** Indoor Radon Levels and Lung Cancer on Guam, *35<sup>th</sup> Annual Research Conference*, University of Guam, March 11, 2014.

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