



INTRODUCTION TO RESEARCH ACTIVITIES & TEACHING PROGRAMS

by

**Gary R.W. Denton Ph.D.
Director**



WERI

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

February 2011

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



Photo courtesy of Dr. Shahram Khosrowpanah

WERI Director, Dr. Gary Denton (first left) and fellow WERI scientist, Dr. Shahram Khosrowpanah (second left) recently presented aspects of their water resources research conducted in Guam, the FSM and the CNMI, at the *Island, Environment, Resources International Symposium*, held at the University of Ryukus, Okinawa, Japan, on December 18, 2010. Also shown are (third left to right) Dr. Takashi Hirose (Department of Geography, University of Ryukyus); Dr. Mohammad Golabi (WPTRC Soil Scientist, University of Guam); Dr. Masaaki Gabe (Director, International Institute for Okinawan Studies, University of Ryukyus); and Dr. Hajime Oshiro (Vice President of the University of Ryukyus).



Photo courtesy of Phil Card

The *GuamWaterKids* website, created by Ann and Phil Card and sponsored by WERI, was showcased at the *2010 Conference on Sustainability* at the Marriott Hotel, Guam, September 2-3. The site was designed to provide teachers of 9 to 12 year olds with materials about Guam's fresh water resources and to serve children of this age group interested in individual study. Shown here are Ann Card (center), WERI hydrologist, Dr. John Jenson (left), and WERI Director, Dr. Gary Denton (right). Dr. Jenson served as scientific advisor to the project.



WERI

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



The Water & Environmental Research Institute of the Western Pacific, or WERI, is one of 54 water research institutes established by U.S. Congressional legislation at each Land Grant University in the United States and in several territories. The institute is now in its 36th 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. WERI provides technical expertise, and conducts vigorous research and both undergraduate and graduate teaching programs aimed at improving economic conditions and the quality of life for citizens of Guam and various regional island nations. WERI also runs a state of the technology water analytical laboratory and geographical information systems facility.

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 Mariana Islands (CNMI), and in the Federated States of Micronesia (FSM).

In FY-2010 WERI faculty were involved as Principal Investigators and/or advisors on 16 research and training projects with a combined budget of approximately \$1,000,000. Of this, \$229,000 was awarded through the Water Resources Research, Institute Program administered by USGS,

while \$378,000 was received as a special appropriation from the Guam Legislature. The remainder came from Federal sources awarded either directly to the Institute, or indirectly through local Government Agencies.

Currently, WERI has six fulltime research faculty, one of whom serves as Director on a rotational basis; one emeritus research faculty; a water analysis laboratory manager and technician; two office staff, as well as several graduate and undergraduate research assistants. WERI faculty collectively teach six undergraduate courses in UOG's Pre-Engineering Program and more than double that number of graduate course in the Environmental Science MS Program.

Over the last ten years, WERI faculty have collectively published their works in 54 refereed journal articles, 41 technical reports, and well over 100 conference proceedings. They have also given numerous professional presentations and training workshops. Following our most recent 5-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 Commonwealth of the Northern Mariana Islands (CNMI) and the Federated States of Micronesia (FSM).

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

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DIRECTOR



Dr. Gary Denton
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Prof. Engineering



Dr. Mark Lander
Assist. Prof. Meteorology



Dr. Charles Luo
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Jennifer Cruz
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Nathan Habana
Staff Hydrologist

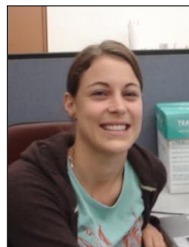
Graduate Research Assistants:



Tomo Bell



Vivianna Bendixson



Marie Kottermair



Blaz Miklavic



Von Apuya



Kennedy Tolenoa

Undergrad. Res. Assistants

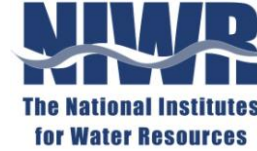


ACTIVE PROJECTS

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



US GEOLOGICAL SURVEY WATER INSTITUTE PROGRAM



GUAM:

Presenting 'Guam Water Kids': Private, DoDEA School Outreach/Teacher Relations Program

Comprehensive Analysis of Salinity Trends in the Northern Guam Lens Aquifer

Reconstructing the Sea Surface Temperature and Wet-Dry Climate History of Guam

Sediment Analysis and Modeling of the Ugum Watershed in Southern Guam

CNMI:

Environmental Impact of FUDS and Brownfields Sites in Watersheds on the Eastern Side of Saipan. Phase 1: Contaminant Analysis of Soil and Sediments

Presenting 'CNMI Water Kids': Public School Outreach/Teacher Relations Program

Reconfiguration of Saipan's Water Distribution System Model

Water System Leak Detection Training for Saipan, Commonwealth Utilities Corporation (CUC)

FSM:

Heavy Metal Status of Soils and Stream Sediments Impacted by Leachate from a Municipal Dump in Yap, Federated States of Micronesia (FSM)

Identifying Watershed Discharge Patterns and Linkages with Ecological Assemblages in Nimpal Area, Yap State, Federated States of Micronesia

Developing Flow Duration Curves for Use in Hydropower Analysis at Ungaged Sites in Kosrae, Federated States of Micronesia

Atoll Water Budget Modeling: Information Transfer and Training for the Federated States of Micronesia

OTHER FUNDED PROJECTS

NATIONAL WEATHER SERVICE

Pacific ENSO Applications Center

GUAM BUREAU OF STATISTICS AND PLANS (NOAA)

Development of a Digital Watershed Atlas for Northern Guam (ongoing)

GUAM EPA (USEPA)

GWUDI Study: Precision Mapping of Isohyets in Target Storms over the Northern Guam Lens Aquifer (ongoing)

DIRECT LOCAL FUNDING

1. GUAM HYDROLOGIC SURVEY

Spatial and Temporal Analysis of Groundwater Contamination on Guam Using GIS Technology

2. WATER RESOURCES MONITORING PROGRAM

Stream-flow, Sediment Discharge, Rainfall and Groundwater Characteristics Data Collections in Guam (ongoing)



Presenting 'Guam Water Kids': Private, DoDEA School Outreach/Teacher Relations Program



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

**Principal Investigator:
Ann Card**

Funding: \$7,620

Recognizing a need to familiarize teachers with the environmental educational materials for students age 9-12, "Guam Water Kids," and to demonstrate the value of incorporating them into curriculum. WERI funded six on-site presentations in Guam *public* schools which were conducted during the Fall 2010 semester. Some 1,150 6th grade students and 40 teachers were engaged in these presentations. The teachers who attended these sessions received a follow up survey. Preliminary results from this survey indicate that the teachers found the presentation effective, appropriate to grade level, and all indicated they are likely to use the materials on their own in future school terms.

In addition, the "Guam Water Kids" presentation was also screened in fall 2010 at the UOG Conference on Sustainability, in a small group session at the International Reading Association, and at the annual Leadership Forum sponsored by the 4-H youth organization. A number of teachers in attendance requested that the presentation also be made at private schools. Additional interest was shown by members of the home school association, teachers from the gifted and talented GATE programs, and teachers of other grade levels.

Based on this response, we intend to offer the Guam Water Kids presentation to 6th graders in private schools and the Department of Defense school system on Guam by making six presentations in fall 2011. Specifically, we intend to offer the presentation to private schools scheduling them on a first come, first served basis and the DoDEA school system following their guidelines to schedule presentations follow the presentations with an evaluation by educators involved in teaching

subjects related to water resource issues. Pending the acquisition of requested funds, our projected work plan will proceed as follows:

1. Contact and present materials to the head administrators for approval and scheduling.
2. Conduct six team presentations of the "Guam Water Kids" program led by Ann Card and educational consultant. Leave participating teachers with a packet of the educational materials including the CD presentation, printed copies of the two related Lesson Plans and Activities, and WERI contact information as appropriate.
3. Conduct a survey of participating educators to evaluate the "Guam Water Kids" presentation and related lesson plans. Include additional questions about needs teachers may have and specifically poll interest in participating in future teacher-training courses in water resources, a critical need which has been identified by the advisory council. Contact information will be preserved in order to facilitate future communication with educators. Analyze and report survey results



Comprehensive Analysis of Salinity Trends In the Northern Guam Lens Aquifer



Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
John Jenson & Mark Lander

Funding: \$25,595

The Northern Guam Lens Aquifer (NGLA) provides 80% of Guam's drinking water. Total withdrawal by all producers is currently about 45 million gallons per day (mgd), against a currently estimated sustainable yield of about 80 mgd. The anticipated military buildup during the next decade is expected to require an additional 5-6 mgd of drinking water to support the new military activities alone, and additional economic growth on the island will certainly further increase demand for municipal and private production as well. It has now been a full decade since the most recent comprehensive survey of the incidence and trends of chloride concentrations in Guam's water production wells. Moreover, the past decade has been relatively dry; some of the reported recent upward trends in chloride in production wells may therefore be driven by natural processes, but no study has yet been undertaken to ascertain how much of the observed increases, if any, may be due to the recent natural decline in recharge. There is thus a compelling need for a new survey, incorporating historical knowledge, to (1) precisely determine the current salinity trends in the freshwater lens and in particular drinking water production wells, (2) investigate the possible causes of the trends, and (3) recommend appropriate responses to the trends to promote sustainable development of additional capacity.

The proposed project will compile and evaluate historical and current data from existing sources to support statistical and graphical analyses. Spatial relationships and trends will be identified by using GIS applications to display them on 2-D and 3-D maps of the aquifer and Guam's groundwater production infrastructure. The data will thus be evaluated to determine not only the

current distribution of relatively low- and high-chloride zones in the aquifer, but also the historical spatial and temporal trends in the relationships between chloride concentrations in Guam's freshwater lens and production wells on the one hand, and spatial and historical trends in production rates and recharge on the other hand. The resulting graphics, maps, and analyses will be placed on WERI's website. The work will be done primarily in WERI's meteorology and hydrology laboratories, by a WERI-sponsored graduate research assistant under the supervision of WERI hydrologists. If separate funding can be obtained from other local and federal sources, this project will be augmented by piloting a new methodology to the determination of chloride profiles in existing and perhaps additional new deep penetrating observation wells.

The objectives of this project are to (1) update the analyses of historical trends in *chloride profiles* observed in the CWMP *observation wells*, (2) update the analyses of historical trends in *water levels* and *chloride concentrations* documented in Guam's *production wells*, alongside the record of *production rates*, (3) compile the *rainfall and evaporation* histories for the applicable portions of the aquifer, (4) *compare the patterns and trends* of the data sets, and statistically evaluate how (a) the *chloride profiles in the observation wells* and (b) the *chloride concentrations in production wells* may be responding to changes in (c) drinking water *production rates* and/or (d) natural aquifer *recharge*.



Reconstructing the Sea Surface Temperature And Wet-Dry Climate History of Guam



Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
John Jenson & Mark Lander

Funding: \$30,475

Following the 1997-1998 El Niño, which brought to Guam one of the severest droughts in living memory, the governor and legislature of Guam committed the island to research, development, and maintenance of long-term drought planning and management. Long-term planning has received additional emphasis lately, given the economic and population growth that will accompany the relocation of thousands of US military members and families from Okinawa during the next decade-and-a-half. The *Critical Water Resources Research Needs* identified by the 2010 Guam Advisory Council, for example, now include (1) developing water budgets for Guam's surface and groundwater watersheds, (2) re-evaluation of sustainable development estimates for the island's principal aquifer, and 3) expanding and updating the rainfall database of Guam to include long-term rainfall variability. In addition, the USGS-NIWR program has encouraged research related to climatic effects on the water cycle. For long-term planning it is necessary to have a long-term record of past climatic cycles, however. Unfortunately, the historical record of El Niño-related rainfall and drought for Guam is very limited, dating back only to the end of World War II.

Climate research has shown that climate trends (e.g., rainfall, drought, sea-surface temperature) in tropical areas correlate well with chemical signatures in the annual growth layers of local corals. In Guam, it is well known that El Niño brings higher sea surface temperature and lower precipitation. Sea surface temperature, for example, which is the best index of El Niño strength, rose 4° C in the Western Pacific in 1997. Guam is fortunate to have robust coral growth in its coastal waters. In August, 2010, WERI researchers extracted a coral core of the central west coast of Guam. Analysis has already begun on this specimen by collaborators at the University of Texas, Austin, and the initial results show that it will be possible to reconstruct

the past sea surface temperature history from this specimen. WERI researchers have also been collecting real-time seawater and temperature data at the sampling site since September 2009. These data will be compared with the 60-year instrumental record, which will provide a basis for interpreting the record through the past two centuries.

The immediate objective is to identify the rhythms and strengths of past El Niño events from Guam coral skeletons and correlate, and correlate them with observed conditions in the current and historical instrumental record. Guam is especially well suited for such work. Previous similar studies lack long-term *in situ* ocean environment monitoring of coral because academic facilities tend to be remote from study sites. The resources from the proposed project will enable WERI to take advantage of being able to continue ocean environmental monitoring at the coral collection sites. Moreover, WERI researchers are also collecting prehistoric climate data from stalagmites in nearby caves, which when correlated with the coral record, may provide accurate estimates of drought/rainfall cycles for the past several millennia. Ultimately, by combining the coral record with the cave record, WERI researchers and their collaborators at the University of Texas may ultimately produce a very-long-term (10s of thousands of years) record of climate history for the entire West Pacific region. Revealing these dramatic past climate cycles on Guam will allow water resource managers to more reliably predict and model the future climate trends and contribute to the preparation for drought in the future. The proposed project thus provides the seed for a very productive long-term endeavor.



Sediment Analysis and Modeling of the Ugum Watershed in Southern Guam



Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Charles Luo & Shahram Khosrowpanah

Funding: \$17,415

Guam Waterworks Authority (GWA) has collected turbidity data in the Ugum Watershed for several years. The simplicity of taking turbidity measurements allows for the continuous in-situ gathering of such data. This is very useful when monitoring rapidly varying turbidity conditions in tropical rivers. However, turbidity is not the same as the suspended sediment concentration (SSC), which is an important quantity from engineering perspective. A correlation is therefore needed between turbidity and SSC. Luckily, USGS has 4 years of daily sediment data (October 1 2005 to September 30, 2009) from the Ugum River gauging station located above Talofof Falls (ID: 16854500). The SSC data are recorded in milligrams per liter and suspended sediment discharges in tons per day. Unfortunately, there are several data gaps in the USGS 2005 and 2006 records. However, by using the available USGS daily SSC data in combination with GWA's turbidity data, it should be possible to estimate the missing values using linear regression and other methods of regression analysis.

A large-scale, unified and optimization model - LUOM (Luo, 2007) - has recently been developed. This two-dimensional distributed watershed model predicts various hydrological components of a watershed. Another model, LUOM-SED (Luo, 2003), is a basin-wide distributed sediment production and transportation model that was developed from LUOM (Luo, 2007) and employs diffusive wave model equations to govern the surface water flow. Sediment is produced from each grid relating to rainfall intensity, flow velocity, slope, vegetation, and soil types. The concentration continuity equation is utilized to govern the sediment transportation across the

basin. Then, the sediment gradually reaches and accumulates in the channel it falls into and is computed in two transportation patterns: bed load and suspended load, according to the flow capacity. One dimensional equations are adopted to simulate the sediment movements in the river and riverbed change, and finally output the time series of sediment volume at selected locations. This model will be calibrated using the data available for the Ugum watershed. The objectives of this project are: 1) To find the correlation between the turbidity and SSC data sets collected by GWA and USGS respectively; 2) Use this correlation to estimate the 2005 and 2006 missing SSC data; and, 3) Calibrate and validate the LUOM-SED using the SSC data with the missing data added.

The benefits of this project will be enormous not only to Guam but also to other islands in the Western Pacific. It provides not only the correlation of turbidity and SSC, but also the calibrated model LUOM-SED, both of which could be applied to water quality studies in any watersheds in Guam with similar geological and hydrological conditions. The calibrated model could also be used for environmental evaluation for badland regeneration and/or deterioration. Researchers studying the impact of various watershed management practices could generate sediment output with the calibrated model. Additionally, turbidity data at various section of a watershed could also be used to produce SSC data. By providing a clearer understanding of the sediment situation in Guam's rivers and streams, GWA will also be better positioned to determine which surface water sources in southern Guam could best be tapped for drinking water purposes.



Environmental Impact of FUDS and Brownfields Sites in Watersheds on the Eastern Side of Saipan. Phase 1: Contaminant Analysis of Soil and Sediments



Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
John A. Starmer, Brian G. Bearden & Gary R.W. Denton

Funding: \$29,379

The massive clean-up and redevelopment of Saipan at the end of WWII presented waste disposal problems that were largely solved by either bulldozing unwanted materials into the ocean, burying them in caves, or dumping them at specific locations on land. Virtually every kind of material used in warfare were among the items disposed of in this way, in addition to demolition and construction debris and other residual materials associated with the rebuilding effort. At the time, little if any thought was given to the impact of these dumpsites on the surrounding environment. As a consequence, the majority of disposal sites that arose out of that period in Saipan's history were soon overgrown by natural vegetation and largely forgotten within the space of a few years. Renewed interest in their existence did not come until almost half a century later following the implementation of the Department of Defense (DOD) Formerly Used Defense Site (FUDS) Environmental Restoration Program in 1986 and the Brownfields Program that evolved out of the Brownfields Revitalization and Environmental Restoration Act of 2001. Shortly thereafter, thirty two confirmed FUDS were identified throughout the CNMI. Twenty three of these were located in Saipan along with forty one other suspected Brownfields sites.

To date, inventories of materials disposed of in the FUDS and Brownfield sites of the CNMI are based largely on visual assessment with unexploded ordnances, munitions and demolition materials ranking among the more obvious wastes present. What little chemical data there are indicate that heavy metals, pesticides, PCBs, organic solvents (TCE, PCE, vinyl chloride, methyl tertiary butyl ether), petroleum and polycyclic aromatic hydrocarbons are the most commonly encountered contaminants. Few studies have attempted to quantitatively delineate

the extent of any chemical contamination at these sites and no definitive watershed studies, other than those conducted by WERI along the western seaboard of Saipan, have assessed the impact of any bioaccumulative compounds present (e.g., metals, pesticides and PCBs) on the edible quality of aquatic resources harvested for food in downgradient locations.

The study described herein builds upon the earlier WERI studies by extending them to the eastern seaboard of Saipan where no such information currently exists. It will be conducted in two discrete phases. Phase 1 is the subject of this proposal and aims to identify potentially troublesome dumpsites in watersheds on the eastern side of the island, along with potential drainage pathways that could facilitate the movement of chemical contaminants downgradient towards the coast. Extensive soil and sediment sampling within impacted watersheds and along the coast will delineate the existence and severity of any such contamination. Phase 2 will follow at some later date and determine contaminant levels in aquatic resources from impacted areas as well as evaluate potential health risks associated with their long-term consumption. Overall, the study will add significantly to the existing contaminant database and command the interest of all involved with environmental remediation and resource management in the CNMI. It will also provide the necessary foundations for the continued monitoring and assessment of pollution problems in the area. Such information is vital for the overall protection and sustainable development of aquatic resources in Saipan's watersheds and coastal waters.



Presenting 'CNMI Water Kids': Public School Outreach/Teacher Relations Program



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

**Principal Investigator:
Ann Card**

Funding: \$17,887

The environmental educational materials for students age 9-12 about fresh water resource issues on Saipan, Rota and Tinian, CNMI, have been developed recently. The "CNMI Water Kids" materials emphasize the importance of fresh water as a key natural resource, explain hydrological concepts, and introduce a sense of stewardship for conserving and protecting fresh water in the CNMI. These materials include a pre-recorded presentation, teacher's lesson plans and suggested activities, a Chamorro language glossary, and a companion website. The educational materials are correlated to learning standards used by the CNMI Public School System. The materials were developed, in part, to support outreach efforts by WERI. There is a need to familiarize teachers with the materials and demonstrate the value of incorporating them into curriculum. Working directly with these educators will increase awareness of WERI as a resource for water related issues and will open opportunities for WERI to engage educators in the future. As materials are employed and as teachers become engaged in water resource issues, an evaluation is needed to assess the effectiveness of the "CNMI Water Kids" materials and to explore additional needs teachers may report such as a willingness to participate in water related courses for educators which may be developed in the future.

Specifically, we intend to follow the public schools' chain of approval, schedule a presentation targeted to reaching the 6th graders at each public elementary school (9 on Saipan, 1 on Rota, 1 on Tinian) and follow the presentations with an evaluation by educators

involved in teaching subjects related to water resource issues. Procedures include:

- Contact and present materials to the CNMI Public School System's Chancellor's Office for approval as required and schedule presentations to all sixth grade sections to be conducted in the fall 2011 semester.
- Conduct 11 team presentations of the "CNMI Water Kids" program led by Ann Card to include the educational consultant Jennifer Berry and one technical assistant. Leave participating teachers with a packet of the educational materials including the CD presentation, printed copies of the two related Lesson Plans and Activities, and WERI contact information as appropriate.
- Conduct a survey of participating educators to evaluate the "CNMI Water Kids" presentation and related lesson plans. Include additional questions about needs teachers may have and specifically poll interest in participating in future teacher-training courses in water resources, a critical need which has been identified by the advisory council. The survey will be conducted online with an "on paper" option in order to facilitate participation. Contact information will be preserved in order to facilitate future communication with educators.
- Analyze and report survey results.
- Make any appropriate adjustments to existing "CNMI Water Kids" materials indicated by educators' assessments.



Reconfiguration of Saipan's Water Distribution System Model



Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Shahram Khosrowpanah, Leroy F. Heitz & Mariano R. Iglecias

Funding: \$26,355

Water hours and low delivery pressure have long been a part of the daily lives of the people in the islands of the Western Pacific. In Saipan, Commonwealth of the Northern Mariana Islands (CNMI), large investments have been made in system improvements, but delivery problems still exist. A stated goal of the CNMI government is to provide 24-hour water to all residents served by the Commonwealth Utilities Corporation (CUC) water system.

Recently, Stipulated Orders have been filed in the US District Court for the Northern Mariana Islands to compel the utility company to adhere to federal regulations governing water, sewer, and power (Eaton, 2008). As part of this act, CUC should develop a hydraulic model of the water distribution system that will be used for system improvement, system operation, and future system expansion.

Researchers at the University of Guam Water and Environmental Research Institute of the Western Pacific (WERI) developed computerized models of each of the fifteen sub-regions of the CUC water system using the Haestad WaterCAD water system modeling program. Later on, they developed a source, transmission and storage model of the Saipan water system, and a GIS data base of the system. Recently CUC has been added many additional sources of water, new tanks and pipes have been added to the system, and system operation has been changed. To comply with the stipulated order and enable CUC to provide a 24-hour water service, there is a need to reconfiguring the skeleton model of

the water distribution system reflecting new changes in physical and operation of the system. The goal of this project is to:

1. Gather new data on the physical and hydraulic description of all the new water system development for the last three years.
2. Connecting the sub-region according to the new CUC water routing plans.
3. Input the water production to the model and run the model in steady state and time simulation modes.
4. Export the information from Saipan's Haestad model into the GIS layers.
5. Updating the GIS data base and develop the most efficient and cost effective means of transmitting water from water supply rich regions to those that have supply shortages.

The benefit to the CUC will be the ability to: a) determine the amount of water that is being lost through the system (un-accounted for), b) implement various operational systems for transferring water among the 15-sub region for providing 24-hour water service to the costumers, and 3) comply with stipulation order.



Water System Leak Detection Training for Saipan, Commonwealth Utilities Corporation (CUC)



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

**Principal Investigator:
Shahram Khosrowpanah**

Funding: \$14,180

Water system leakage is a serious problem for all utility agencies throughout the Western Pacific. It reduces the performance of the system and represents a big money loss to water utility agencies. The development of modern water distribution systems for most of the islands in this area started in 1970 with periodic upgrades sponsored through a series of US capital improvements projects. Despite this, the majority of systems operating today suffer from excess water leakages, some as high as 60% on some islands. Aside from the negative impact on revenues, such losses all too often result in water utility agencies being unable to provide their customer base with a reliable 24-hour water service. One relatively rapid and cost-effective means of overcoming this problem is to implement a simple leak detection program with appropriate equipment and training for water utilities personnel. At the 2010 Water Resources Advisory Council meeting in the CNMI, the Saipan Commonwealth Utilities Corporation (CUC) requested that WERI carry out a leak detection training program for their water distribution system. This proposal seeks funding to implement such a training program on the island of Kosrae, which currently ranks among the most severely affected islands, insofar as no-revenue water losses from leaks are concerned.

The proposed training will be conducted over a period of one week and will provide participants with a workable knowledge of leak detection theory. It will also consider common cause of water leakages in distribution systems and provide participants with hands-on field experience on how to find leaks and fix them. The topics to be presented at this proposed training exercise are summarized below:

- 1) Leak detection theory and how to determine when a leaky survey is required.
- 2) Economic benefits of a leak detection survey.
- 3) How to incorporate a leak detection survey and/or permanent leak detection crew for your water facility.
- 4) How to become familiar with various sounds created by leaks and type of leaks encountered.
- 5) Types of leak detection surveys and proper record keeping.
- 6) Getting familiar with various leak detection equipment and techniques.

Field demonstration and actual leak detection scenarios and exercises. This will include field demonstration, general survey, general pinpointing, emergency pinpointing, estimating leakage, reporting, and vehicle setup



Heavy Metal Status of Soils and Stream Sediments Impacted by Leachate from a Municipal Dump in Yap State, Federated States of Micronesia



Funded by:
US Geological Survey, Water Institute Program

Principal Investigator:
Christina Filledmed

Funding: \$4,500

The main public dump in Yap State, FSM, is an open, unsanitary facility located approximately 2 miles west of Colonia in the municipalities of *Rull* and *Dalipebinaw*. It was officially opened by the State government in the late 1970s and has served as the main repository of non-segregated wastes from Yap Proper/Main Island since then. The dump receives around 4 tons of garbage and other residential wastes per day from Colonia town area and surrounding rural communities. Currently, it covers an area of approximately 1,460 square meters, and rises to a height of 10 meters at its highest point.

The dump is maintained by the Department of Public Works & Transportation who focuses largely on trash compaction and site stability. While soil cover is used to reduce odor, flies and vermin, it is applied only intermittently and largely inadequate. Of far greater concern, however, is the fact that the dump is not lined and there are no leachate retention systems in place. As a consequence, leachate that exudes at intervals around the dump perimeter during wet weather conditions flow down gradient into a nearby stream known as *Lul nu Tamthaw*. This stream flows east for about 1 km before emptying into a forest of mangroves at the coast. Both the stream and the mangroves are popularly used by local residents for fishing, food gathering and recreational activities. The potential impact of the raw leachate on aquatic resources in these areas has been of long-standing concern to the people of Yap both from an ecological and human health standpoint.

The proposal described herein seeks funding to perform preliminary heavy metal analysis of soil and stream sediments down gradient of the Yap

dump and addresses a critical need recently identified by the FSM-WERI Advisory Council Meeting at their annual meeting in Yap. Heavy metals are common contaminants of concern in unmitigated leachate flows from such solid waste facilities as the one described above. Moreover, certain metals some such as lead, cadmium and mercury are highly persistent poisons that are readily accumulated by fish, shellfish, crustaceans and other aquatic resources commonly harvested for food.

Soil samples will be collected for heavy metal analysis at strategic points around the dump perimeter and down gradient of the facility. Sediments from the impacted *Lul nu Tamthaw* stream (upstream and downstream of the dump) will also be examined at discrete intervals between the dump and the coast. All Chemical analysis will be performed by the WERI Water Quality Testing Laboratory at the University of Guam where adequate facilities and infrastructure exist.

Results are especially crucial at this juncture in view of heightened community concerns, as well as need for baseline information to aid Government & Non-Government planning for improved management and rehabilitation of the dump site over the next five years. The project receives support from the Department of Public Works & Transportation and the Safe Disposal Management Group which leads waste improvement efforts in the State. This project follows current efforts for information gathering and collection in and relating to the current dump site and its possible effects on the surrounding environment and people.



Identifying Watershed Discharge Patterns and Linkages with Ecological Assemblages in Nimpal Area, Yap State Federated States of Micronesia



Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Peter Houk & Yimnang Golbuu

Funding: \$20,240

Throughout Micronesia the impacts of land-based sources of pollution to nearshore marine resources are increasing in severity. Numerous conservation planning documents cite land-based pollution among the highest priority items for improved science and management to address, evidenced through WERI's 2010 critical needs list. Briefly, much of the scientific insight to date surrounding land-based pollution and coral reef assemblages has emerged through examining 'heavily polluted' locales and drawing comparisons with 'pristine' locales to define somewhat obvious conditions on reef assemblages that are associated with watershed status. Yet, throughout Micronesia the overwhelming majority of sites lie somewhere between these extreme pollution endpoints. It is critical that we collectively build upon the science to identify more relevant thresholds for efficiently identifying and quantifying sources of water quality impairment. This should include building new science and using the existing body of evidence to approach numerous, site-specific management needs that exist.

Here, we propose to conduct coupled water quality and ecological sampling in Yap State, along the coastline associated with the Nimpal marine conservation area (MCA). The MCA was established in May 2008 by the community to address growing concerns of marine resource depletion and declining coral reef 'health'. Our project would build upon an existing community-led watershed project awarded by the Micronesian Conservation Trust (MCT) that led to the general characterization of discharge patterns and relative volumes of freshwater input, both inside and outside of the MCA. As a result of MCT-funded efforts, the extent of each sub-drainage is becoming better defined, paving the way for enhanced data collection within each to identify where, and what type of improvements to community-based

management will best facilitate success. Here we propose to:

- Build a better understanding (statistically) of the pertinent water quality and discharge patterns in the nearshore environment,
- Enhance water quality data collection to begin approaching sub-drainage patterns,
- Draw affinities with the contemporary seagrass and macroalgae assemblages.

Following these steps our project aims to approach local concerns regarding macroalgae proliferation over the years. The proposed methods are all collaborative in nature, with an underlying theme of producing sound science through partnerships that build local capacity. All data collection will be conducted with community-based monitoring teams that already have positive relationships with both principle investigators (PI's). Methods include:

- Surface current data collected using GPS-mounted drones,
- Water quality profiles collected using high-resolution, continuously-recording, water quality instrumentation. These data would be integrated with locational data to yield GIS layers for interpretive purposes,
- Enhanced nutrient sampling of priority nearshore waters,
- Ecological data collection to investigate ecological-environmental coupling.

Initially habitat maps will be created that will define the boundaries of relevant ecological assemblages. For this project we will focus on submerged aquatic vegetation habitats, and will establish several study locations in the project vicinity, parallel to shore. Each study site will consist of 5 x 50 m transect lines where replicate estimates of seagrass and macroalgae abundances, and associated datasets described within, are derived with statistical confidence.



Developing Flow Duration Curves for Use in Hydropower Analysis at Ungaged Sites in Kosrae, Federated States of Micronesia



Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Shahram Khosrowpanah & Leroy F. Heitz

Funding: \$23,462

The cost and availability of energy resources is one key factor in the economic development and quality of life of any developing country. This is especially true in the Kosrae, Federated States of Micronesia (FSM), where essentially all of the energy produced is from costly, non-renewable, and potentially environmentally damaging fossil fuel (oil) resources. The cost of fuel to operate the local power plant has risen dramatically over the past years and no doubt will continue to rise in the future. With these increases of fuel costs, it becomes more and more important to explore other means of providing energy to the islands power grid.

Kosrae is blessed with an abundance of surface water resources and because of the extreme topography of the island many of these streams have very high slopes. This combination of abundant streamflow and high stream gradient or slope is ideal for the application of run-of-river-hydropower development. This kind of hydropower development has the least environmental impact and is generally less capital intensive than typical hydropower plants built in conjunction with high dams with large amounts of water storage. While in general hydropower plants are high in first cost, the cost per kilowatt hour of energy production is lower than fossil fuel plants and has the advantage of remaining relatively stable over the life of the project.

In order to explore the feasibility of using hydropower as an additional energy source for Kosrae, it is necessary to be able to define the variability of flow available in the streams where the hydropower plants might be constructed. 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 gaged to an ungaged stream or from a gaged location on a stream to an ungaged location on that same stream. What is needed in Kosrae is a better means of predicting the variability of flow at ungaged locations that are likely to become candidate sites for future water resources development.

The results of this project will be the development of a means of predicting flow duration curves at ungaged sites in Kosrae. All of the major streams of the island will be divided into stream reaches, or homogenous sections of a stream, that have similar flow properties. These reaches will be identified on maps developed from the detailed Geographic Information System (GIS) map inventory of Kosrae available at WERI. Various statistical and analytical methods, will be applied to the existing streamflow data and physically characteristics of the reaches in order to predict the streamflow in each stream reach.

The final results will be a series of GIS maps of the streams of Kosrae with each stream reach identified. By selecting a reach on the provided GIS maps, the user will be able to obtain the average flow in a reach. Those wishing to explore the feasibility of hydro power at the site will be able to enter the average flow information into a simple spreadsheet application which will be provided as part of the study. This application will allow the user to explore various turbine sizing and economic consideration to determine the preliminary feasibility of developing a hydropower facility at a particular site.



Atoll Water Budget Modeling: Information Transfer and Training for the Federated States of Micronesia



Funded by:
US Geological Survey, Water Institute Program

Principal Investigator:
John Jenson

Funding: \$10,300

Water shortages are a persistent concern for residents of atoll islands. Normally, water demand is met by rooftop rain catchment, but prolonged droughts, such as those associated with ENSO events in the western Pacific region, can exhaust water storage, leaving residents dependent on groundwater or imported water. In response to the recommendation by the FSM Advisory Council meeting of October 23, 2006 in Pohnpei, WERI researchers developed an accurate and practical saltwater intrusion and groundwater evaluation model for atoll islands in the FSM. During 2008 and 2009, the developers of the model presented initial demonstrations to a limited number of available water resource managers and government officials on Yap and Pohnpei. Use of the model to predict the amount of fresh groundwater during average seasonal climatic conditions as well as periods of intense drought for the atolls of the FSM was carried out during the summer of 2010, and results of this analysis, along with additional training on atoll island geology and hydrology, were presented to FSM officials on Pohnpei in October 2010. During this year's Advisory Council meeting on October 5, 2010, on Pohnpei, council members specifically requested further training and presentation of results to be given next year on Chuuk, which contains 11 of the 32 atolls in the FSM. (Item III.5, Education and Professional Training, FSM Critical Water Resources Research, Education And Training Needs: Continue Atoll Groundwater Modeling

workshops in all FSM States with atoll islands.)

This is an information transfer project in which end-users will be trained by WERI instructors on the derivation of the model, the operation of the model, the application of the model to estimate the responses of atoll island aquifers in the Caroline Islands to expected types of seasonal and inter-annual changes in rainfall, and finally results of the model when applied to specific FSM atoll islands. Application of the model thus also meets and additional identified need to continue the development of appropriate groundwater management plans for low and high islands throughout the FSM (Item II.4, Water Quantity Projects).

The objective is to train users of the model so that they can independently operate it and interpret the results. Training will be tailored for application of the model to the atolls of Chuuk. Such use may include making forecasts of the effects of selected changes in rainfall on atoll islands affected by significant natural events, such ENSO-driven droughts, tropical storms, or wash-over events. A second objective is to establish an ongoing technical support relationship between the authors and users so that there will be a continuing dialogue to support continued successful use and application of the model to water resource management in the Federated States of Micronesia.

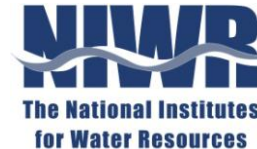


PROJECTS COMPLETED MARCH 2011



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

US GEOLOGICAL SURVEY WATER INSTITUTE PROGRAM



GUAM:

The Influence of Sediment Load and Riparian Vegetation on the Diversity and Habitat use of Native Streamfish and Invertebrates of Guam.

**Presenting 'Guam Water Kids': Public School Outreach and Teacher Relations Program
Reconstructing the Ancient Rainfall-Drought History of Guam**

Reconstructing the Pre-Historic Rainfall-Drought History of Guam

Continuing Calibration and Application of LUOM in Southern Guam Watersheds

Applications of LiDAR Data for Inarajan Watershed Management

CNMI:

Development of a GIS Data Base for Saipan's Drinking Water Delivery System

CNMI Water Kids: An Educational Resource for Teaching Children about Fresh Water and How to Protect It (*An adaptation of Guam Water Kids*)

Impact of Urban Runoff, Wastewater Discharges and Past Solid Waste Disposal Practices on Contaminant Profiles in Fish from Saipan Lagoon

FSM:

Comprehensive Survey of the Current State, Infrastructure, and Usage of Freshwater Resources in the Mortlock Islands, Chuuk State, Federated States of Micronesia

Atoll Island Sustainability: Information Transfer and Training for the Federated States of Micronesia (FSM)

Water System Leak Detection Training for Kosrae State, Federated State of Micronesia

OTHER FUNDED PROJECTS

NATIONAL WEATHER SERVICE

Pacific ENSO Applications Center

GUAM BUREAU OF STATISTICS AND PLANS (NOAA)

Development of a Digital Watershed Atlas for Northern Guam (ongoing)

GUAM EPA (USEPA)

GWUDI Study: Precision Mapping of Isohyets in Target Storms over the Northern Guam Lens Aquifer (ongoing)

DIRECT LOCAL FUNDING

1. GUAM HYDROLOGIC SURVEY

Spatio-temporal Analysis of Groundwater Quality in Guam (ongoing)

2. WATER RESOURCES MONITORING PROGRAM

Stream-flow, Sediment Discharge, Rainfall and Groundwater Characteristics Data Collections in Guam (ongoing)



The Influence of Sediment Load and Riparian Vegetation on the Diversity and Habitat Use of Native Streamfish and Invertebrates on Guam



Funded by:
US Geological Survey, Water Institute Program

Principal Investigator:
Frank Camacho

Funding: \$15,735

Fresh water is one of Guam's premier natural resources and is vital to life on our island. Beyond drinking, washing and the daily activities of life, we must have a reliable and ample source of clean water to support our industries including tourism, to preserve community health, to control fires, and for recreation. A stable supply of fresh water improves property values and is essential to the island's economy. Guam residents must have access to information about the value of our freshwater supply if they are to take responsibility for curtailing pollution originating in households and businesses, conserving water through consumer-side system maintenance and water saving practices, and participating in community action and decision-making.

This education program will create an awareness of public policies and an interest in adopting personal practices that support the protection of clean and abundant fresh water on Guam. The working title, "Protect Guam's Fresh Water," is intended to target adult residents of Guam especially home owners, business owners, and farmers who handle hazardous chemicals or toxic waste. The program consists of a (1) Public Service Campaign, (2) an Online Clearinghouse, and (3) Partner Recruitment of businesses and agencies. The Public Service Campaign includes the components needed to promote awareness and methods to "Protect Guam's Fresh Water." Local mass media will be alerted to the campaign and oriented to the purpose and availability of campaign materials, and will be able to conveniently download print ads, radio spots, and a television spot in appropriate formats for use by their respective publications and broadcast needs. Information about avoiding pollution,

practicing conservation and participating in community action will be emphasized. Simple methods and tips that take into consideration local lifestyles and conditions will be included. The Online Clearinghouse will give easy, 24/7 public access to information in the following three areas: 1) Information tips and FAQs on how one can make a difference in Protecting Guam's Fresh Water with simple practices at home and work; 2) Ideas for speaking to key officials, media outlets, and online forums will be included in a directory; 3) A registry will offer community action groups an opportunity to recruit participants. The Partnership Recruitment will target the mass media, businesses, agencies, civic groups and community leaders providing opportunities to help spread information by reprinting and sending statement stuffers, posting tips on bulletin boards, and adopting 'fresh water friendly' practices.

The program objectives are to 1) provide the public with easy access to information about protecting Guam's freshwater resources; 2) promote personal responsibility for controlling pollution at home and work especially from household-type chemicals, landscaping and farming activities and septic tanks; 3) promote personal responsibility to repair consumer-side water leaks and instituting water saving practices; 4) provide access to information about participating in decision-making and community discussions and 5) serve as an ongoing reminder of the value and importance of the island's natural resource of fresh water.



Presenting Guam Water Kids': Public School Outreach and Teacher Relations Program



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

**Principal Investigator:
Ann Card**

Funding: \$7,685

The environmental educational materials for students age 9-12 about fresh water resource issues on Guam have recently been developed. The "Guam Water Kids" materials emphasize the importance of Guam's fresh water as a key resource, explain hydrological concepts, and introduce a sense of stewardship for conserving and protecting Guam's fresh water. These materials include a pre-recorded presentation, teacher's lesson plans and suggested activities, a Chamorro language glossary, and a companion website. The educational materials are correlated to learning standards recognized by the Guam Department of Education and have been approved for use in Guam public schools by the superintendent's office and announced in the GDOE newsletter. The materials were developed, in part, to support outreach efforts by WERI. There is a need to familiarize teachers with the materials and demonstrate the value of incorporating them into curriculum. Working directly with these educators will also increase awareness of WERI as a resource for water related issues and will open opportunities for WERI to engage educators in the future. As materials are employed and as teachers become engaged in water resource issues, an evaluation is needed to assess the effectiveness of the "Guam Water Kids" materials and to explore additional needs teachers may report such as a willingness to participate in water related courses for educators which may be developed in the future.

Specifically, we intend to follow the public schools' chain of approval, schedule a presentation targeted to reaching the 5th graders at each of the 6 elementary schools and follow the presentations with an

evaluation by educators involved in teaching subjects related to water resource issues. Procedures include:

- 1) Contact and present materials to the principals at each of the six elementary schools in the Guam public school system for approval at the school level. Upon principal's approval, contact appropriate head teacher and schedule presentation to all fifth grade sections to be conducted in the spring 2010 and fall 2010 semesters.
- 2) Conduct six team presentations of the "Guam Water Kids" program led by Ann Card and with WERI professionals serving as resource persons. Leave participating teachers with a packet of the educational materials including the CD presentation, printed copies of the two related Lesson Plans and Activities, and WERI contact information as appropriate.
- 3) Conduct a survey of participating educators to evaluate the "Guam Water Kids" presentation and related lesson plans. Include additional questions about needs teachers may have and specifically poll interest in participating in future teacher training courses in water resources, a critical need which has been identified by the advisory council. The survey will be conducted online with an "on paper" option in order to facilitate participation. Contact information will be preserved in order to facilitate future communication with educators.
- 4) Analyze and report survey results. Make any appropriate adjustments to existing "Guam Water Kids" materials indicated by educators' assessments.



Reconstructing the Pre-Historic Rainfall-Drought History of Guam



Funded by:
US Geological Survey, Water Institute Program

Principal Investigator:
John Jenson

Funding: \$16,241

At its 2008 meeting, the Guam Water Resources Advisory Council identified as one of its research priorities “expanding and updating the rainfall database for Guam,” to include long-term rainfall variability (Item 16, under *Water Quantity Issues, Guam’s Critical Water Resources Research, Education And Training Needs*). This need was reiterated at the 2009 meeting. Although the instrumental climate record for Guam begins only at the end of World War II, current research is revealing that regional climates everywhere are characterized by decadal, centennial, and millennial scale oscillations. Even the oldest of historical instrumental records in the world—which date at best from the early Eighteenth Century—are too short to document long-term cycles. It is becoming increasingly important for economic planners and managers, however, to be able to anticipate or understand the likely duration and severity, if not the causes, of long-term or persistent shifts in weather and climate patterns. Of particular interest in the west Pacific Ocean region are the patterns of flooding/drought, prevailing winds, and the frequency and severity of major storms, which are already known to follow cycles of decadal and longer duration. To characterize long-term rainfall and temperature patterns prior to the historical record, however, requires estimating them from proxies, i.e., indirect evidence recorded in natural features such as ocean or lake sediment layers, pollen and tree-ring records, or cave deposits.

One the most productive sources of long-term pre-historic climate data is stalagmites, i.e., layered calcite deposits precipitated from cave dripwater. With current laboratory techniques, stalagmites can reveal datable changes in

certain chemical parameters that can be resolved at intervals ranging from seasons to millennia and spanning histories ranging from decades to hundreds of millennia. Changes in the amount and/or sources of rainfall and sometimes above-ground temperature can be inferred from the chemical parameters and changes in rate of growth, especially if the relationship is known between the chemistry of the modern calcite layers and the dripwater from which they precipitate. Fortunately, WERI researchers working have identified and mapped a number of accessible caves on Guam that contain promising stalagmite records from which the pre-historical climate record of Guam might thus be reconstructed.

This project will continue and extend the very promising work begun during the past year to collect regular monthly samples of dripwaters from caves in which speleothems have been collected, and which are currently undergoing analysis at the Jackson School of Geosciences at the University of Texas at Austin, in a separately funded project. The proposed project would continue the detailed investigation of the chemical environment from which the climate data are to be derived. Instrumentation of one of the caves in northern Guam has produced very promising data so far. Moreover, since the current year has brought a fairly strong El Nino, we now have an opportunity to capture a representative El Nino signal. Finally, the project will be an important element in a larger collaborative project for which we have applied for National Science Foundation funding, and that will include similar work on caves in Borneo, The Philippines, The Solomon Islands, and Vanuatu to determine the climate history of the entire western Pacific region.



Calibration and Application of LOUM in Southern Guam Watersheds



Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Charles Luo and Shahram Khosrowpanah

Funding: \$25,971

The Large-scale, Unified and Optimization Model, LUOM (Luo, 2007) is a fully physically based, 2-dimensionally distributed watershed model simulating the hydrologic cycle on a watershed scale. The model discretizes the watershed into rectangular grid cells and makes use of DEM (Digital Elevation Model) data, vegetation data and climate input data, mainly precipitation, temperature and wind speed, to generate one-dimensional output – discharge hydrographs and two-dimensional hydrologic quantities such as evapotranspiration, infiltration, soil moisture, groundwater table and surface water depth. Simulating impacts of land use (vegetation) transformation and global climate changes are within the model's capability.

During the preceding project, Calibration and Application of LUOM (Luo, 2007) in Southern Guam Watersheds With and Without Flow Data, DEM, vegetation, soil, rainfall and streamflow data have been collected, hydrologic watershed boundaries and stream networks have been delineated, and LUOM has been calibrated in the Ugum watershed and 4 other watersheds with both rainfall and flow data, and 7 other watersheds without flow data. Combining all available climate stations in southern Guam provided 54 years of rainfall data from which time series of flow data were generated by the calibrated model for all 12 watersheds.

The objective of the project described herein, is to continue the calibration and application of LUOM in the rest southern Guam watersheds that were not covered in the previous project. Using the data collected in the preceding project, LUOM will be calibrated in Talofoto, Ylig, Pago and other watersheds with available streamflow data. The calibrated model will be used to provide any missing data for these watersheds as well as for other southern Guam watersheds without streamflow data.

The benefits of this project will be enormous not only to Guam but also to other islands in Western Pacific. Researchers will be able to implement various watershed management practices within the watershed. For example, by having flow data, researchers studying the impact of various watershed management practices, can develop a correlation between stream flow, rainfall, and turbidity at various sections of a watershed. The model will also assist the Guam Waterworks Authority (GWA) with future explorations for potential sources of potable surface water in southern Guam. Finally, by providing flow data for the 16 ungaged streams on island, potential sites for small dam construction may be identified.



Applications of LiDAR Data for Inarajan Watershed Management



Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Yuming Wen and Shahram Khosrowpanah

Funding: \$25,171

Guam, an unincorporated U.S. territory in the western Pacific, is the largest (about 541.3 km²) and southernmost island in the Mariana Islands. The population of Guam has gradually increased since WWII and currently stands at around 180,000. Because of military buildup activities, an estimated 40,400 active military personnel and dependents are expected by 2014. With more population to stream to Guam in the next few years and beyond, more solid wastes will be generated.

On February 11, 2004, the Government of Guam (Guam Department of Public Works and Guam Environmental Protection Agency) entered into a Consent Decree (Civil Case No. 02-00022) with the United States of America (U.S. Environmental Protection Agency with the U.S. Department of Justice) in U.S. District Court, Territory of Guam. The Consent Decree is a settlement agreement to resolve issues related to the unauthorized discharge of pollutants from the Ordot Dump to the Lonfit River. The historical and continuing discharge of pollutants to the Lonfit River is a violation of the Clean Water Act (CWA). The Consent Decree aims to resolve civil penalties and to establish a schedule for construction of a Municipal Solid Waste Landfill Facility (MSWLF) and closure of the Ordot Dump.

As part of the Consent Decree, Guam is required to site and must design, construct, and operate a landfill that is fully compliant with Guam Solid Waste Disposal Rules and Regulations. As part of the agreement, the landfill must be in operation on September

23, 2007, or earlier. Within the constraints of the Consent Decree and in accordance with the 2000 Integrated Solid Waste Management Plan (ISWMP), the Government engaged in a site screening and site selection process. Based on the selection process, an area in Layon, Dandan, Inarajan, was selected for the future landfill site.

This research proposal focuses on applications of LiDAR data collected in early 2007 for Inarajan Watershed management. Raw LiDAR data will be used to obtain watershed characteristics for Inarajan Watershed. In this project, GIS and related technologies such as remote sensing and global positioning system (GPS) will be used to collect, digitize, organize, model and analyze data on watershed characteristics. GPS can be used for data ground-truthing, remote sensing can be used to collect data for hard-to-reach areas and to update GIS database, while GIS, enhanced by remote sensing and GPS capabilities, will be the core tool for this project. The overall objective of the project aims to obtain watershed characteristics from LiDAR data for the Inarajan Watershed.

The main objectives of this project are listed as follows:

1. Preprocess the raw LiDAR data collected in early 2007;
2. Find and remove noises from the LiDAR data if they exist;

Obtain watershed characteristics for the Inarajan Watershed.



Development of a GIS Data Base for Saipan's Drinking Water Delivery System



Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Shahram Khosrowpanah, Yuming Wen & Mariano Inglecias

Funding: \$30,490

The environmental educational materials about water resource issues in earth science textbooks and online at the websites of government agencies now available to Commonwealth of the Northern Mariana Islands (CNMI) school children and educators are focused on conditions existing on the U.S. mainland. These materials and accompanying illustrations and images do not fully address basic features related to water resources and the critical need to protect and conserve as related to Saipan, Rota and Tinian.

Recently, environmental educational materials for students age 9-12 about fresh water resource issues on Guam were developed. The "Guam Water Kids" materials emphasize the importance of Guam's fresh water as a key resource, explain hydrological concepts, and introduce a sense of stewardship for conserving and protecting fresh water. These materials include a pre-recorded presentation, teacher's lesson plans with suggested activities, a Chamorro language glossary and a companion website.

Specifically, in order to foster a better understanding of the importance of fresh water as a key resource and a sense of stewardship, we intend to adapt the existing materials in "Guam Water Kids" to create "CNMI Water Kids" featuring water resource information and issues pertaining to Saipan, Rota and Tinian. Some materials such as the animated illustration of the water cycle, the photos defining fresh water featuring a tropical setting, and conservation at home, may be retained. The Chamorro language glossary will require only minor revisions. Illustrations featuring maps with the location of ground and surface water for each of the three islands and

some place-specific photos will need to be developed. In addition to revising illustrations, the written text and script will need to be adapted and recorded.

Components for CNMI will include (1) a CD PowerPoint™ presentation with pre-recorded narrator and music with animation that can be used as (a) a scripted or extemporaneous slideshow, (b) a stand-alone presentation with pre-recorded narrator and music, or (c) a continuous "unmanned" presentation such as at an exhibit booth, (2) two Lesson Plans for teachers with activities, related vocabulary, and Chamorro glossary, and (3) "CNMI Water Kids" website featuring self-study slide shows, activities, and downloadable copies of the educational resource materials including the teacher lesson plans.

The project will accomplish the following objectives.

1. Provide an online resource for teachers and other youth leaders that will enable them to share the importance of water resources and the need for protecting them using materials that students in the CNMI can easily relate to.
2. Provide a website to support educators with downloadable materials and for youth to independently explore CNMI water resources while developing a sense of stewardship.
3. Provide a convenient, self-contained classroom presentation that shares the basic concepts of the hydrological cycle and water resource issues with support materials for teachers on CD.



CNMI Water Kids: An Educational Resource for Teaching Children about Fresh Water and How to Protect It (*an adaption of 'Guam Water Kids'*)



Funded by:
US Geological Survey, Water Institute Program

Principal Investigator:
Ann Card

Funding: \$7,980

In March of 2009, the Commonwealth Utilities Corporation (CUC) entered into a stipulated order (STO) for preliminary relief under an agreement with the Government of the United States. The order provided for a long list of compliance items that CUC must complete in order to satisfy the stipulated order. One major item that CUC must prepare is a Master Plan for their water supply and waste water systems. A part of the Master Plan is the "Development of a Geographic Information System (GIS) of the CUC drinking water and wastewater systems to facilitate better management of the CUC's system". As mentioned in the STO, the GIS shall locate, map, and develop GIS layers for all of the following: treatment facilities, wells, water lines, storage tanks, collection systems, pump stations, and CUC's and DEQ's water quality monitoring stations.

A healthy water system that can perform all of its essential functions requires a good record of system inventory, location, connectivity, and maintenance. This information should be easily available to the water managers and field operators. At the present time, the water and wastewater inventory and maintenance data are being entered manually and stored in file folders. This has created excess paperwork and makes it very difficult to track the frequency of maintenance, which makes it hard to provide timely information to the field operator groups, and creates a lack of close communication between system managers and

field operators. Additionally there is no link between the physical description of the water system that has been previously created by WERI and the maintenance and system inventory. What is needed as mentioned in the stipulated order is a GIS data base that contains all the system descriptions and system maintenance schedules and that can be made readily available to system managers and field operators. The proposed project will satisfy this need and will be divided into four discrete phases. The primary emphasis will be on the drinking water system. Later we will focus on the wastewater system and the data from water meters that are being installed.

The benefit of this project will be to provide and improved and more efficient management and operation of the Saipan water system by development of a GIS database. The specific objectives of this project will be to: a) install GIS software on a newly purchased computer and provide three days training on the use of GIS and data entry to one or two personnel from CUC; b) export the information from Saipan's Haestad model into GIS layers, c) using GPS, locate components of the CUC water distribution system not included in the Haestad model; d) create data layers for each component of the water system; e) integrate the maintenance schedule and system inventory into GIS layers, and f) make the data base available to the system managers and system operators.



Impact of Urban Runoff, Wastewater Discharges and Past Solid Waste Disposal Practices on Contaminant Profiles in Fish from Saipan Lagoon



Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Michael Trianni and Gary R.W. Denton

Funding: \$29,164

Saipan is the largest and most densely populated island of the Commonwealth of the Northern Mariana Islands (CNMI) and experiences many of the environmental pollution problems seen in the larger industrialized nations of the world. Solid and hazardous waste disposal, illegal dumping, urban runoff, unregulated waste discharges from various commercial premises, and the disposal of primary treated sewage effluent directly into the ocean, rank among the most critical environmental problems seen on the island today. A large lagoon that borders the western side of the island serves as a sink for many of the more recalcitrant pollutants mobilized into the ocean from land-based sources in wastewater discharges and during major storm events. Locally referred to as Saipan Lagoon, this body of water is geographically divided into three separate lagoonal entities all of which are impacted to some degree by the activities of man. The largest and most northerly of these is Tanapag Lagoon, which extends along some of the most industrialized coastline on island. The smallest and most southerly entity is Chalan Kanoa Lagoon, which borders mostly rural and residential areas. While this body of water receives relatively little in the way of stormwater runoff, it does receive effluent from a sewage treatment plant and was used as a solid waste disposal site until the mid 1970s. Immediately to the north of Chalan Kanoa Lagoon is Garapan Lagoon, a relatively long narrow stretch of water that borders both residential and commercial premises between the villages of Susupe and Garapan. At least 20 storm water drains discharge into this centrally located lagoonal entity.

An ongoing pollution monitoring and assessment program for Saipan Lagoon was initiated by WERI in 1997. We now have a reasonable understanding of the distribution and abundance

of the contaminants of primary concern (heavy metals and PCBs) in biotic and abiotic components of Tanapag Lagoon. Comparable studies from the two lagoonal entities further south have only recently been initiated. Relatively high levels of mercury have subsequently been discovered in fish and several species of intertidal bivalves from the northern end of Garapan Lagoon. The contamination source was traced back to a storm drain that receives drainage from a disused incinerator site at the local hospital about 1 km inland. Intertidal bivalves from the southern end of Chalan Kanoa Lagoon were also found to contain relatively high levels of lead. The source of this contamination remains to be identified. Studies are currently underway to determine distribution profiles of heavy metals in sediments within both of these lagoonal entities. Considering the importance of subsistence and recreational fishing in these waters, the proposal described herein seeks funding to extend the monitoring program to fish inhabiting these waters. Squirrel fish, *Myripristis* spp, and snapper, *Lethrinus* spp. will be the primary bioindicators of interest. Both types of fish have limited foraging ranges and are favored by local fisherman. Samples will be analyzed for total mercury, lead and PCBs.

The study will add significantly to the existing contaminant database and should command the interest of those involved with environmental protection, water quality and resource management. It will also identify potential health risks (if any) associated with the unrestricted consumption of fish from these waters. Overall, the program will provide the necessary foundations for future monitoring, assessment and regulation of pollution problems in the area. Such information is vital for the overall protection and sustainable development of aquatic resources in Saipan's coastal waters.



Comprehensive Survey of the Current State, Infrastructure, and Usage of Freshwater Resources in the Mortlock Islands, Chuuk State, Federated States of Micronesia



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

**Principal Investigator:
Danko Taborosi**

Funding: \$27,762

Atolls and other carbonate islands in the Federated States of Micronesia are extremely limited in area and resources yet support a disproportionately high number of residents. The so-called Outer Islands of Chuuk State alone, for example, are home to well over 10% of the entire Micronesian population. Due to the islands' truly miniscule sizes, the resultant population densities are among the highest in the world. Their freshwater resources are threatened by overuse due to population growth and changing lifestyles, damage by pollution and unsustainable practices, and obliteration by global climate change. However, the extent of specific problems on individual islands cannot be evaluated at present due to the lack of baseline information. In response to that concern, we have begun two years ago a comprehensive effort to characterize freshwater resources, infrastructure, and practices on each of Pohnpei State's low islands and have already acquired an exhaustive body of vital data. That information is currently being processed for dissemination and publication, so that it can be provided to government planners, resource managers, engineers, educators, environmental scientists, and others involved in sustainable development in Micronesia. We now propose to continue the comprehensive study of the current state, infrastructure, and usage of freshwater resources on FSM's low islands by surveying the most densely populated atolls in Chuuk State: the Mortlock Islands. We intend to investigate the islands of Ta, Satowan, Moch, Kuttu, Lukunor, Oneop, and Ettal, and document the condition of their freshwater resources and related infrastructure, as well as examine the local people's relationship with those resources. Such information is urgently needed from the Mortlocks in order to clarify the water situation there and help us avoid or better respond to fresh water emergencies, agricultural difficulties, food shortages, health problems and

other environmental crises that may arise due to lack of knowledge, awareness or preparation. Specifically, we intend to use a combined hydrogeologic/engineering/sociologic fieldwork approach to document hydrologically relevant natural aspects and infrastructure, as well as people's usage patterns and perceptions of freshwater resources on each of the mentioned seven islands. Essentially, the project will comprise of separate research trips (one per island), each of which will include hydrogeologic component comprising of field observations and mapping, engineering component comprising of infrastructure examinations and measurements, and "people-oriented" component comprising of standardized surveys and freeform interviews of local residents. The immediate objectives of the project are to: a) compile a comprehensive reference source for the Mortlock Islands; b) examine and describe the state of freshwater resources and their usage patterns on each island, as well as other relevant lifestyle practices; c) inventory, assess and map the hydrologically significant infrastructure on each island; d) record each island residents' attitudes and other relevant cultural norms, perceptions, behavior and opinions related to freshwater resources; e) Identify and report any critical problems related to freshwater resources.

Information outlined above is urgently needed for the Mortlock Islands. We wish to make it available as information-packed technical reports, supporting databases, and photo and GIS data collections, all readily accessible to government bodies, regulatory and utility agencies, NGOs, research and academic institutions, and the private sector entities involved in the utilization, monitoring, management, and protection of the freshwater resources of Chuuk State.



Atoll Island Sustainability: Information Transfer and Training for the Federated States of Micronesia



Funded by:
US Geological Survey, Water Institute Program

Principal Investigator:
John W. Jenson

Funding: \$18,433

This is an information transfer project specifically requested by FSM water managers at the 2009 WERI Advisory Council meeting, which will build on the instructional services provided last year. In summer 2009, the authors of the model trained FSM users on how to operate WERI's atoll island spreadsheet groundwater model to estimate the responses of atoll island aquifers in the Caroline Islands to expected types of seasonal and inter-annual changes in rainfall. This year the authors of the model will present it at a workshop that will be conducted as part of a national meeting of FSM water resource managers to address central concerns regarding the sustainability of live on atoll islands.

Users of the model will include local government water resource managers, environmental staff, and educators (Item III.1, Education and Professional Training, FSM

Critical Water Resources Research, Education And Training Needs, September 16, 2008).

The objective of this year's training program is not only to train additional end-users of the model, but to demonstrate its application to questions of sustainability, such as the calculation of groundwater responses to sea level rise and changes in crop management practices. Such use may also include making forecasts of the effects of selected changes in rainfall on atoll islands affected by significant natural events, such ENSO-driven droughts, tropical storms, or wash-over events. A second objective is to cultivate an ongoing technical support relationship between the authors and end-users so that there will be a continuing dialogue to support continued successful use and application of the model to water resource management in the Federated States of Micronesia.



Water System Leak Detection Training for Kosrae State, Federated States of Micronesia



Funded by:
US Geological Survey, Water Institute Program

Principal Investigator:
Shahram Khosrowpanah

Funding: \$19,070

Water system leakage is a serious problem for all utility agencies throughout the Western Pacific. It reduces the performance of the system and represents a big money loss to water utility agencies. The development of modern water distribution systems in the FSM started in 1970 with periodic upgrades sponsored through a series of US capital improvements projects. Despite this, the majority of systems operating today suffer from excess water leakages, some as high as 60% on some islands. Aside from the negative impact on revenues, such losses all too often result in water utility agencies being unable to provide their customer base with a reliable 24-hour water service. One relatively rapid and cost-effective means of overcoming this problem is to implement a simple leak detection program with appropriate equipment and training for water utilities personnel. At its 2009 meeting, the FSM Water Resources Advisory Council requested that WERI carry out a leak detection training program on all the major islands of the FSM (Yap, Chuuk, Pohnpei and Kosrae). This proposal seeks funding to implement such a training program on the island of Kosrae, which currently ranks among the most severely affected islands, insofar as no-revenue water losses from leaks are concerned. One representative from each of the other islands will be invited to participate in the program. We anticipate conducting similar training programs on other islands in future years.

The proposed training will be conducted over a period of one week and will provide participants with a workable knowledge of leak detection theory. It will also consider common cause of water leakages in distribution systems and provide participants with hands-on field experience on how to find leaks and fix them. The topics to be presented at this proposed training exercise are summarized below:

- 7) Leak detection theory and how to determine when a leaky survey is required.
- 8) Economic benefits of a leak detection survey.
- 9) How to incorporate a leak detection survey and/or permanent leak detection crew for your water facility.
- 10) How to become familiar with various sounds created by leaks and type of leaks encountered.
- 11) Types of leak detection surveys and proper record keeping.
- 12) Getting familiar with various leak detection equipment and techniques.
- 13) Field demonstration and actual leak detection scenarios and exercises. This will include field demonstration, general survey, general pinpointing, emergency pinpointing, estimating leakage, reporting, and vehicle setup



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 in a WERI hydrology class calculate stream flow of a local river

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. John Jenson**, 'phone: 671-735-2689, e-mail: jjenson@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 University of Guam offers a program in Engineering Science that parallels the engineering programs offered during the first two years at major colleges and universities.

The first two years of engineering study places emphasis on learning the tools and theories and providing the background for all engineering fields. Rigorous studies in mathematics and the physical sciences are required of all students. Students are also required to take courses in the social sciences and humanities to round out their educational experience.

Each fall semester the University of Guam offers a course titled "**INTRODUCTION TO ENGINEERING**". This course is designed to acquaint students to the engineering profession. Discussions are held on all of the various engineering fields. Educational and professional registration requirements are also introduced. Various guest speakers relate their experiences in the real world of engineering. Finally,

students get a taste of the problem-solving techniques used by engineering students and practicing engineers.

WHAT IF I HAVE A WEAK BACKGROUND IN MATHEMATICS AND THE PHYSICAL SCIENCES?

Engineering requires a strong aptitude for both math and science. For students with these kinds of aptitudes but with weaknesses in prior training, there are remedial classes available to help bring the student up to a competitive level. These students will require more than the normal two years to complete the Pre-Engineering Program.



Students in WERI computer/GIS lab

WHERE TO GET MORE INFORMATION

For more information on the Pre-Engineering Program, contact the Dean of the College of Natural and Applied Sciences, at the University of Guam or Program Coordinator, **Dr. Shahram Khosrowpanah**, 'phone: 671-735-2685, e-mail: khosrow@uguam.uog.edu



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