INTRODUCTION TO RESEARCH ACTIVITIES & TEACHING PROGRAMS

by

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

February 2009

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

WERI Director Dr. Gary Denton (right) and Dr. Shahram Khosrowpanah (left) meet with Yap Governor, Sebastian Anefal (center) to discuss water resources issues and problems in Yap State during the WERI/FSM Advisory Council Meeting in Colonia, Yap, September 16, 2008

WERI conducts a *Water System Operation and Training Workshop* for water resources professionals in Yap State, December 2007.

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 34th 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-2007 WERI faculty were involved as Principal Investigators on twenty research and training projects with a combined budget of about $858,000: $232,000 from seven 104-B projects, $100,000 from federal agencies, $103,000 from Federal sources awarded through Local Agencies and $378,000 from local grants and direct funding from the Guam Legislature.

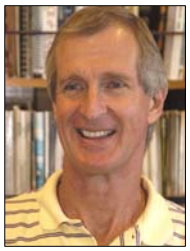
Currently WERI has a fulltime director who is also a UOG faculty member, five regular research faculty, one adjunct research faculty, a water analysis laboratory manager and technician, two office staff, as well as seven graduate research students who are completing their MS degree in the Environmental Sciences program. During the year 2007, WERI faculty and staff taught 10 graduate courses and three undergraduate courses in the Environmental Science MS program and the undergraduate Pre-Engineering curriculums respectively. At the same time, WERI faculty were first or second authors on 12 refereed journal articles or conference proceedings, nine technical reports, and 25 professional presentations and workshops. WERI faculty currently serve as members or chairs of 19 research thesis committees of students in the Environmental Science and Biology graduate programs..

For further information on WERI's activities, please see us on the web at:

www.uog.edu/weri

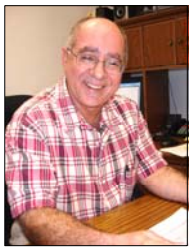
WERI FACULTY, STAFF & STUDENTS

DIRECTOR



Dr. Gary Denton
Prof. Environmental Toxicology

Dr. John Jenson
Prof. Hydrogeology



Dr. Shahram Khosrowpanah
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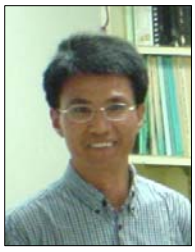
Dr. Mark Lander
A/Prof. Meteorology

Dr. Charles Luo
Prof. Engineering



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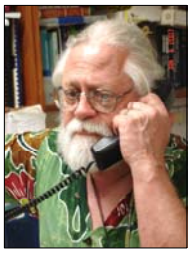

Rick Wood
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Cris Tagudin
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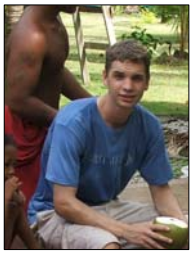
John Jocson
Staff Hydrologist



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ACTIVE PROJECTS

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

US GEOLOGICAL SURVEY WATER INSTITUTE PROGRAM

GUAM:

Protect Guam's Fresh Water: Taking Personal Responsibility for Pollution, Conservation and Community Action.

Calibration and Application of LUOM (Luo, 2007) in Southern Guam Watersheds With and Without Flow Data

Reconstructing the Ancient Rainfall-Drought History of Guam

Impacts of Land Cover Change on Groundwater Quality in Guam

CNMI:

Sustainable Well Yield Determinations Using Conductivity Probes on Active wells

Influence of Stormwater and Wastewater Discharges on the Distribution and Abundance of Heavy Metals in Sediments from Saipan Lagoon

Development of Optimal Operation of Saipan's Water Distribution System Using a Newly Developed Hydraulic Model

FSM:

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

Prediction of Flow Duration Curves for Use in Hydropower Analysis at Ungaged Sites in Pohnpei, FSM

OTHER FUNDED PROJECTS

NATIONAL WEATHER SERVICE

Pacific ENSO Applications Center (ongoing)

GUAM BUREAU OF STATISTICS AND PLANS (NOAA)

Development of a Digital Watershed Atlas for Guam Phase (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

- **a) Spatio-temporal Analysis of Groundwater Quality in Guam (ongoing)**
- **b) Stratigraphic Sections of the Revised Geologic Map of Guam**
- **b) Reconstructing the Climate History of Guam**

2. WATER RESOURCES MONITORING PROGRAM

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

Protect Guam's Fresh Water: Taking Personal Responsibility for Pollution, Conservation and Community Action.

Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Ann Card and John Jocson

Funding: $20,000

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 amply 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..

Calibration and Application of LUOM (Luo 2007) in Southern Guam Watersheds with and without Flow Data

Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Charles Luo and Shahram Khosrowpanah

Funding: $26,687

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 spatial distributed GIS (Geographic Information Systems) data such as DEM (Digital Elevation Model), vegetation, soil and aquifer data. The model comprises of a series of sub-models for climate data distribution, evapotranspiration, infiltration, groundwater, surface flow, etc. The surface flow sub-model solves the two-dimensional Saint Venant equations. Making use of climate input data, mainly precipitation, temperature and wind speed, the model is able to generate not only one-dimensional output – discharge hydrographs, but also 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.

In southern Guam, there are some watersheds with both rainfall and flow gages. But some other watersheds have only rainfall gages but no flow gages. In these watersheds without a flow gage, it is obviously difficult to carry out watershed management studies which require flow data. Even in some those watersheds with a flow gage, the flow gage is not always located at the watershed outlet but a distance upstream of the outlet.

The objective of this research is to calibrate the LUOM (Luo, 2007) in a watershed with both rainfall and flow gages such as Ugum Watershed. Then to apply the calibrated model to those watersheds without a stream flow gage or the whole watershed that the flow gage is not located at the outlet. The application of the calibrated model will generate hydrographs for the whole watershed.

The benefits of this project will be enormous not only to Guam but also to other island in Western Pacific. Researchers will be able to implement various watershed management practices within the watershed. For example, by having flow data, researchers could develop a correlation between stream flow, rainfall, and turbidity at various section of a watershed for studying the impact of various watershed management practices. The model will benefit to Agencies such as Guam Water Authority (GWA) for exploring potential sources of drinking water in Southern Guam. As mentioned earlier, there are 16 streams that are not gauged; by having flow data, potential sites for developing drinking water supply such as construction of small dam will be identified.

Reconstructing the Ancient Rainfall Drought History of Guam

Funded by:
US Geological Survey, Water Institute Program

Principal Investigator:
John Jenson

Funding: $33,636

Current research on climate dynamics around the world is revealing, regional climates everywhere are typically characterized by decadal, centennial, and even millennial scale oscillations. Unfortunately, the long-term historical rainfall record for Guam begins only at the end of World War II and even the oldest of historical records—which date at best from the early Eighteenth Century—are too short to document such 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 making estimates of 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, to name only a few.

One the most productive sources of long-term pre-historic climate data is speleothems, i.e., calcite mineral deposits that are precipitated from cave dripwater. With current laboratory techniques, stalagmites (which develop distinct and datable layers, like tree rings, as they accumulate on the floors of caves) 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 over the past decade 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 capitalize on previous work by WERI researchers to collect 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. More important, the proposed project would support a detailed investigation of the geologic and speleogenetic history of the caves from which the climate data are to be derived. This will provide researchers with an understanding of the sequence of deposition and its relation to the changes in the cave environment over time, which in turn will provide additional data and insights with which to make more confident inferences regarding the actual climate and environmental conditions of the island over time. Finally, the project will be an important element in a larger collaborative project that includes similar work on caves in Borneo, The Philippines, The Solomon Islands, and Vanuatu to determine the climate history of the entire western Pacific region.

Impacts of Land Cover Change on Groundwater Quality in Guam

Funded by:
US Geological Survey, Water Institute Program

Principal Investigator:
Yuming Wen

Funding: $16,177

Guam has one of the finest limestone aquifers in the world. Located in the northern half of the island, this vital underground resource supplies island residents with about 80% of their drinking water needs. The population of Guam has gradually increased since WWII and currently stands at ~180,000. The majority of island inhabitants live in the northern half of the island where significant economic growth and urban development has occurred over the last two decades. The US military has also occupied large tracts of land in this region for the past 60 years. The risks of groundwater contamination are, therefore, very real considering the population density in northern Guam and the rapid recharge rates to the underlying aquifer. Since April 1996, Guam Waterworks Authority (GWA) has monitored the island's drinking water resources annually for all contaminants listed under the US Safe Drinking Water Act. Over 100 wells and two surface water sources are analyzed on a quarterly basis, and approximately 10,000 water samples have been tested to date. Data obtained to date are used only to determine which wells are out of compliance with no further statistical analysis to determine spatial or temporal trends. The proposed project described herein will incorporate all the data collections into GIS map coverages for each contaminant that has so far been detected. By so doing, the impacts of land cover change on groundwater quality in Guam can be evaluated; time-dependant changes in the distribution profiles of commonly occurring contaminants, e.g. fecal coliforms, chlordane, tetrachloroethylene (PCE) and trichloroethylene (TCE) can the be easily visualized, and areas of maximum concentration identified and delineated for the implementation of appropriate remediation strategies as necessary.

The water quality data are available on file from GWA. Land cover changes will be determined using Landsat images of 1993, historical aerial photos, and one scene of Landsat TM or ETM + image at the end of 2006, or early 2007 if available. However, QuickBird image of 2006 may be harnessed as an alternative data if necessary. These satellite images will be applied to extract land cover information. How land cover change affects groundwater quality will be the main concern for this research project.

The main objectives of this project are listed as follows:

1. Preprocessing of Landsat images for derivation of land cover information;
2. Classification of land cover information from available images and/or aerial photos;
3. Evaluation of the relationship between land cover change and groundwater quality
4. Temporal and spatial changes in the distribution and abundance of frequently occurring chemical and biological contaminants

The project outcome will be of tremendous benefit GWA and the Guam Environmental protection Agency whose collective responsibility is to maintain the chemical and biological integrity of the island's water resources and provide a reliable and continuous supply of safe drinking water for the people of Guam.

Sustainable Well Yield Determinations Using Conductivity Probes on Active Wells

Funded by:
US Geological Survey, Water Institute Program

Principal Investigator:
Derek Chambers

Funding: $17,950

The major source of drinking water for the island of Saipan is groundwater pumped from the karst (fractured limestone) aquifers by the local water utility, the Commonwealth Utilities Corporation (CUC). The most productive (most heavily pumped) well fields on Saipan are located over the basal lens aquifers, where the fresh water lens floats on salt water. Poor well construction (penetration through the fresh water lens), poor pump placement (too far below dynamic water levels), and over pumping have resulted in salt water intrusion at individual wells and well fields. The volume-weighted chloride ion concentration from the total amount of water pumped from wells on Saipan is about 1,100 mg/l, well above the USEPA recommended limit of 250 mg/l. In fact, the chloride ion concentration at individual wells can on occasions exceed 3,000 mg/l.

In order to improve the quality of the water pumped from the basal lens aquifers on Saipan, a reliable method needs to be developed to determine the sustainable yield for individual wells, while minimizing the chloride ion concentration. This project proposes to use conductivity probes in active production wells to measure electrical conductance (EC) of groundwater in three wells, to determine the highest sustainable yield while trying to keep the chloride ion concentration below 250 mg/l. The probes will also be used to determine the drawdown at each well, so that the pump intake can be placed at the highest possible elevation. This project also addresses the critical State water quality issue regarding a baseline for season and usage related changes in salinity in drinking water production wells.

Three active production wells in one well field will be studied simultaneously in the following manner: A 1-1/4 inch diameter sounding tube will be installed such that it penetrates the well cap and extends to 5 feet above the bottom of the hole. The sounding tube will be screened from 5 feet above the static water level to the bottom end of the sounding tube. A conductivity, temperature, depth (CTD) probe will be lowered into the sounding tube to measure and record the conductivity profile of the well during static conditions and compared with the profile measured later during pumping conditions. Recording conductivity values in two adjacent wells will help determine how pumping rates in one well affects nearby production wells.

The ultimate goal of the study are to develop a method to optimize the pump rate and pump depth setting for individual wells to minimize chloride ion concentration in the groundwater delivered to customers on Saipan..

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Influence of Stormwater and Wastewater Discharges on the Distribution and Abundance of Heavy Metals in Sediments from Saipan Lagoon

Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
John A. Starmer and Gary R.W. Denton

Funding: $27,414

Saipan is the second most densely populated island in Micronesia 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 on 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 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.

An ongoing pollution monitoring and assessment program for Tanapag Lagoon was established by WERI in 1997 and we now have a reasonable understanding of the abundance and distribution of the contaminants of primary concern in these waters (i.e., heavy metals and PCBs). In 2008 the study was extended into the two lagoonal entities further south. The smaller and most southerly of these two water bodies is Chalan Kanoa Lagoon which borders mostly rural and residential areas and receives relatively little in the way of stormwater runoff. It does, however, receive effluent from a sewage treatment plant and is, therefore, of special interest from an environmental monitoring standpoint. 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. Relatively high levels of mercury were recently discovered in fish taken from the northern end of this lagoon and were attributed, at least in part, to storm drain discharges from two land-based sources identified in the Garapan area. Heavy metal contributions into Garapan Lagoon from the many other storm drains that discharge along much of its length are currently being evaluated in sediments and nearshore biota. The impact of these discharges on ecosystems further off shore remains to be evaluated.

This project will address this deficiency by conducting an evaluation of heavy metals in surface sediments within Garapan Lagoon and Chalan Kanoa Lagoon along strategically positioned transect lines extending from the coast to the outer reef margin. Such a program is fundamental to understanding the dynamics of pollutant transport processes operating within these two lagoonal entities and is an essential first step towards protecting and preserving the vital fisheries resources therein. The overall objectives of the proposed study are to establish a reliable database for surface sediments within the southern half of Saipan Lagoon with which future findings may be compared and evaluated; delineate impacted offshore areas within the study area for later biological monitoring and assessment purposes, and determine the current degree of contamination by reference to levels reported for clean and polluted environments in tropical regions from elsewhere in the world, including Guam..

Development of Optimal Operation of Saipan's Water Distribution System Using a newly Developed Hydraulic Model

Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Shahram Khosrowpanah and Mariano R. Iglecias

Funding: $26,950

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. This goal will be unattainable until the CUC has complete knowledge of their water delivery capabilities and operation.

Over the years the CUC water distribution system has grown and new wells have been added to the system. This physical expansion has been well documented, but improvements in the hydraulic characteristics and delivery capabilities of the entire system have never been fully examined. 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. 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 university of Guam Water and Environmental Research Institute of the Western Pacific (WERI) have 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. This includes a skeleton of the existing 15-region water system models that are joined together at the boundary points. Using a Geographic Information System (GIS) capability and Saipan's 2003 census data, the WERI researchers determined the number of users at each system junction node for residential and commercial customers. During the past several months WERI researchers collected the flow production from the renovated wells during dry and wet seasons. To comply with the stipulated order there is a need to update the hydraulic model and input the inflow/outflow to the system and determine the optimum system operation.

This project proposes to update the Saipan water distribution model and to explore the most effective means of transferring the water sources between the regions. The specific objectives of this project will be to:

1. Update the skeleton model of the CUC water distribution that reflects all the new subdivisions that have been added to the whole system.
2. Determine the amount of water production in each sub-region.
3. Using Geographical Information System (GIS) techniques, locate all production sites.
4. Explore various operational scenarios for effectively transferring water throughout the regions.

The resulting improvements to the water production estimates and the transfer efficiency studies will provide the CUC water division with the capability to: a) identify the rates of unaccounted water throughout the system, b) determine what changes in operation and system improvements are required in order to meet the goals of improved water quality and 24-hour water delivery to all of the CUC customers and, c) comply with stipulated order #1..

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 W. Jenson

Funding: $15,382

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 have developed an accurate and practical saltwater intrusion and groundwater evaluation model for atoll islands in the FSM. During April and May 2008, the developers of the model presented an initial demonstration to a limited number of available water resource managers and government officials. At this year's Advisory Council meeting on September 16, 2008 in Yap, council members specifically requested that systematic training be conducted on the model for designated users in each of the states with 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).

This is an information transfer project in which end-users will be trained by WERI instructors on how to operate the model and apply it to estimate the responses of atoll island aquifers in the Caroline Islands to expected types of seasonal and inter-annual changes in rainfall. It is proposed that the authors of the model will travel, in accordance with the Advisory Council's request, to Yap, Chuuk, and Pohnpei to meet with and train designated users of the model and modeling results.

The objective is train the end-users of the model and its results sufficiently that they can independently use the model and interpret the results. 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 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.

Prediction of Flow Duration Curves for Use in Hydropower Analysis at Ungaged Sites in Pohnpei, FSM

Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Shahram Khosrowpanah and Leroy F. Heitz

Funding: $31,746

In 1987, the Pohnpei State legislature passed the Pohnpei Watershed Forest Reserve and Mangrove Protection Act in which close to 5,000 hectares (12,500 acres) of upland forest were set aside as a protected Watershed Forest Reserve. The purpose of this act was to halt the degradation of the interior forests from road construction and population encroachment as well as to protect the watershed and water supply for the island's population. However, when surveyors attempted to mark the boundary of this reserve, suspicious and angry villagers with machetes and guns turned them back. With this single act, the story of watershed management on Pohnpei began and continues to unfold today.

According to the Conservation Society of Pohnpei (CSP), recent land clearing for agriculture, road construction and housing developments have been paralleled by a degradation of water quality in some of Pohnpei's major rivers and streams. Such negative changes emphasize an urgent need for developing and implementing sound watershed management strategies. A fundamental prerequisite for the development of any watershed management/protection plan is a complete understanding of the physical and environmental components of the watershed and their interrelationships with one another.

The overall objective of this project is to study the impact of man's activities on the quality of the water in the watershed and make recommendations to reduce the impact of these activities. The specific objectives are to continue to 1) monitor stream flow, turbidity, and rain gages for previously selected sites within the Senipehn and Nanpil Watersheds; 2) develop a correlation between stream flow, turbidity and rainfall; 3) make a comparison with the findings of these two watershed with Enipein Watershed that have been monitored during previous studies, and 4) develop recommendation on watershed management.

The result of this project will be the development of baseline information and correlations among the dynamic components of the Senipehn watershed environment. The baseline information will be used for comparison between Senipehn watershed, where there is less human activity, and other watersheds such as Enipein and Nanpil where there is a high human impact in the watershed. The results will reveal the impact of the various activities such as land clearing, land sliding/slope failures, and population growth on the quality of the watershed. This information will help various parties such as Conservation Society of Pohnpei (CSP), Land Management, the Pohnpei EPA, and local mayors to implement plans for protecting the watersheds in Pohnpei.

PROJECTS
COMPLETED MARCH 2009

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

US GEOLOGICAL SURVEY WATER INSTITUTE PROGRAM

GUAM:

Guam Water Kids: An Educational Campaign for Children to Learn about Guam's Water and How to Protect It.

A Field-Based Simulation for Groundwater Education on Guam

Using Remote Sensing to Determine Changes in Soil Erosion and Sediment Loads from Guam Badlands

CNMI:

Water System Operation and Maintenance Training for Yap State, FSM

Development of Sub-Region Water Production for the Saipan Water Distribution System Model and Exploration of Scenarios for Optimal Operation

Spatial and Temporal Nitrate Variations in Groundwater from Southern Saipan

Heavy Metals in Biotic Components from Saipan Lagoon with Emphasis on Nearshore Areas Impacted by Stormwater and Wastewater Discharges

FSM:

Comprehensive Survey of the Current State, Infrastructure, and Usage of Freshwater Resources on Low Islands of Pohnpei State

Watershed Management for Pohnpei Island in the Federated States of Micronesia

Groundwater Resources Management Training in FSM

OTHER FUNDED PROJECTS

NATIONAL WEATHER SERVICE

Pacific ENSO Applications Center

GUAM BUREAU OF STATISTICS AND PLANS (NOAA)

Development of a Digital Watershed Atlas for Guam Phase

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

- **a) Spatially Distributed Precipitation and Water Table Response of the NGLA**
- **b) Modeling Groundwater Recharge**

2. WATER RESOURCES MONITORING PROGRAM

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

Water Kids: An Educational Campaign for Children to Learn about Guam's Water and How to Protect It.

Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Ann Card and John Jocson

Funding: $16,060

The environmental educational materials about water resource issues in earth science textbooks and online at the websites of government agencies now available to Guam 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 of Guam's fresh water resources and the island's critical need to protect and conserve them. The island's unique needs must be taken into consideration if an understanding of the importance of Guam's fresh water as a key resource in our lives and a sense of stewardship are to be developed.

The project proposed here will create materials that will support teachers of children from 9 to 12 years of age about Guam's fresh water resources and will serve children interested in individual study. The materials will feature Guam-based issues and images including photos of Guam children engaged in discovery activities, Guam place names, English-Chamorro vocabulary, and typical island flora, fauna and geological features. Interactive Flash™ animation will be used to illustrate basic concepts such as how an aquifer functions using the unique specifics of Guam's aquifer.

The following components will be developed: a (1) "GUAM WATER KIDS" WEBSITE with corresponding downloadable lesson plans for teachers and group leaders; (2) a CD ROM PRESENTATION in PowerPoint ™ with animation that can be used as (a) a scripted or extemporaneous slideshow, (b) a stand-alone Presentation with pre-recorded narrator and music, and (c) a continuous "unmanned" Presentation in an exhibit booth, and (3) EXHIBIT banner and POSTERS promoting Guam water conservation awareness and the web address and (4) COLLATERAL promotional items (a) a direct mailing of postcards to announce the website, (b) a recycled sports bottle to remind children of the website and water issues, and (c) "business" cards with water conservation tips and the web address.

The objectives of the project are to provide:

1. An online resource for teachers and other youth leaders that will enable them to share the importance of Guam's water resources and the need for protecting them.

2. A website for youth to independently explore Guam's water resources while developing a sense of stewardship.

3. A convenient Presentation that WERI professionals can use to fulfill speaking invitations at schools, career days, and other gatherings of youth groups, and to enhance exhibit opportunities with a narrated CD Rom Presentation and a portable exhibit banner with the purpose of sharing the importance of Guam's fresh water resources with children age 9-12.

4. An ongoing reminder of the importance of Guam's water resources and publicize the Guam Water Kids website address to children, teachers, village mayors and youth organizations.

A Field-Based Simulation for Groundwater Education on Guam

Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Paul R. Wallace and John W. Jenson

Funding: $18,873

Studies reveal that middle school and high school students hold inappropriate conceptions of the importance of groundwater in their daily lives as well as inaccurate mental models of the scale and structure of groundwater. Moreover, it has been shown that middle school and high school science teachers receive inadequate formal education concerning groundwater, and possess inaccurate mental models of groundwater. Given the poor scores of local students on national standardized tests for science concepts, it is likely that very few students or teachers on Guam hold appropriate concepts regarding the structure and importance of groundwater, one of the most vital natural resources of the island.

This project will result in increased awareness of the importance of groundwater and a more accurate spatial understanding of fundamental groundwater concepts for teachers and students on Guam. A group of twelve middle school and high school science teachers from the Guam Public School System (GPSS) will receive training in the development of field-based simulations for engaging students in fundamental issues related to the structure, scale, and the role of groundwater in the hydrologic cycle on the island. Field-based educational simulations supported by handheld technologies, also known as augmented reality simulations, are an emerging type of learning tool that integrate game-design principles and scenarios; and incorporate rich media content, such as images, audio, and video. Users employ location-aware mobile devices to receive information and explore the environment in a field-based setting.

As a result of the teacher training, a field-based simulation on groundwater concepts will be developed and implemented with students from GPSS and participants from youth organizations, with approximately 40 youth expected to take part in the simulation during the first year. Data collected will be used to assess the effectiveness of both the teacher training and the simulation. Results and analysis will be fully documented in a final report, an article submitted for publication in a refereed journal, and a conference paper.

Project objectives are to:

1. Train GPSS middle school and high school science teachers in the development of a field-based simulation related to the importance, structure, and scale of groundwater systems on the island of Guam;
2. Assess the effectiveness of the teacher training among GPSS middle school and high school science teachers on their perceived importance of knowing about groundwater, and conceptions regarding groundwater scale and structure;
3. Develop a field-based simulation, based on fundamental groundwater concepts, that can be used for GPSS field trips, youth group excursions, and outreach programs on Guam;
4. Implement the water resource field-based simulation with youth participants on Guam;
5. Assess the effectiveness of the field-based simulation on perceived importance of knowing about groundwater, among Guam's youth;
   Provide an online resource for schools and organizations to access teaching materials, field-based simulation examples, and results of this study.

Using Remote Sensing to Determine Changes in Soil Erosion and Sediment Loads from Guam Badlands

Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Shahram Khosrowpanah and Yuming Wen

Funding: $21,161

In southern Guam, dramatic erosion processes are visibly evident in large, bare plots of earth that occur throughout watersheds in the southern half of the island. These areas of land along the steeply sloping topography are called “badlands” and are continually eroding soil leaving patches of exposed earth. Previous studies have indicated that badlands can contribute an average of 157 tons/acre/year of soil erosion in a watershed, which is 30 times more than any other type of land coverage. The major problems with badlands are that they have tendency to move and expand within a watershed. To implement effective erosion control practices on badlands requires: 1) knowledge of the location and the extent of current badland areas, 2) identification of where the badlands have expanded in size over time, and 3) details on the underlying soil type and slope angle where the badland expansion has occurred. Traditional field inventories and surveys may accurately delineate the boundaries of each badland area, but it difficult to monitor changes in the badland areas over time by this method alone. Remote sensing applications provide a useful means of overcoming this disadvantage.

Currently, there are satellite images as well as aerial photos of Guam which were recorded on different years. By using remote sensing applications, changes in the total area of badlands can be identified, and mapped over time. The specific remote sensing software application that will be used in this study is called ERDAS Imagine®, created by Leica Geosystems. Satellite images of Guam are analyzed by the remote sensing software to detect changes in the area of badlands over time. The slope angle, soil type, and estimated soil erosion for each badlands will be determined by the GIS soil erosion base model that has been developed by WERI researchers. The model combines the Universal Soil Loss Equation (USLE), the Geographic Information Systems (GIS), and the Digital Elevation Model (DEM) for predicting potential soil erosion. The model is capable of identifying the areas of high erosion potential, evaluating the effectiveness of various soil erosion reduction practices, and estimating the sediment yield for an entire watershed. The objectives of this project are to: 1) identify, map, and monitor the changes in badland areas over time, 2) use the GIS erosion base model to identify the underlying soil types and slope angle of the terrain where badland expansion is occurring, and 3) provide recommendation on appropriate soil erosion control practices and re-vegetation methods for the areas where badland expansion is occurring..

Water System Operation and Maintenance Training for Saipan, Commonwealth of the Northern Mariana Islands

Funded by:
US Geological Survey, Water Institute Program

Principal Investigator:
Shahram Khosrowpanah

Funding: $14,787

Due to budgetary constraints, the Saipan Commonwealth Utility Commission (CUC) operation and maintenance division has undergone relatively large changes in personnel over the last few years. Many of the technicians have left the agency and new personnel, currently working on the system, are relatively untrained. Presently, CUC is experiencing a serious operation and maintenance problems with the various components of water and waste water systems. This includes mechanical and electrical controls for pumps in the water supply and wastewater collection systems and the maintenance and repair of altitude and pressure regulating valves in the distribution system. The CUC has requested that we carry out a hands-on training program in pump and automatic regulating valve repair and maintenance for their operation and maintenance people in both the water supply and wastewater areas.

We are proposing to provide and one weeklong comprehensive training program in operation and maintenance of pumps and valves for utility personnel. The training will be made avalailble to utility employees of the Commonwealth of the Northern Mariana Islands (CNMI) and will be carried out in Saipan.

The proposed training will consist of the following topics:

PUMP REPAIR AND MAINTENANCE

1. Site inspection of water and wastewater facilities
2. Pump station equipment design, operation and maintenance
3. Hands on training at the CUC maintenance shop covering preventative and overhaul maintenance of existing pumps and controls
4. Discussion of future needs and required actions for long term preventative maintenance program

VALVE REPAIR AND MAINTENANCE

1. Site inspection of existing altitude and pressure regulating valves (PRV)
2. Theory of operation of Altitude and PRVs
3. Hands on training at the CUC maintenance shop covering preventative and overhaul maintenance of valves

Discussion of future needs and required actions for long term preventative maintenance program for automatic valves in utility systems

Development of Sub-Region Water Production for the Saipan Water Distribution System Model and Exploration of Scenarios for Optimal Operation

Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Shahram Khosrowpanah and Leroy F. Heitz

Funding: $25,816

The Saipan water distribution system has been divided into 10 sub-regions. Each region is expected to operate somewhat independently. However, due to inadequate inflow to some of the sub-regions, system leakage, and lack of knowledge of the system behavior as a whole, the system is unable to provide 24-hour water services. A stated goal of the Commonwealth of the Northern Marianas Islands (CNMI) government is to provide 24-hour water to all residents served by the Commonwealth Utility Corporation (CUC) water system. The CNMI Governor created a task force whose primary purpose is to find funding and oversee the CUC accomplishments toward the 24-hours water service goal. To assist in reaching their goals, the CUC commissioned the University of Guam, Water and Environmental Research Institute of the Western Pacific (WERI), to develop a hydraulic model of the Saipan water system and to train CUC water division staff in the use of that model.

WERI researchers have developed computerized models of each of the ten sub-regions of the CUC water system using the Haestad WaterCad water system modeling program. They also, developed a source, transmission and storage model of the Saipan water system. This included a skeleton of the existing 10-region water system models that are joined together at the boundary points. For the model to provide optimal results, it is essential to have a good knowledge of the residential and commercial demands being placed on the distribution system. This estimation has been completed by WERI and the water usage values have been imported into the model. The next vital pieces of information required include estimates of how much water is being put into the system from each source and the most effective way of transferring this source water between the regions.

This project proposes to refine estimates of both the quantities and spatial distribution of water production from wells and springs in each sub-region and to explore the most effective means of transferring the water sources between the regions. The specific objectives of this project are:

5. To determine the amount of water production in each sub-region.

6. To locate all production sites using Geographical Information System (GIS) techniques.

7. To explore various operational scenarios for effectively transferring water throughout the regions.

The resulting improvements to the water production estimates and the transfer efficiency studies will provide the CUC water division with the capability to better identify the rates of unaccounted water throughout the system and to determine what changes in operation and system improvements are required in order to meet the goals of improved water quality and 24-hour water delivery to all of the CUC customers.

Spatial and Temporal Nitrate Variations in Groundwater from Southern Saipan

Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Derek Chambers and Heidi Yelin

Funding: $29,900

Ingestion of water containing high nitrate or nitrite concentrations can be fatal to infants. Nitrate and nitrite are rarely a problem for people older than six months. However, long term exposure to nitrate and nitrite can lead to diuresis, starchy deposits, and hemorrhaging of the spleen. In fact, nitrate and nitrite are such a significant health threat that public water systems are required to monitor delivered waters for these constituents at regular intervals, no less than once a year, with increasing sampling frequencies required if concentrations fluctuate significantly over time. The maximum contaminant level (MCL) for nitrate and nitrite is 10 mg/l and 1 mg/l respectively.

The major source of drinking water for the island of Saipan is groundwater pumped from the karst (fractured limestone) aquifer by the local water utility, Commonwealth Utilities Corporation (CUC). The groundwater is susceptible to nitrate contamination from the numerous on-site septic systems that exist in many villages on Saipan, and possibly from the use of nitrate based fertilizers on agricultural plots. CUC monitors for nitrate and nitrite at 45 sites throughout the distribution system. In June of 2006, one water sample from the CUC southern water distribution system exceeded the nitrate MCL. While this was the first exceedence since monitoring began in 2001, one additional violation was noted in December 2006 and eight in June 2007 with levels as high as 14 mg/l. CUC was required to notify their customers of nitrate contamination and the risks from consuming the contaminated water.

The concentration of nitrates in the groundwater of the southern end of Saipan appears to fluctuate rapidly. Three sites with nitrate concentrations a little over 14 mg/l in June 2007, had concentrations between 6 and 8 mg/l two weeks later. Notably, during the timeframe when nitrate levels were high there was little rain, and several days of heavy rain in the following two weeks resulted in lower nitrate concentrations. Accordingly, this project aims to further investigate the potential relationship between rainfall and nitrate concentration in the groundwater of the southern end of Saipan. To this end, weekly samples will be collected from approximately 20 wells in southern Saipan, over a one year period, and analyzed for nitrate at the CNMI Division of Environmental Quality (DEQ) lab, following EPA-approved methods. Additional analysis (pH, conductivity, temperature, dissolved oxygen or turbidity) may be conducted in the field at each sampling site as deemed necessary. Electronic rainfall gauges will be installed at four sites in the watershed of the southern Saipan well field and the data downloaded monthly.

The objectives of the study are to conduct regression analyses to determine the dependence of nitrate levels upon rainfall, and if so, to quantify the negative relationship (e.g. rates and concentrations). The result of this project will provide regulatory guidance to CUC on how frequently the monitoring for nitrate concentration should be conducted for southern Saipan's aquifers.

Heavy Metals in Biotic Components from Saipan Lagoon with Emphasis on Nearshore Areas Impacted by Stormwater and Wastewater Discharges

Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
John A. Starmer,
Gary R.W. Denton and H. Rick Wood

Funding: $34,534

Saipan is the second most densely populated island in Micronesia 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 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. An ongoing pollution monitoring and assessment program for Tanapag Lagoon was established by WERI in 1997 and we now have a reasonable understanding of the abundance and distribution of the contaminants of primary concern in these waters (i.e., heavy metals and PCBs). Comparable data for the two lagoonal entities further south is, however, lacking. The smaller and most southerly of these two water bodies is Chalan Kanoa Lagoon which borders mostly rural and residential areas and receives relatively little in the way of stormwater runoff. It does, however, receive effluent from a sewage treatment plant and is, therefore, of special interest from an environmental monitoring standpoint. 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. Relatively high levels of mercury were recently discovered in fish taken from the northern end of this lagoon and were attributed, at least in part, to storm drain contributions from two land-based sources identified in the Garapan area. Sediment deposition patterns around these storm drains suggest that fisheries further south may also be impacted. Heavy metal contributions into Garapan Lagoon from the many other storm drains that discharge along much of its length are currently unknown.

Extending the baseline survey for Tanapag Lagoon into the southern half of Saipan Lagoon therefore seems a logical extension of WERI's ongoing pollution monitoring and assessment program for Saipan's coastal waters. To this end, the project described herein proposes to determine heavy metals in dominant ecological representatives inhabiting the shallow, nearshore waters of Garapan Lagoon and Chalan Kanoa Lagoon with emphasis given to those groups with proven bioindicator capability and/or food potential for local residents (e.g., algae, seagrass and bivalve mollusks). The objectives of the study are to establish a reliable database with which future findings may be compared and evaluated; identify 'hotspots' and delineate areas of contaminant enrichment within the study area, and assess the degree of contamination in the southern half of Saipan Lagoon by reference to levels reported for clean and polluted environments in tropical regions from elsewhere in the world, including Guam. Potential health risks (if any) associated with the long-term consumption of edible resources surveyed will also be evaluated.

Comprehensive Survey of the Current State, Infrastructure, and Usage of Freshwater Resources on Low Islands of Pohnpei State

Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Danko Taborosi and John W. Jenson

Funding: $17,845

Freshwater resources on coral atolls and other low islands in the Federated States of Micronesia (FSM) are under threat of overuse due to changing lifestyles and increasing population pressures, damage by pollution and unsustainable development, and obliteration by global climate change. The extent of specific problems are different on various islands, but cannot be evaluated at present due to the lack of basic field data. Despite the rapid socioeconomic and environmental changes being experienced by the low islands in the FSM, there has been no comprehensive study to examine the current condition, infrastructure and utilization of their freshwater resources. The lack of such information represents a huge obstacle to government planners, resource managers, engineers, educators, environmental scientists, and others dedicated to the sustainable use of freshwater resources in Micronesia. Funding permitting, we therefore propose to carry out a comprehensive study of all low island atolls in Phonpei State (Ahnd, Pakin, Pingelap, Mwoakilloa, Oroluk, Sapwuahfik, Nukuoro, and Kapingamarangi) 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 needs to be made available not only to improve our understanding of the water situation in the low islands, but also to 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 Pohnpei's eight low islands. Essentially, the project will comprise of eight 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:

- Compile a comprehensive reference source of low islands of Pohnpei State (e.g., descriptions of each island's natural and human environment, highlights of significant natural, man-made, and cultural features).
- Examine and describe the state of freshwater resources and their usage patterns on each island, as well as other relevant lifestyle practices (e.g., waste disposal, burial practices, animal husbandry, etc.)
- Inventory, assess and map the hydrologically significant infrastructure on each island (e.g., rainwater catchment systems, storage tanks, shallow wells, etc.)
- Record island residents' attitudes and other relevant cultural norms, perceptions, and opinions related to freshwater resources.
- Identify and report any critical problems related to freshwater resources.

Information outlined above is urgently needed due to the high rate of development, human modification and population increase in the Micronesian low islands. We plan to make it available as an on-line series of information-packed technical reports, supporting databases, photographic collection, and GIS coverages, so that it is readily accessible to the FSM and US government bodies, regulatory agencies, utility corporations, non-government organizations, research and academic institutions, and the private sector entities involved in the utilization, monitoring, management, and protection of the freshwater resources of Pohnpei State.

Watershed Management for Pohnpei Island in the Federated States of Micronesia

Funded by:
US Geological Survey, Water Institute Program

Principal Investigators:
Shahram Khosrowpanah,
Leroy F. Heitz and Mark A. Lander

Funding: $35,273

In 1987, the Pohnpei State legislature passed the Pohnpei Watershed Forest Reserve and Mangrove Protection Act in which close to 5,000 hectares (12,500 acres) of upland forest were set aside as a protected Watershed Forest Reserve. The purpose of this act was to halt the degradation of the interior forests from road construction and population encroachment as well as to protect the watershed and water supply for the island's population. However, when surveyors attempted to mark the boundary of this reserve, suspicious and angry villagers with machetes and guns turned them back. With this single act, the story of watershed management on Pohnpei began and continues to unfold today.

According to the Conservation Society of Pohnpei (CSP), recent land clearing for agriculture, road construction and housing developments have been paralleled by a degradation of water quality in some of Pohnpei's major rivers and streams. Such negative changes emphasize an urgent need for developing and implementing sound watershed management strategies. A fundamental prerequisite for the development of any watershed management/protection plan is a complete understanding of the physical and environmental components of the watershed and their interrelationships with one another.

The overall objective of this project is to study the impact of man's activities on the quality of the water in the watershed and make recommendations to reduce the impact of these activities. The specific objectives are to continue to 1) monitor stream flow, turbidity, and rain gages for previously selected sites within the Senipehn and Nanpil Watersheds; 2) develop a correlation between stream flow, turbidity and rainfall; 3) make a comparison with the findings of these two watershed with Enipein Watershed that have been monitored during previous studies, and 4) develop recommendation on watershed management.

The result of this project will be the development of baseline information and correlations among the dynamic components of the Senipehn watershed environment. The baseline information will be used for comparison between Senipehn watershed, where there is less human activity, and other watersheds such as Enipein and Nanpil where there is a high human impact in the watershed. The results will reveal the impact of the various activities such as land clearing, land sliding/slope failures, and population growth on the quality of the watershed. This information will help various parties such as Conservation Society of Pohnpei (CSP), Land Management, the Pohnpei EPA, and local mayors to implement plans for protecting the watersheds in Pohnpei.

Groundwater Resources Management Training in the Federated States of Micronesia

Funded by:
US Geological Survey, Water Institute Program

Principal Investigator:
John W. Jenson

Funding: $32,204

Water shortages are a serious concern to the residents of atoll islands. Small size and isolation subject entire island populations to the stresses of drought and difficult, expensive, and sometimes untimely aid operations. Under normal conditions, water demand is met by rooftop rain catchment. Prolonged droughts, such as those associated with El Niño, however, exhaust water storage, leaving residents dependent on groundwater or imported water. Typhoons can destroy the rain catchments and coconut crops, leaving residents dependent on groundwater. However, wash-over of storm-driven surf can contaminate groundwater just when it is needed most.

The proposed project will meet the following needs of the Federated States of Micronesia, as specified during the WERI Advisory Council meetings from 2006 and 2007:

1. "Develop a water resources management scheme for low island atolls in Yap and elsewhere in FSM"

2. "Make training manuals used in various training activities available to all interested parties"

3. "Presentation of Atolls Groundwater Modeling to appropriate users through workshops in each of the states with atoll islands"

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The purpose of the project is to disseminate the knowledge gained from the past year's efforts in understanding the behavior of the freshwater lens on atoll islands. This will occur through the preparation of spreadsheet model of atoll island aquifer response to recharge, the preparation of a user's manual for the spreadsheet model, the training of water resources managers on Yap, Chuuk, and Pohnpei on the manual, and the preparation and printing of an instruction pamphlet on groundwater resources and its distribution to schools located on atoll islands, and presentation of the model and user's at a scientific meeting with other professional scientists and educators working in similar areas.

The previous project has produced a simple algebraic model, based on numerical modeling results, which predicts the thickness of the freshwater lens in both steady-state and transient conditions. This model can easily be placed into a spreadsheet and made available to water resources managers in FSM. The model is also an excellent teaching tool, as it explains the relationship between the freshwater lens and the geological and climatic factors which govern its behavior and thickness. This model will aid FSM island leaders and water resource managers in establishing sustainable and practical groundwater extraction practices.

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. Mohammad Golabi**, ‘phone: (671) 735-2134, **e-mail: mgolabi@uguam.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 University of Guam Counseling Center, the Dean of the College of Natural and Applied Sciences, or Dr. Shahram Khosrowpanah (khosrow@uguam.uog.edu) at the Water and Environmental Research Institute of the Western Pacific, UOG Station, Mangilao, Guam 96923 (telephone number (671) 735-2685).

RECENT PUBLICATIONS BY WERI FACULTY AND ASSOCIATE INVESTIGATORS

(2000-2008)

WERI TECHNICAL REPORTS

2008

Denton, G.R.W., Bearden, B.G., Houk, P., Starmer J.A., and Wood H.R. (2008). Heavy Metals in Biotic Representatives from the Intertidal Zone and Nearshore Waters of Tanapag Lagoon, Saipan, Commonwealth of the Northern Mariana Islands (CNMI). *WERI Technical Report* No. 123: 50 pp.

Bailey, R.T., J.W. Jenson & A.E. Olsen (2008). An Atoll Freshwater Lens Algebraic Model for Groundwater management in the Caroline Islands. *WERI Technical Report* No. 120: 35 pp.

Bailey, R.T., J.W. Jenson, D. Rubinstein & A.E. Olsen (2008). Groundwater Resources of Atoll Islands: Observations, Modeling and Management. *WERI Technical Report* No. 119: 83 pp.

Heitz, L.F., S. Khosrowpanah & M. Iglecias (2008). Development of Junction Water Demands for the Saipan Water Distribution System Numerical Model. *WERI Technical Report* No. 122: 37 pp.

Hoffman, S.M., Jenson, J.W., Moran, D.C., Denton, G.R.W., Wood, H.R. & H.L. Vacher (2008). Background Fluorescence in Guam's Coastal Waters. *WERI Technical Report* No. 121: 48 pp.

Wuerch, H.V., Cruz, B.C. & Olsen A.E. (2008). Analysis of the Dynamic Response of the Northern Guam Lens Aquifer to Sea level Change and Recharge. *WERI Technical Report* No. 118: 39 pp.

2007

Keel, T.M., Mylroie, J.E. & Jenson J.W. (2007). A Preliminary Report on the Sabana Watershed/Talakhaya Springs System Rota (LUTA), CNMI. *WERI Technical Report* No. 114: 26 pp.

Khosrowpanah, S., L.F. Heitz, Y. Wen & M. Park (2007). Developing a GIS-Based Soil Erosion Potential Model of the UGUM Watershed. *WERI Technical Report* No. 117: 95 pp.

MacCracken, R., Jenson, J.W., Heitz, L.F., Rubinstein, D.H. & Mylroie J. (2007). Water Resource Analysis of Fais Island, Federated States of Micronesia. *WERI Technical Report* No.111: 41 pp.

2006

Denton, G.R.W., Kelly, W.C., III, Wood, H.R. and Wen, Y. (2006) Impact of Metal Enriched Leachate from Ordot Dump on the Heavy Metal Status of Biotic and Abotic Components in Pago Bay. *WERI Technical Report* No. 113: 68 pp.

Keel, T.M., Mylroie, J.E., & Jenson, J.W. (2006). The Caves and Karst of ROTA Island, Commonwealth of the Northern Mariana Islands. *WERI Technical Report* No. 107: 183 pp.

Krishnapillai, M.V., Scheidth, T. and Fillmed, C. (2006). Qualitative Examination of Groundwater from Yap and Neighboring Islands. *WERI Technical Report* No. 115: 27 pp.

Taboroši, D. (2006). Karst Inventory of Guam, Mariana Islands. *WERI Technical Report* No. 112: 214 pp.

2005

Denton, G.R.W., Sian-Denton, C.M., Concepcion, L.P. and Wood, H.R. (2005). Nutrient Status of Tumon Bay in relation to Intertidal Blooms of the Filamentous Green Alga, *Enteromorpha clathrata*. *WERI Technical Report* No. 110: 60 pp.

Denton, G.R.W., Wood H.R., Wen, Y., Golabie M. and Iyekar C. (2005). Mobilization of Aqueous Contaminants Leached from Ordot Landfill in Surface and Subsurface Flows. *WERI Technical Report* No. 108: 83 pp.

Khosrowpanah, S. and Jocson, J.M.U. (2005). Environment Assessment for Ugum Watershed. *WERI Technical Report* No. 109: 53 pp.

2004

Keel T.M. and Jenson, J.W. (2004). Preliminary Report on the Caves and Karst of ROTA (LUTA), CNMI. *WERI Technical Report* No. 105:1 13 pp.

Lander, M.A. (2004). Rainfall Climatology for Saipan: Distribution, Return-Periods, El Nino, Tropical Cyclones, and Long-Term Variations. *WERI Technical Report* No. 103: 59 pp.

Lander, M.A. and Khosrowpanah, S. (2004). Rainfall Climatology for Pohnpei Island, Federal State of Micronesia. *WERI Technical Report* No. 100: 58 pp.

McDonald, M.Q. and Jenson, J.W. (2003). Chloride History and Trends of Water Production Wells in the Northern Guam Lens Aquifer. *WERI Technical Report* No. 98: 70 pp.

Moran, D. and Jenson, J.W. (2004). Dye Trace of Groundwater Flow from Guam International Airport and Harmon Sink to Agana Bay and Tumon Bay Guam. *WERI Technical Report* No. 97: 38 pp.

Stafford, K. and Jenson, J.W. (2004). Karst Geology of Aguijan and Tinian, CNMI. *WERI Technical Report* No. 106: 239 pp.

Taboroši, D., Jenson, J.W. and Mylroie, J.E. (2004). Karst Features of Guam Mariana Island. *WERI Technical Report* No.104: 28 pp.

2003

Khosrowpanah, S. and Heitz, L.F. (2003). Slow Sand Filter Conceptual Design for the Federal States of Micronesia FSM. *WERI Technical Report* No. 101: 23 pp.

Lander M.A. and Guard, C.P. (2003). Creation of a 50-Year Rainfall Database, Annual Rainfall Climatology, and Annual Rainfall Distribution Map for Guam. *WERI Technical Report* No. 102: 31 pp.

Stafford, K., Mylroie, J.E. and Jenson, J.W. (2003). Karst Geology and Hydrology of Tinian and Rota (Luta), CNMI. *WERI Technical Report* No. 96: 29 pp.

2002

McDonald M.Q. (2002). Nitrate-Nitrogen Concentrations in the Northern Guam Lens and Potential Nitrogen Sources. *WERI Technical Report* No. 95: 41 pp.

Scheman, N.D., Khosrowpanah, S., Golabi, M. and Heitz, L.F. (2002). Identification of Erosion Process and Sources of Exposed Patches in the Lasa Fua Watershed of Southern Guam. *WERI Technical Report* No. 99: 77 pp.

2001

Denton, G.R.W., Bearden, B.G., Concepcion, L.P., Siegrist, H.G., Vann, D.T. and Wood, H.R. (2001). Contaminant Assessment of Surface Sediments from Tanapag Lagoon, Saipan. *WERI Technical Report* No. 93: 145 pp.

Heitz, L.F., Habana, N.C. and Raza, J. (2001). Designing Your Rainwater Catchment and Storage System for Rainwater Catchment Systems in Saipan CNMI. *Water Information Bulletin* No. 3: 22 pp.

Khosrowpanah, S. and Heitz, L.F. (2001). FSM Rainfall Erosivity Factors for Selected Islands in the Federated States of Micronesia. *WERI Technical Report* No. 92: 50 pp.

Khosrowpanah, S., Heitz, L.F. and Beausoliel, C.G. (2001). The Application of Slow Sand Filtration Technology for Kosrae State, Federated States of Micronesia: A Pilot Study. WERI Technical Report No. 91A: 192 pp.

Lander, M.A. (2001). Responses of Well Water Levels on Northern Guam to Short-Term and Long-Term Variations of Rainfall and Tide. *WERI Technical Report* No. 94: 41 pp.

2000

Khosrowpanah, S. and Taboroši, D. (2000). Environmental Impact Statemen:t Inarajan River Dam River. *WERI Technical Report* No. 91: 41 pp.

JOURNAL ARTICLES

2008

Denton, G.R.W., Golabi, M.H.,Wood, H.R., Iyekar, C., Concepcion, L.P. and Wen, Y (2008). Impact of Ordot Dump on Water Quality of the Lonfit River Basin in Central Guam. 2. Aqueous Chemical and Biological Contaminants. *Micronesica,* 40 (1/2): 149-167.

Sane, S.M., Desai, C.S., Jenson, J.W., Contractor, D.S., Carlson, A.E. and Clark, P.U. (2008). Disturbed State Constitutive Modeling of Two Pleistocene Tills. *Quaternary Science Reviews,* 10.1016/j.quascirev.2007.10.003, 27: 267-283.

Taboroši, D., Jenson, J.W. and Stafford, K. (2008). Artefatosmilitares E Uso De Cavernas Durante a Segunda Guerra Mundial Nas Ilhas Marianas, Pacifico Oeaste [in Portuguese; English Title: Artifacts and Wartime Use of Caves in the Mariana Islands]. In: L.E.P. Travassos and L.A.V. Figueiredo (Editors), *Antopoespeleologia: imaginário, religião eoutras relações humanas com as cavernas*. Brazilian Speleological Society, Minas Gerais, Brazil. (in press)

2007

Carlson, A.E., Jenson, J.W., and Clark P.U. (2007). Modeling the Subglacial Hydrology of the James Lobe of the Laurentide Ice Sheet: *Quaternary Science Reviews*. doi: 10.1016/j.quascirev.2007.02.002.

Denton, G.R.W and Sian-Denton, C.M. (2007). Unsightly Algal Blooms in Tumon Bay, Guam's Premier Tourist Location: Possible Connection to Hotel Landscaping Activities (2007). *Journal Interdisciplinary Environmental Review,* IX (1): 94-106.

Golabi, M.H., Denton, G.R.W., Wood, H.R., Wen, Y. and Iyekar, C. (2007). Impact of Ordot Dump on Water Quality of the Lonfit River Basin in Central Guam. 1. Soil Characterization of Nutrient Retention. *Micronesica,* 39: 41-45.

Lander, M.A. (2007). Current Conditions and Local U.S. Affiliated Pacific Island Weather and Climate Summaries and Forecasts. *Pacific ENSO Newsletter*. NOAA National Weather Service.

Taboroši, D., Jenson, J.W., Stafford, K.W. and Matsuzawa, R. (2007). World War II Artifacts and Wartime Use of Caves in the Mariana Islands, Western Pacific. *Journal of the Speleological Society of Japan*, 32: 42-53.

Vuki, M., Limtiaco, J., Aube, T., Emmanuel, J., Denton, G.R.W. and Wood, H.R. (2007). Arsenic Speciation Study in Some Spring Waters of Guam, Western Pacific Ocean. 379: 176-179

2006

Denton, G.R.W., Concepcion, L.P., Wood, H.R. and Morrison R.J. (2006). Trace Metals in Marine Organisms from Four Harbours in Guam. *Marine Pollution Bulletin*, 52: 1784-1804

Denton, G.R.W., Bearden, B. Concepcion, L.P., Wood, H.R. and Morrison R.J. (2006). Contaminant Assessment of Surface Sediments from Tanapag Lagoon, Saipan, Commonwealth of the Northern Mariana Islands. *Marine Pollution Bulletin*, 52: 703-710.

Denton, G.R.W., Concepcion, L.P., Wood, H.R. and Morrison R.J. (2006). Polychlorinated Biphenyls (PCBs) in Sediments from Four Harbours in Guam. *Marine Pollution Bulletin*, 52: 711-718.

Denton, G.R.W., Concepcion, L.P., Wood, H.R. and Morrison R.J. (2006). Polycyclic Aromatic Hydrocarbons (PAHs) in Small Island Coastal Environments: A Case Study from Harbours in Guam, Micronesia. *Marine Pollution Bulletin*, 52: 1090-1098.

Denton, G.R.W., Concepcion, L.P., Wood, H.R. and Morrison R.J. (2006). Polychlorinated Biphenyls (PCBs) in Marine Organisms from Four Harbours in Guam. *Marine Pollution Bulletin* 52: 214-238.

Jenson, J.W., Keel, T.M., Mylroie, J.E., Mylroie, J.R., Stafford, K.W, Taboroši, D. and Wexel, C. (2006). Karst of the Mariana Islands: The Interaction of Tectonics, Glacio-eustasy and Fresh-water/Sea-water Mixing in Island Carbonates: *GSA Special Paper 404, Geological Society of America,* Pp. 129-138.

Lander, M.A. (2006). Current Conditions and Local U.S. Affiliated Pacific Island Weather and Climate Summaries and Forecasts. *Pacific ENSO Newsletter*. NOAA National Weather Service.

Lander, M.A., Velden, C., Harper, B., Wells, F., Beven, J.L. II, Zehr, R. Olander, T. Mayfield, M., Guard, C., Edson, R., Avila, L., Burton, A., Turk, M., Kikuchin, A., Christian, A., Caroff, P. and McCrone P. (2006). The Dvorak Tropical Cyclone Intensity Estimation Technique: A Satellite-Based Method that Has Endured for over 30 Years. *Bulletin of the American Meteorological Society,* 87**:** 1195-1210.

2005

Denton, G.R.W., Concepcion, L.P., Wood, H.R. and Morrison R.J. (2005). Trace Metals in Sediments of Four Harbours in Guam. *Marine Pollution Bulletin,* 50: 1133-1141.

Stafford, K.E., Mylroie, J.E., Taborosi, D. and Jenson, J.W. (2005). Eogenetic Karst Development on a Small, Tectonically Active Carbonate Island: Aguijan, CNMI, Mariana Islands, *Transactions of the British Cave Association,* 31: 101-108.

Stafford, K.W, Mylroie, J.E., Taboroši, D., Jenson, J.W. and Mylroie, J.R. (2005). Karst Development on Tinian, CNMI: Controls on Dissolution in Relation to the Carbonate Island Karst Model. *Journal of Cave and Karst Studies,* 67: 14-27.

Taboroši, D., Jenson, J.W. and Mylroie, J.E. (2005). Karst Features of Guam. *Micronesica,* 38: 17-46.

2004

Carlson, A.E., Jenson, J.W., and Clark P.U. (2004). Field Observations from the Tiskilwa Till, II and Sky Pilot Till, MB of the Laurentide Ice Sheet: *Geographie Physique et Quaternaire,* 58: 229-239.

Taboroši, D., Jenson, J.W. and Mylroie, J.E. (2004). Karren Features in Carbonate Island Karst: Guam, Mariana Islands: *Zeitschrift fur Geomoprhologie,* 48: 369-389.

2003

Gamble, D. W., Taboroši, D., Mylroie, J.E., Jenson, J.W., Carew, J. L., Jocson, J. M. U., Mylroie, J. R., and Vann, D. T. (2003). The Use of Water Temperature to Characterize Groundwater Discharge of a Coastal Fracture on Guam, U.S.A. *Journal of Coastal Research,* 19: 462-471.

Keel, T. M., Stafford, K.W., Mylroie, J.E., Jenson, J.W. and Mylroie, J.R. (2003). The Carbonate Island Karst Model as Applied to Rota (Luta), Tinian, and Aguijan Islands, Commonwealth of the Northern Marian Islands. *Journal of Cave and Karst Studies,* 65: 186.

Khosrowpanah, S. and Heitz L.F. (2003). Water Resources Management: A Challenging Issue for Tropical Islands in the Western Pacific. *Journal of Water Resources, American Water Resources Association,* 5: 25-30, May 2003.

Lander M.A., Duval, P., Beven, J., Clark, D., Lulofs, H., Marra, J., Mojica, R. and Waters K. (2003). Service Assessment: Super Typhoon Pongsona (December 8, 2002). *U.S. Dept. Commerce, NOAA/National Weather Service.* 32 pp. plus appendices.

Lander, M.A., Guard, C.P. and Chiu, A.N. (2003). Meteorological Assessment: Super Typhoon Pongsona (December 8, 2002). *US Dept of Commerce, NOAA/National Weather Service.* 54 pp.

Stafford, K.W., Keel, T. M., Mylroie, J.E., Jenson, J.W. and Mylroie, J. R. (2003). Eogenetic Karst Development in the Mariana Islands: Aquijan, Rota, and Tinian: *Journal of Cave and Karst Studies*, 65: 188.

Stafford, K.W., Taboroši, D., Keel, T.M., Mylroie, J.E., Mylroie, J.R. and Jenson, J.W. (2003). 2002-2003 Joint Research Expeditions to the Mariana Islands: Aguijan, Rota, and Tinian: Journal of Cave and Karst Studies, 65: 179-180.

Stafford, K.W., Mylroie, J.E., Mylroie, J. R. and Jenson, J.W. (2003). Tinian, CNMI: A Carbonate Island Karst Model Evaluation (Abstract). *Geological Society of America*, 35: 3.

Taboroši, D., Jenson J.W. and Mylroie, J.E. (2003). Zones of Enhanced Dissolution and Associated Cave Morphology in an Uplifted Carbonate Island Karst Aquifer, Northern Guam, Mariana Islands. *Speleogenesis and Evolution of Karst Aquifers*, http://www.speleogenesis.info/archive/publication.php?Type=publication&PubID=3255, 1: 16.

2002

Mylroie, J.E. and Jenson, J.W. (2002). Karst Flow Systems in Young Carbonate Islands. *Karst Waters Institute Special Publication 7*. Karst Waters Institute, Charles Town, West Virginia. Pp. 107-110.

Jenson, J.W., Mylroie, J.E., Mylroie, J.R. and Wexel, C. (2002). Revisiting the Carbonate Island Karst Model (Abstract). *Geological Society of America*, 34: 226.

Jocson, J.M.U., Jenson, J.W. and Contractor, D.N. (2002). Recharge and Aquifer Response: Northern Guam Lens Aquifer, Guam, Mariana Islands, *Journal of Hydrology*, 260: 231-254.

Taboroši, D. and Jenson, J.W. (2002). World War II Artifacts and Wartime use of Caves in Guam, Mariana Islands. *Cave Archaeology and Palaeontology Archive CAPRA 4*, available at http://www.shef.ac.uk/~capra.

2001

Lander, M.A. (2001). Tropical Cyclones: Meteorological Aspects. *Horticultural Science*, 36: 242-246.

Lander, M.A. and Guard, C.P. (2001). Western North Pacific, North Indian Ocean, and Southern Hemisphere Tropical Cyclones of 1997. *Monthly Weather Review,* 129: 3015-3036.

Mylroie, J.E. and Jenson, John W. (2001). The Carbonate Island Karst Model Applied to Guam: *Theoretical and Applied Karstology*, 13-14: 51-56.

Mylroie, J.E., Jenson, J.W., Taboroši, D., Jocson, J.M.U., Vann, D.T. and Wexel, C. (2001). Karst Features of Guam in Terms of a General Model of Carbonate island Karst. *Journal of Cave and Karst Studie*s, 63: 9-22.

Mylroie, J.E., Mylroie, J. R., Jenson, J.W. and Wexel, C. (2001). Cave and Karst Development of Saipan. *Journal of Cave and Karst Studies*, 63: 113.

2000

Contractor, D.N. and Jenson, J.W. (2000). Simulated Effect of Vadose Infiltration on Water Levels in the Northern Guam Lens Aquifer. *Journal of Hydrology*, 229: 232-254.

Heitz, L.F., Khosrowpanah, S. and Nelson J. (2000). Sizing of Surface Water Runoff Detention Ponds for Water Quality Improvement. *Journal of the American Water Resources Association,* 36: 541-548.

Mylroie, J.R., Gamble, D.W., Taboroši, D.S., Jenson, J.W., Jocson, J.M.U. and Mylroie, J.E. (2000). Air and Water Cave Temperature Variation in Three Cave Types in Guam, USA: Implications for Aquifer Characteristics. *Journal of Cave and Karst Studies,* 62: 196-197.

CONFERENCE PROCEEDINGS, PRESENTATIONS AND ABSTRACTS

2008

Bailey, R.T., Jenson, J.W. and Olsen, A.E. (2008). Numerical Modeling of Atoll Island Hydrogeology, *14th Symposium on the Geology of the Bahamas and other Carbonate Regions*, Gerace Research Centre, San Salvador, Bahamas.

Bailey, R.T., Jenson, J.W. and Olsen, A.E., (2008). An Algebraic Model to Predict the Freshwater Lens Thickness of an Atoll Island, *14th symposium on the geology of the Bahamas and other carbonate regions*, Gerace Research Center, San Salvador Island, Bahamas

Denton, G.R.W and Sian-Denton, C.M. (2008). Chemical and Biological Integrity og Guam's Groundwater: 1996-2007. *American Water Works Association Annual Conference and Exposition 2008*, Georgia World Congress Center, Atlanta, Georgia. June 8-12, 2008.

Golabi, M.H. and Denton G.R.W. (2008). The Role of Soil Components Such as Charge Characteristics on the Mobility of Contaminants Leached Down Gradient of the Ordot Landfill Area in Central Guam. *2008 Joint Meeting of The Geological Society of America, Soil Science Society of America, American Society of Agronomy, Crop Science Society of America, Gulf Coast Association of Geological Societies with the Gulf Coast Section of SEPM* Houston, Texas. October 5-9, 2008

Hoffman, S.M., Jenson, J.W., Denton, G.R.W., Moran, D.C. and Vacher, H.L. (2008). Variability of Background Fluorescence in Tropical Karst Aquifers, *14th symposium on the geology of the Bahamas and other carbonate regions*, Gerace Research Center, San Salvador Island, Bahamas.

Khosrowpanah S., and Park, M. (2008). Identifying the Optimum Land Coverage Practices for Reducing Soil Erosion in Southern Guam's Watershed using a Newly Developed GIS Based Erosion Potential Model. *Annual Meeting of Association of American Geographers*, Boston, Massachusetts, April 15-19, 2008.

Lander M.A. (2008). A Comparison of Typhoon Best-track Data in the Western North Pacific: Irreconcilable Differences. *Proceedings of the American Meteorological Society 28th Conference on Hurricanes and Tropical Meteorology*, Orlando FL, May 2008. (http://ams.confex.com/ams/28Hurricanes/techprogram/paper_137395.htm)

Mylroie, J.E., Mylroie, J.R. and Jenson, J.W. (2008). Caves and Non-Caves of Fais Island, Federated States of Micronesia, *National Speleological Society Convention*, pp. 114. (Abstract)

Sinclair, D.J., Banner, J.L., Taylor, F.W., Quinn, T.M., Jenson, J.W. and Mylroie, J.E. (2008). Deglacial Climate Dynamics in the Western Pacific Ocean Measured in a Stalagmite from Guam, *Goldschmidt Conference*, Vancouver, B.C.

Wen Y., and Khosrowpanah, S. (2008). Land Cover Classification Accuracy Assessment in Guam. Presented at 2008 Annual Meeting, *Annual Meeting of Association of American Geographers*, Boston, Massachusetts, April 15-19, 2008.

2007

Denton, G.R.W., Olsen, M.C. and Wen, Y. (2007). Solid Waste Disposal in Guam: The Impact of an Unsanitary Landfill on the Metal Status of Adjacent Aquatic Community Representatives. *Proceedings of the 2007 International Symposium on Environment Science and Technology*, Beijing, China, November 13-16, 2007. p. 1169-1176.

Denton, G.R.W., Olsen, M.C. and Wen, Y. (2007) Solid Waste Disposal in Guam: The Impact of an Unsanitary Landfill on the Metal Status of Adjacent Aquatic Community Representatives. *13th International Interdisciplinary Conference on the Environment*, June 30-July 3, 2007, Portland, Maine.

Olsen, A.E., Habana, N., Heitz, L.F. and Jenson, J.W. (2007). A Transfer Function Model for Deep Karst Vadose Zones, *The ASA-CSSA-SSSA International Annual Meetings*, New Orleans, Louisiana.

Sian-Denton and Denton, G.R.W. (2007). Microbiological Contaminants in Guam's Groundwater Past and Present: Benefits of Sound Management Practices. *13th International Interdisciplinary Conference on the Environment*, June 30-July 3, 2007, Portland, Maine.

2006

Denton, G.R.W. and Sian-Denton, C.M. (2006). Unsightly Algal Blooms in Tumon Bay, Guam's Premier Tourist Location: Possible Connection to Hotel Landscaping Activities. *Proceedings 12th International Interdisciplinary Conference on the Environment.* Kona, Hawaii, June 22-24, 2006.

Desai, C.S., Sane, S., Jenson, J.W., Contractor, D.S., Carlson, A.E. and Clark, P.U., (2006). A Unified Constitutive Model for Subglacial Till, Part Ii: Laboratory Tests, Disturbed State Modeling, and Validation for Two Subglacial Tills, *American Geophysical Union, Fall Meeting*, San Francisco, pp. C31A-1223.

Jenson, J.W., Desai, C.S., Clark, P.U., Contractor, D.S., Sane, S. and Carlson, A.E., (2006). A Unified Constitutive Model for Subglacial Till, Part I: The Disturbed State Concept, *American Geophysical Union, Fall Meeting*. AGU, San Francisco, pp. C31A-1222.

Khosrowpanah, S. and Heitz, L.F. (2006). Sources to Tap: Virtual Management of a Water Delivery System. *Proceeding of 2006th UCOWR/NIWR Annual Conference,* Santa Fe, New Mexico, July 18-20, 2006.

Lander, M.A. and Guard C. (2006). The Urgent Need for a Re-analysis of Western North Pacific Tropical Cyclones. *Proceedings 27th AMS Annual Conference on Hurricanes and Tropical Meteorology,* Monterey, CA, April 2006.

Mylroie, J.E., Mylroie, J.R., Jenson, J.W. and MacCracken, R.S. (2006). Fresh-Water Lens Anisotropy and Flank Margin Cave Development, Fais Island, Federated States of Micronesia, *Proceedings 13th Symposium on the Geology of the Bahamas and other Carbonate Regions*, Gerace Research Center, San Salvador Island, Bahamas. (in press)

Reece, M.A., Mylroie, J.E., and Jenson, J.W. (2006). Notches in Carbonate Cliffs and Hillslopes: Origin and Implications. *Proceedings of the 12th Symposium on the Geology of the Bahamas and Other Carbonate Regions*, Gerace Research Center, San Salvador, Bahamas. Pp. 143-152.

Sian Denton, C.M. and Denton G.R.W. (2006). Impact of Economic Growth and Urban Development on the Chemical Integrity of Guam's Groundwater Resources. *Proceedings 12th International Interdisciplinary Conference on the Environment.* Kona, Hawaii, June 22-24, 2006.

Taborosi, D., Jenson, J.W. and Mylroie, J.E. (2006). Karst Environments of Guam, Mariana Islands. *Proceedings of the 12th Symposium on the Geology of the Bahamas and Other Carbonate Regions*, Gerace Research Center, San Salvador, Bahamas. Pp. 220-227.

2005

Khosrowpanah, S., Lander, M.A. and Heitz, L.F. (2005). Pohnpei-the Wettest Island on Earth? Tools for Managing Watersheds. *Proceedings of the Institutions for Sustainable Watershed Management, American Water Resources Association,* Honolulu, Hawaii, June 27-29, 2005.

Khosrowpanah, S., Lander, M.A. and Heitz, L.F. (2005). Pohnpei-the Wettest Island on Earth? Tools for Managing Watersheds. *Proceedings of the Institutions for Sustainable Watershed Management, American Water Resources Association,* Honolulu, Hawaii, June 27-29, 2005.

2004

Keel, T.M., Jenson, J.W., Mylroie, J.E., Mylroie, J.R., Stafford, K.W. and Camacho, R. (2004). The Caves of Rota, Commonwealth of the Northern Mariana Islands. *Proceedings of the 12th Symposium on the Geology of the Bahamas and Other Carbonate Regions*, Gerace Research Center, San Salvador, Bahamas. Pp. 76-87.

Mylroie, J.E., Jenson, J.W., Mylroie, J.R. and Carew, J.L. (2004). Epikarst on Eogenetic Rocks. *Proceedings of the Epikarst Conference, Karst Waters Institute Special Publication*, 9: 132-134

Mylroie, J.E., Mylroie, J.R. and Jenson, J.W. (2004). Modeling Carbonate Island Karst. *Proceedings 11th Symposium on the Geology of the Bahamas and other Carbonate Regions*, Gerace Research Center, San Salvador Island, Bahamas. Pp.135-144

Reece, M.A., Mylroie, J.E. and Jenson, J.W. (2004). Notches in Carbonate Cliffs and Hillslopes: Origin and Implications. *12th Symposium on the Geology of the Bahamas and Other Carbonate Regions.* Pp. 25-26.

Stafford, K.W, Mylroie, J.E., Mylroie, J.R., Jenson, J.W. and Taboroši, D. (2004). Coves and Pocket Beaches: Littoral Erosion of Flank Margin Caves. *Geological Society of America Abstracts and Programs*, 36(5): 284

Stafford, K. W., Mylroie, J.E., Jenson, J.W., Mylroie, J.R., and Taboroši, D. (2004). Dissolution Controls Related to the Carbonate Island Karst Model on Tectonically Active, Carbonate Islands: Tinian and Aguijan, CNMI. *Proceedings of the 12th Symposium on the Geology of the Bahamas and Other Carbonate Regions*. Pp. 205-219.

Stafford, K.W., Mylroie, J.,E., Jenson, J.W., Mylroie, J.R. and Taboroši, D. (2004). Dissolution Controls Related to the Carbonate Island Karst Model on Tectonically Active, Carbonate Islands: Tinian and Aguijan, CNMI. *Proceedings 12th Symposium on the Geology of the Bahamas and Other Carbonate Regions.* Pp. 30-31.

Stafford, K.W., Taboroši, D., Keel, M., Mylroie, J.M., Mylroie, J.R. and Jenson, J.W. (2004). Joint Research Expeditions to Mariana Islands: Aguijan, Rota, and Tinian. *Proceedings of the National Speleological Society National Convention.*

Stafford, K.W., Mylroie, J.E., Jenson, J.W., Mylroie, J.R. and Taboroši, D. (2004). Dissolution Controls Related to the Carbonaet Isladn Karst Model on Tectonically Active, Carbonate Islands: Tinian and Aguijan, CNMI. *Proceedings of the 12th Symposium on the Geology of the Bahamas and Other Carbonate Regions.* Pp. 205-219.

Taboroši, D., Jenson, J.W. and Mylroie, J.E. (2004). Karst Features of Guam, Mariana Islands. *Proceedings12th Symposium on the Geology of the Bahamas and Other Carbonate Region.* Pp. 31.

Taboroši, D., Jenson, J.W. and Mylroie, J.E. (2004). Karst Environments of Guam, Mariana Islands. *Proceedings of the 12th Symposium on the Geology of the Bahamas and Other Carbonate Regions.* Pp. 220-227.

Wen, Y. and Wang, Y. (2004). Validation of Spatial Diffusion Model for Simulation of Suburban Sprawl, *ASPRS Annual Conference Proceedings*, Denver, CO, May 23–28, 2004.

Wen, Y. and Wang, Y. (2004). Cell-based Dynamic Modeling of Urban Land Cover Change. *Proceedings 100th Annual Meeting of the Association of American Geographers (AAG),* Philadelphia, Pennsylvania, March 14-19, 2004

2003

Heitz L.F. and Rumong, L. (2003). Water Water Everywhere but I Can't Take a Shower: Using Rainwater Catchment Systems for Emergency Backup Water Supplies. *Proceeding of the 11th International Rainwater Catchment Systems Conference,* Mexico City, Mexico, September 2003.

Iyekar, C., Golabi, M. Denton, G.R.W. and Wood, H.R. (2003). Impact of Ordot Dump on Water Quality of Lonfit River Basin in Central Guam. *Proceedings 20th Pacific Science Congress,* Bangkok, Thailand, March 17-21, 2003.

Khosrowpanah, S. and Scheman, N. (2003). Badland Erosion rates and Sources in a Tropical Watershed. *Proceedings of 2003rd Annual Conference, Soil and Water Conservation Society,* Spokane, Washington, July 2003.

McDonald, M.Q. and Jenson, J.W. (2003). Historical Analysis of Chloride ion Concentrations in Production Wells in the Northern Guam Lens Aquifer, Guam, Mariana Islands. *Proceedings 2nd International Conference on Saltwater Intrusion and Coastal Aquifers: Monitoring, Modeling and Management*, March 30-April 2, 2003, Merida, Yucatan, Mexico.

Mylroie, J.E., Jenson, J.W., Mylroie, J.R. and Carew, J.L. (2003). Epikarst on Eogenetic Rocks. *Proceedings of the Epikarst Conference, Karst Waters Institute*. Pp. 17.

Stafford, K.W., Mylroie, J.E., Mylroie, J.R. and Jenson, J.W. (2003). Tinian, CNMI: A Carbonate Island Karst Model Evaluation (Abstract). *Geological Society of America Abstracts and Programs*, 35(1): 3.

Stafford, K.W., Mylroie, J.E., Taboroši, D., Mylroie, J.R., Keel, T.M. and Jenson, J.W. (2003). Structurally Controlled Eogenetic Karst: Mariana Islands. *Proceedings GSA Annual Meeting,* Seattle, WA, 34: 452.

Wen, Y. and Wang, Y. (2003). Coupling Spatial Diffusion and Fractals for Simulation of Suburban Sprawl. *Proceedings GeoInformatics 2003 International Conference,* Toronto, Canada.

Wen, Y. and Wang, Y. (2003). Spatial Diffusion Modeling for Simulation of Suburban Sprawl. *ASPRS 2003 Annual Conference Proceedings*, Anchorage, Alaska, May 5-9, 2003.

2002

Jenson, J.W., Mylroie, J.E., Mylroie, J.R. and Wexel, C. (2002). Revisiting the Carbonate Island Karst Model. *Geological Society of America, Abstracts with Programs*, 34(6): 226.

Lander, M.A. and Edson, R.T. (2002). Evaluation of Microwave Imagery in the Life Cycle of Tropical Cyclones. *Proceedings of the 25th AMS Conference on Hurricanes and Tropical Meteorology,* May 2002, San Diego, California. Pp. 477-478

Khosrowpanah, S. (2002). Rainfall Erosivity Factors for Selected Islands in the Federated States of Micronesia. *Proceedings American Water Resources Association,* New Orleans, Louisiana. Pp. 225-230, May 2002.

Lander, M.A. Edson, R.T., Cantrell, C.E., Franklin, J.L., Chang, P.S. and Hawkins, J.D. (2002). Operational Use of Quickscat Over Tropical Cyclones. *Proceedings of the 25th AMS Conference on Hurricanes and Tropical Meteorology*, May 2002, San Diego, California. Pp. 41-42.

Lander, M.A. (2002). A Look at Global Tropical Cyclone Activity with Respect to the Atlantic Change-Point Year of 1995. *Proceedings of the 25th AMS Conference on Hurricanes and Tropical Meteorology,* May 2002, San Diego, California. Pp. 142-143.

Lander, M.A. and Ward, B.D., Jr. (2002). Distal and Sympathetic Surface Trough Development Induced by TUTT Cells: A Case Study. *Proceedings of the 25th AMS Conference on Hurricanes and Tropical Meteorology,* May 2002, San Diego, California. Pp 446-447.

Mylroie, J.E. and Jenson, J.W. (2002). Karst Flow Systems in Young Carbonate Islands. In: J.B. Martin, C.M. Wicks and I.D. Sasowsky (Editors), *Karst Frontiers: Florida and Related Environments. Karst Waters Institute Special Publication 7*. Karst Waters Institute, Charles Town, West Virginia, pp. 107-110.

Mylroie, J.E., Mylroie, J.R. and Jenson, J.W. (2002). Modeling Carbonate Island Karst. In: R. Martin and B. Panuska (Editors), *11th ssymposium on the Geology of the Bahamas and Other Carbonate Regions*, Gerace Research Center, San Salvador Island, Bahamas, pp. 135-144

Taboroši, D. and Jenson, J.W. (2002). Fluviokarst on a Small Carbonate Island: Guam, Mariana Islands. *Geological Society of America Abstracts with Programs*, 34(6).

Wen, Y. and Wang, Y. (2002). Spatial Diffusion Modeling: A New Approach in Simulation of Urban Sprawl. *ACSM- ASPRS 2002 Annual Conference Proceedings*, Washington DC, April 19-22, 2002.

2001

Concepcion, L.P. and Denton, G.R.W. (2001). PCBs in Agana Swamp, Guam: Historic Overview and Current Research. *Proceedings of the 10th Pacific Science Inter-Congress*, Guam, June 1-6, 2001.

Denton, G.RW. (2001). Nutrient Sources and Pathways into Tumon Bay. *Proceedings 20th Annual Pacific Islands EPA Conference*, Hyatt Hotel, Guam. June 11-15, 2001.

Denton, G.R.W. and Heitz L.F. (2001). Potential Impact of Landscaping Activities on the Nutrient Status of Tumon Bay, Guam. *Proceedings of the 10th Pacific Science Inter-Congress*, Guam, June 1-6, 2001

Denton, G.R.W. and Siegrist H.G. (2001). Metal Deficiencies and Imbalances in Wetland Plants from Guam. *Proceedings of the 10th Pacific Science Inter-Congress*, Guam, June 1-6, 2001

Gamble, D. W., Mylroie, J.E., Jenson, J.W., Carew, J.L., Taboroši, D., Jocson, J.M.U., Vann, D.T. and Mylroie, J.R. (2001). Freshwater resources on Guam: Calculating Halocline position and fresh water discharge via temperature profile. *Proceedings of the 10th Pacific Science Inter-Congress*, Guam, June 1-6, 2001. Pp.104

Heitz, L.F. and Denton G.R.W. (2001). A Fully Automated Sequential Sampling Device for Monitoring Contaminants in Urban Runoff. *Proceedings of the 10th Pacific Science Inter-Congress*, Guam, June 1-6, 2001

Heitz L.F. (2001). Rainwater Catchment System Design: A Delicate Balancing Act with Examples from Iloilo City, Philippines. *Proceedings 2nd East Asia Conference on Rainwater Utilization*. Sponsored by Philippine Watershed Management Coalition and Central Philippine University, Iloilo, Philippines, November 7-9, 2001

Heitz, L.F. (2001). Rainwater Catchment System Design In The Western Pacific, Proceedings of the 10th Pacific Science Inter-Congress, Guam, June 1-6, 2001.

Lander, M.A. (2001). Global Tropical Cyclone Activity During the 1990's: Pronounced Effects of ENSO and Inter-decadal Changes. *Proceedings of the 10th Pacific Science Inter-Congress.* June 2001. Tumon, Guam.

Lander, M.A. (2001). Responses of Well Levels on Northern Guam to Short-term and Long-term Variations of Rainfall and Tide. *Proceedings of the 10th Pacific Science Inter-Congress,* June 2001. Tumon, Guam.

Mylroie, J.E. and Jenson, J.W. (2001). The Carbonate Island Karst Model. *Proceedings of the 10th Pacific Science Inter-Congress,* Guam, June 1-6, 2001. Pp. 101.

Nadeau, T. and Denton G.R.W. (2001). Nutrient Studies in the Togcha River, Guam: Phosphorus and Total Organic Carbon. *Proceedings of the 10th Pacific Science Inter-Congress,* Guam, June 1-6, 2001

Okura, S., Denton, G.R.W. and Smith B. (2001). Imposex in Gastropod Molluscs from Apra Harbor, Guam. *Proceedings of the 10th Pacific Science Inter-Congress,* Guam, June 1-6, 2001.

Wexel, C., Jenson, J.W., Mylroie, J.R. and Mylroie, J.E. (2001). Carbonate Island Karst of Saipan. *Proceedings Geological Society of America,* 33: A-6.

Soto, A.D., Denton, G.R.W. and Wood H.R. (2001). Mobility and Persistence of Carbaryl in a Guam Soil. *Proceedings of the 10th Pacific Science Inter-Congress,* Guam, June 1-6, 2001.

2000

Gamble, D.W., Mylroie, J.R., Mylroie, J.E., Taboroši, D.S. and Jenson, J.W. (2000). Field Assessment of Coastal Fracture Discharge on the Northwest Coast of Guam Using Temperature Sensors. *Proceedings Limestone Island Aquifers Conference,* June 8, 2000, University of Guam.

Heitz L.F. (2000). Rainwater Utilization and Development in the Caroline and Marianas Islands of the Western Pacific, East Asia (2000). *ProceedingsRainwater Utilization Workshop,* National Taiwan University, Taipei, Taiwan, Oct. 31 – Nov. 3, 2000.

Lander, M.A. (2000). The Tropical Cyclone Distribution in the western North Pacific during the El Niño-La Niña swing of 1997-99: Extraordinary Interannual Changes. *Proceedings of the 24th AMS Conference on Hurricanes and Tropical Meteorology*, June 2000, Fort Lauderdale, Florida

Mylroie, J.R. and Jenson, J.W. (2000). Guam and the Carbonate Island Karst Model. *Proceedings of the Joint Meeting of the Friends of Karst, Theoretical and Applied Karstology, and IGCP* 448. Cluj-Napoca, Romania. Pp. 82-86.

Mylroie, J.R. and Jenson, J.W. (2000). The Carbonate Island Karst Model. . In: J.A. Ballwebber (Editor), *Mississippi Water Resources Conference*, Raymond, MS, pp. 371-375.

Mylroie, J.E. and Jenson, J.W. (2000). The Carbonate Island Karst Model. *Proceedings Mississippi Water Resources Conference*. Pp. 57.

Mylroie, J.E. and Jenson, J.W. (2000). The Carbonate Island Karst Model. *Proceedings Limestone Island Aquifers Conference*, June 8, 2000, University of Guam.

Mylroie, J.E. and Jenson, J.W. (2000). The Carbonate Island Karst Model. *National Speleological Society Annual Meeting*, p. A-15.

Mylroie, J.E. and Jenson, J.W. (2000). CIKM, the Carbonate Island Karst Model. *Geological Society of America* Vol 32, pp. A-355.

Mylroie, J.R., Gamble, D.W., Taboroši, D.S., Jenson, J.W., Jocson, J.M.U. and Mylroie, J.E. (2000). Air and Water Cave Temperature Variation in Three Cave Types in Guam, USA: Implications for Aquifer Characteristics. *National Speleological Society Annual Meeting.* Pp. A-15 - A-16.

Reece, M.A., Mylroie, J.E. and Jenson, J.W. (2000). Cave and Karst Development on Guam: Implications for Aquifer History. *National Speleological Society Annual Meeting.* Pp. A-15.

Reece. M.A., Mylroie, J.E. and Jenson, J.W. (2000). Notches in Carbonates: Paleohydrological Implications. *Proceedings 10th Symposium on the Geology of the Bahamas and Other Carbonate Regions*, Bahamian Field Station, San Salvador Island, Bahamas. Pp. 21.