Water and Environmental Research Institute of the Western Pacific
Annual Technical Report
FY 2004

Introduction

The Water & Environmental Research Institute of the Western Pacific or WERI is one of 55 similar water research institutes set up by U.S. Congressional legislation at each Land Grant University in the United States and in several territories. The institute is now in its 30th year of operation.

WERIs 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 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 money on Guam, in the Commonwealth of the Northern Mariana Islands (CNMI) and in the Federated States of Micronesia (FSM). In the 2003-2004 period, WERI faculty were involved as Principal Investigators on eighteen research and training projects. Funding sources for these projects included US Geological Survey, US Weather Service, NASA, local agencies such as Guam Environmental Protection Agency, Guam Bureau of Planning, Commonwealth Utility Corporation, CNMI and direct appropriations 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, a GIS and network administrator, two office staff, as well as three graduate research students who are completing their MS degree in the UOG Environmental Sciences program. During the 2004-2005 interval, WERI faculty and staff taught ten graduate courses and five 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 fourteen refereed journal articles or conference proceedings, six technical reports, and fifteen professional presentations and workshops. Currently WERI faculty members serve as committee members on, or chairs on twenty MS research theses in the Environmental Sciences and Biology graduate programs.

Following is a list of non USGS Funded Projects carried out by the Institute during the period 2004-2005:

NATIONAL SCIENCE FOUNDATION Collaborative Research: Testing and Constitutive Modeling of Fine Grained Tills Deposited by the Laurentide Ice Sheet

NATIONAL WEATHER SERVICE Pacific ENSO Applications Center

GUAM ENVIRONMENTAL PROTECTION AGENCY

Development of Strategies for the Reduction of Nitrate Contributions from Septic Tanks into the Northern Guam Aquifer

GUAM BUREAU OF STATISTICS AND PLANS

Development of Assessment Strategies for the Reduction of Nitrate Contributions from Septic Tanks to Streams and Coastal Water of Southern Guam

Monitoring Study of the Pago Bay Watershed

Development of Assessment Strategies for A Southern Guam Watershed

DIRECT LOCAL FUNDING

Guam Hydrologic Survey

Water Resources Monitoring Program In Cooperation with Hawaii District, USGS

COMMONWEALTH UTILITY CORPORATION, CNMI

Hydraulic Modeling of Saipans Water Distribution System and training of CUC Engineers to use the model

Research Program

The Water and Environmental Research Institute (WERI) Advisory Council is the body, which determines research goals and priorities for WERI in general and the USGS 104B program in particular. The Research Advisory Council (RAC) for Guam consists of representatives from all Guam governmental agencies involved with water resources development or regulation, members of U.S. Federal agencies, military organizations on Guam that deal with water resources issues and members of the university research community. The RAC for the Federated States of Micronesia and the Commonwealth of the Northern Mariana Islands consist of representatives from various government departments that deal with water resources, representatives from local colleges, private sector engineers, environmentalists, and planners.

WERI held RAC meetings in September and October 2003. Twenty-four (24) people attended the Guam meeting, fourteen (14) people attended the CNMI meeting and twelve (12) people attended the FSM meeting. The RAC groups examined the previous years research priorities and discussed changes to keep the listings up to date.

In early November, a Request for Proposals (RFP) was sent out by e- mail to the three regions: Guam, CNMI, and FSM. RFPs were sent to all regular members of the three RACs as well as to several agencies, institutions, and individuals that had expressed interest during the previous year. Each request for proposal included: a) 104-B proposal guidelines, b) an example of a well-written 104-B proposal, and c) the list of critical water resource needs for each of the regions.

Eleven (8) proposals, two (2) for Guam, four (4) for the FSM, and two (2) for the CNMI were submitted. Review panels were selected for each of the regions. These panels were made up of researchers not submitting proposals or from others highly regarded in the water resources area of each of the regions. The submitted proposals were e-mailed to the members of the appropriate review panels. Each panel member had the list of critical needs and a scoring procedure that had been agreed upon at earlier RAC meetings. They were advised to work independently. Following a three-week interval, reviews were returned to WERI and re-evaluated by the Director. The Director made no changes to the individual ratings by the review panel members. The Director chose the two highest rated projects from each of the regions and two highly rated projects for FSM to be submitted for funding.

Presence and Survival of Fecal Indicator Bacteria in Soil from the Banks of Major Rivers and Streams on Guam

Basic Information

Title:	Presence and Survival of Fecal Indicator Bacteria in Soil from the Banks of Major Rivers and Streams on Guam
Project Number:	2004GU27B
Start Date:	3/1/2004
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	na
Research Category:	Water Quality
Focus Category:	Recreation, Water Quality, Non Point Pollution
Descriptors:	Fecal Indicator, BacteriaNon-fecal Sources, Riverbank Soil
Principal Investigators:	Gary Denton, Roger Fujioka, Annie Leon Guerrero, Harold Wood

Publication

Project Title: Presence and Survival of Fecal Indicator Bacteria in Soil from the Banks of Major Rivers and Streams on Guam

Problem and Research Objectives

The use of fecal bacteria to monitor the hygienic quality of recreational waters has some serious limitations in many tropical and subtropical regions of the world. This is because favorable ambient temperatures encourage extended survival times of these organisms in the environment and dramatically increases the risk of false positives occurring. On Guam, *E. coli* and enterococci are used to monitor rivers and coastal waters around the island respectively. Both organisms have been observed to survive indefinitely in sediments and soils in Hawaii (Hardina and Fujioka 1991), Puerto Rico (Hazen 1988), southern Florida (Solo-Gabriele *et al*. 2000, Desmarais *et al.* 2002), and northern Australia (Davies *et al.* 1995). While the survival, growth and proliferation of *E. coli* and enterococci is suspected to occur in sediments and soils on Guam, the limited available data is inconclusive because it fails to differentiate between possible contributions from fecal and non-fecal sources. The fact remains, however, that exceedences of the recreational water quality standards are far more frequent during wet weather than they are during dry spells. This strongly suggests that local riverbank soil is a major reservoir for enterococci, and that these bacteria are mobilized into the coastal belt by erosive processes during prolonged periods of heavy rain.

The objectives of this study were to: a) confirm seasonal differences in recreational water quality exceedences on Guam from historical data, b) establish the presence of *E. coli* and enterococci in riverbank soil and c) determine whether or not *E. coli* and enterococci are capable of surviving in Guam soils over extended periods of time.

Methodology

To verify seasonal trends in local recreational water quality exceedences, weekly fecal indicator data sets for 39 coastal sites (Fig. 1) were reviewed for the period 1999-2003 (courtesy of Guam Environmental Protection Agency). Monthly water quality exceedences were subsequently plotted against the cumulative monthly rainfall recorded at Naval Air Station (NAS) in central Guam over the same time period.

To establish the presence of fecal indicator bacteria in soil, plugs of sediment were taken from a small holes excavated in the banks of the Pago and Sigua Rivers in central Guam. The Pago River receives drainage from the Ordot Landfill while the Sigua River is relatively unimpacted by the activities of man. Replicate soil samples were collected from both locations in sterile polypropylene syringes (25-ml) with the needle end cut off, 'cork-borer' fashion. They were then sealed in Whirl-Pak bags, chilled immediately on 'blue ice' and transported to the laboratory in insulated containers.

Approximately 5 g of ejected soil was shaken for 2-3 minutes with ~50 ml of sterile deionized water in sterile 100-ml polycarbonate bottles normally used for presence/absence testing. The soil suspensions were allowed to stand for 20 minutes to permit partial settlement of the clay fraction. A 10-ml volume of the clear surface layer was removed from each sample and made up to 100 ml with sterile deionized water.

Bacterial enumerations were made via the Quantitray™ method following addition of the appropriate growth media to the soil dilutions, i.e., Colilert® for *E. coli* and Enterolert® for enterococci. The samples were incubated at 35°C for 18h ± 2h for *E. coli* and 41°C for 24h ± 2h for enterococci. Confirmatory analysis was performed on 50-75% of all fluorescing wells. In such instances, samples were withdrawn into a sterile syringe from the back of the Quantitray™ pouch and streaked onto EMB agar and mE agar for *E. coli* and enterococci respectively.

The survival experiments are currently underway. We are also attempting to differentiate between fecal and non-fecal strains of both organisms using biochemical techniques in a manner similar to that described for *Enterococcus* spp. by Manero and Blanch (1999).

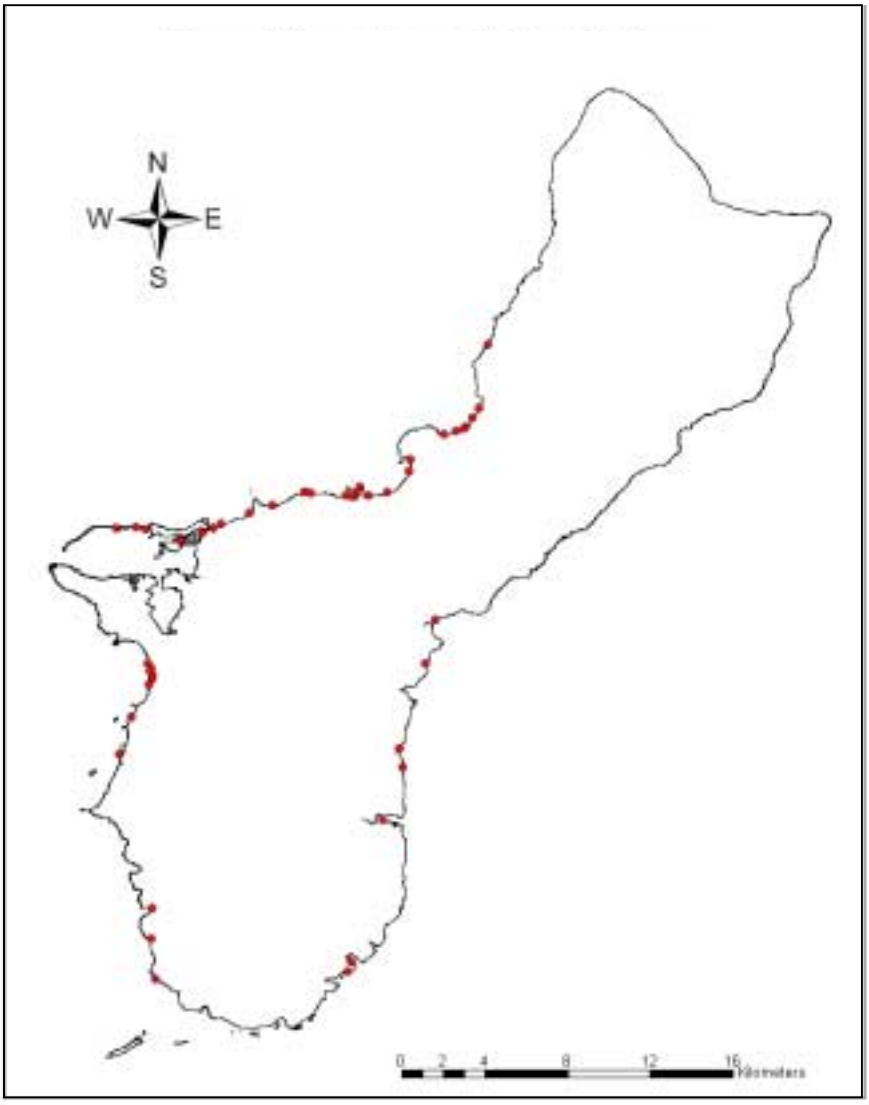

Figure 1: Map of Guam showing GEPA recreational water quality monitoring sites

Principal Findings and Significance

Exceedences of the USEPA recreational water quality standards on Guam are clearly related to storm events (Fig. 2) and predominantly occur during the wet season (July-December).

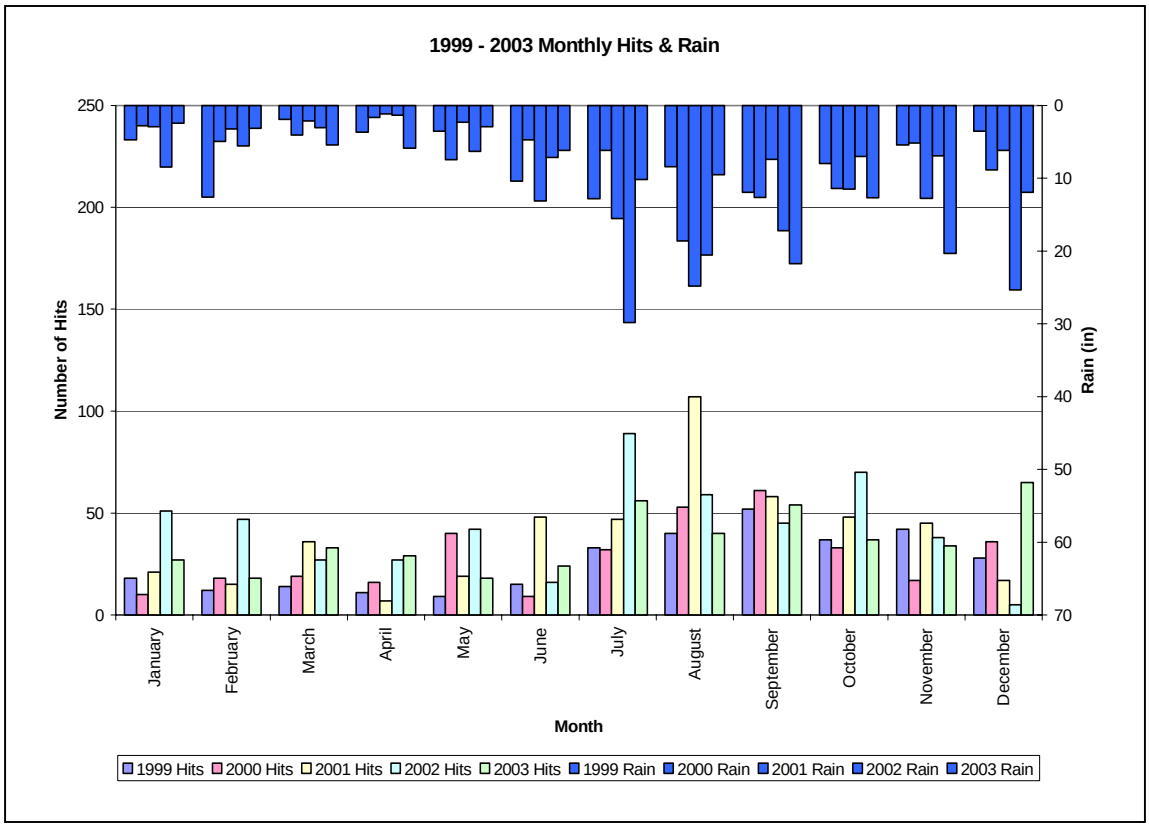

Figure 1: Cumulative monthly exceedences of the USEPA recreational water quality standards for the island of Guam (1999-2003) plotted against rainfall (blue bars) recorded at NAS, Tijan, Guam

The microbiological analysis of riverbank soil from the Pago and Sigua Rivers in central Guam are presented in Table 1. High counts of *E. coli* and enterococci were indicated in soil from both locations following incubation in Colilert® and Enterolert® growth media (Table 1). Differences between replicates were often highly variable and there was no clear relationship between bacterial densities and soil depth for either organism. The data for *E. coli*, however, suggest that horizontal distance from the river is a controlling factor. This may be related to variations in soil moisture content.

Confirmatory analysis consistently confirmed the presence of *E. coli* in all positive wells. In sharp contrast, only ~20% of well isolates confirmed for the presence of enterococci in Pago River samples and 0% confirmed in Sigua River samples. Clearly, there is a component in soil, other than enterococci, which causes fluorescence when incubated with the Enterolert® media. Whether this is removable by filtration is currently unknown.

Table 1: Fecal Indicator Bacteria in Soil from Pago and Sigua Rivers

River	Location	Depth	MPN Index/100 g soil	
			E. coli	Enterococci
Pago	River Bank			
	Site 1	Surface	525 - 2475	5211 - 9799
	Site 2	Surface	2659 - 6256	9697 - 17067
	Site 3	Surface	5929 - 6175	2784 - 9277
	Site 4	Surface	793 - 2854	4889 - 6009
Sigua	River Bank			
	Site 1	Surface	991	999 - 5971
	Site 1	5 cm	702 - 1535	2357 - 4518
	Site 1	10 cm	2020	438 - 1319
Sigua	I Meter Inland			
	Site 1	Surface	3941	2161 - 2617
	Site 1	5 cm	1081 - 1963	6830 - 8356
	Site 1	10 cm	613	1033 - 14213
Sigua	I0 Meters Inland			
	Site 1	Surface	<10	3897 - 10593
	Site 1	5 cm	264	2128 - 4839
	Site 1	10 cm	<10	234 - 523

Quantitray™ method using Colilert® and Enterolert® growth media for *Ecoli* and enterococcus respectively

Literature Cited

Davies, C.M., J.A.H. Long, M. Donald and N.J. Ashbolt (1995). Survival of Fecal Microorganisms in Marine and Freshwater Sediments. *Applied and Environmental Microbiology*, 61 (5): 1888-1896.

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Hazen, T.C. (1988). Fecal Coliform as Indicators in Tropical Waters: A Review. *Toxicity Assessment An International Journal* Vol. 3: 461-477.

Solo-Gabriele, H.M., M.A. Wolfert, T.R. Desmarais and C.J. Palmer (2000). Sources of *Escherichia coli* in a Coastal Subtropical Environment. *Applied and Environmental Microbiology,* 66 (1): 230-237.

Manero, A. and A.R. Blanch (1999). Identification of *Enterococcus* spp. with a Biochemical Key. *Applied and Environmental Microbiology,* (65): 4425-4430.

Speciation studies of arsenic in Guam Waters Phase II.

Basic Information

Title:	Speciation studies of arsenic in Guam Waters Phase II.
Project Number:	2004GU29B
Start Date:	3/1/2004
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	n/a
Research Category:	Water Quality
Focus Category:	Water Quality, Toxic Substances, Recreation
Descriptors:	Arsenic levels,Speciation, Toxicity
Principal Investigators:	Maika Vuki

Publication

1. John Limtiaco, Tovahl Aube, Maika Vuki, Gary Denton, Rick Woods, Arsenic Speciation Studies in Guam Waters, Abstract, CLASS Annual Conference, March 2005, University of Guam.
2. Maika Vuki, John Limtiaco, Tovahl Aube, Rick Woods, Gary Denton, Book of Abstracts, 8th International Conference on the Biogeochemistry of Trace Elements, April 2005, Adelaide, Australia, pages 244-245.

Project Title: Arsenic Speciation in Guam waters, Phase II

Problem and Research Objectives

Arsenic contamination in ground water is a major concern in several states in the US. Arsenic is known to be carcinogenic and several countries, particularly Bangladesh, has been known to suffer from severe health problems that is related to arsenic contamination in ground water. In the US alone, more than 50% of ground water sources have significant levels of arsenic that requires constant monitoring. As a result, USEPA has recently reduced the maximum allowable level of arsenic to 10 μg/L or parts per billion (ppb). Preliminary investigations by the Guam EPA (2001) on the spring waters that discharged from the northern lens aquifer in Guam reported some unusually high levels of arsenic. This was unusual since the major geological formation on the northern region of Guam is predominantly carbonacious rocks and these rocks are known to have low levels of arsenic. About 80% of Guam's water source is derived from the limestone aquifer. There are more than 100 ground water wells on the northern part of the island. Some of these wells are connected through conduits that flow out as springs or seeps along Tumon Bay. A follow up study conducted on the same sites along the Tumon Bay region in 2003 showed show low levels of arsenic. The major differences in sampling and analytical methods in these two separate studies requires further work to validate the arsenic data generated from this northern region. The aim of this project is to verify the differences from the two studies and investigate possible contamination pathways that may contribute to any high levels of arsenic. The objectives are

i. **To investigate the levels of Arsenic in Tumon Bay, the connecting freshwater wells on Guam and other potential sites during the wet and dry season.**
ii. **To conduct speciation studies of arsenic to ascertain the levels of the different forms of As both organic and inorganic.**
iii. **To conduct an inter-laboratory validation exercise**
iv. **To correlate the levels of arsenic to the likely sources and sinks.**
v. **To relate these levels to the parameters; pH, salinity, dissolved oxygen and temperature.**

Methodology

Water samples were collected from the flowing springs and seeps from 10 sites along Tumon Bay. The samples were acidified with a small amount of concentrated hydrochloric acid (0.25mL/100mL) and stored in ice cooled containers and transported to the main laboratory for further treatment. During sample collection, measurement for dissolved oxygen, conductivity, temperature, and pH were also conducted. In the laboratory, samples were filtered and stored under 4^{o}C temperature until the analysis of arsenic under the hydride generation method.

Arsenic speciation involves the treatment of samples under three reagent regimes. Pretreatment 1 (PT1) which measures arsenic (III) uses only HCl with no heating. Pretreatment 2 (PT2) measures As(III) and As(V) and this method uses a mixture of reductant KI and HCl followed by intermediate heating under a microwave oven. Pretreatment 3 (PT3) measures both organic and inorganic arsenic species. The reagent is a mixture of $K_2S_2O_8$ and NaOH followed with a series of heating (under microwave) and cooling cycle. PT3 is then followed by PT2 to reduce all arsenic to As(III) before analysis.
The hydride generation method is coupled with Atomic Absorption Spectroscopy. This method was successfully developed from the first part (Phase I) of this study. The detection limit obtained was 0.30μg/mL (ppb).

Principal Findings and Significance

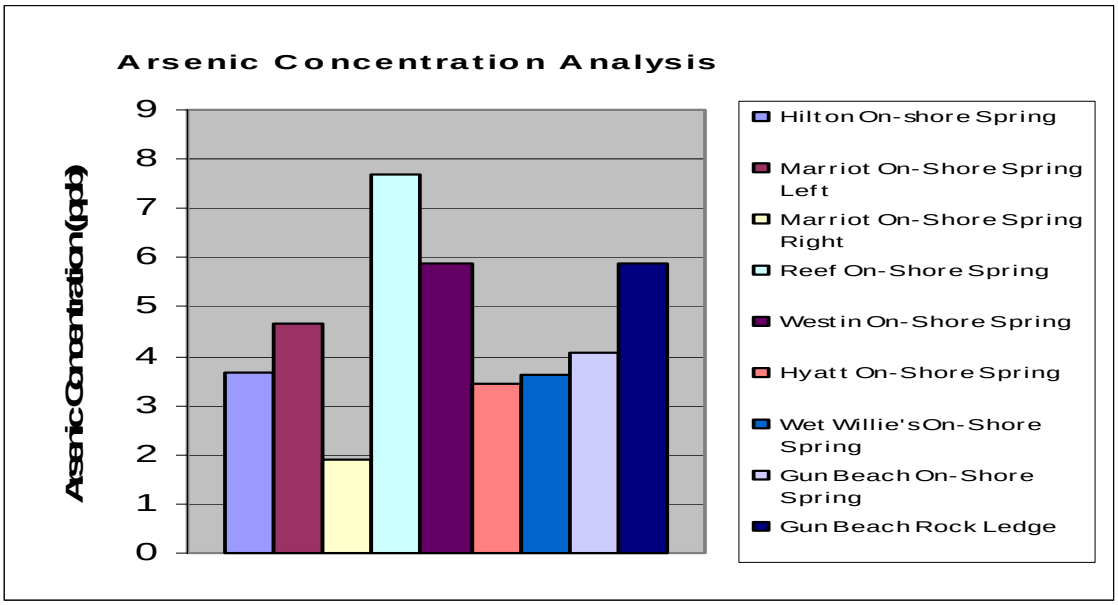
Table 1.0 show a summary of the levels of arsenic from the 10 sampling sites along Tumon Bay. The total inorganic arsenic levels given under pretreatment 2 (PT2) are very low. Arsenic (III) levels (PT1) are all below detection limit. All these values are well below the recommended level stated under the USEPA guideline (10μg/L).

Table 1.0

Sample	PT1	PT2
	As conc. (μg/L)	As conc. (μg/L)
TB1(Hilton)	<0.3	0.8
TB2 (Marriot)	<0.3	1.2
TB3 (Marriot)	<0.3	0.6
TB4 (Wet Willies)	<0.3	0.8
TB5 (Holiday Inn)	<0.3	0.9
TB6 (Outrigger)	<0.3	1.0
TB7 (Outrigger)	<0.3	0.6
TB8 (Reef)	<0.3	0.9
TB9 (Westin)	<0.3	<0.3
TB10 (Okura)	<0.3	<0.3
MilliQ + 20μg/L As(III) + 20 μg/L As(V)	25.1	37.8
Method detection limit: 0.3μg/L		

Figure 1.0 show levels of total arsenic from the same sites using the ICP-AES method of analysis. These results were conducted in partnership with a collaborating laboratory. The evels of As shown in figure 1.0 are higher that those in Table 1.0. These high values are expected due to the interference of metals such as tin and other metals in the similar spectral region under the method used. The ICP-AES analysis method did not involve any speciation procedure and the levels reported are for the total arsenic concentrations in water. The results show the arsenic levels are still lower than 10µg/L. These two sets of data (Table 1.0 and Figure 1.0) clearly show that arsenic levels are low in the Guam springs. Arsenic levels from neighboring streams and rivers on Guam were also analysed for comparison. Results obtained were consistent with the low values measured from spring waters. Organic arsenic levels obtained from PT3 also show low levels. Therefore the total arsenic concentrations in the spring waters are low and pose no immediate threat to the environment or human health.

Figure 1.0. Arsenic levels measured under ICP-AES technique without hydride generation method from the same study sites. Arsenic concentration is reported in part per billion, µg/L.



Conclusion.

The speciation method used was able to distinguish between the inorganic arsenic (III) and inorganic arsenic (V) species in spring water samples. The levels of arsenic in the spring water are well below the maximum allowable limits set under the USEPA guideline. Therefore there is no immediate threat of arsenic pollution along Tumon Bay and the ground water levels of Guam. The values of arsenic levels from this study are also consistent with those reported by Guam Waterworks Authority (GWA). The low values are also consistent with the natural background levels based on the carbonate rocks on the northern region of Guam. However, regular monitoring will be necessary due to the increasing industrial development along the Tumon Bay area and the northern region in general. Such developments may introduce localized point source contamination that would pose environmental and health risk to the community.

Hydrology of the Sabana Watershed and Water Cave, Rota, CNM

Basic Information

Title:	Hydrology of the Sabana Watershed and Water Cave, Rota, CNM
Project Number:	2004GU30B
Start Date:	3/1/2004
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	NA
Research Category:	Climate and Hydrologic Processes
Focus Category:	Groundwater, Drought, Models
Descriptors:	carbonate island karst, karst aquifers, small island water supply
Principal Investigators:	john jenson

Publication

Project Title: Hydrology of the Sabana Watershed and Water Cave, Rota

Problem and Research Objectives

Rota, about 40 miles (64 km) north of Guam, supports a population of about 2500. The island obtains nearly all of its potable water from a karst spring estimated to produce from 0.5 to 1.5 mgd (0.02 to 0.06 m^3/sec). Although the spring has historically produced more than enough during wet years, it can slow to very low flow during dry years, nearly ceasing entirely during the 1998 El Nino event. Reliable management of the water production over the long term requires a better understanding of the hydrology of the Water Cave and the catchment that feeds it. The Sabana area is undergoing active use, including the cultivation of crops in the watershed that feeds the sink points, and hence ultimately the spring. For the island to effectively manage this preeminent water source, it is crucial that engineers and planners understand the properties of the Sabana Watershed and the hydrologic connection between the watershed and spring.

Methodology

The study employed classical methods of geological field investigation. Fieldwork included exploration and mapping of the watershed, particularly the topographic divides, contacts between the limestone and adjacent volcanic outcrops, and the karst features, particularly the sinkholes in the watershed catchment and the discharging springs along the contact above the Talakhaya area. This project supported a graduate student on a full-time research assistantship who was able to visit the site during wet and dry seasons, and following major storms. We located what appear to be the major sink points, geologic boundaries, and hydrologic boundaries. Field information is being input to a GIS from which maps and related analyses can be made.

Principal Findings and Significance

The principal product of this study will be technical report (in preparation) containing a set of maps of the Sabana Watershed showing the boundaries, geologic contacts, vegetation, and land use. The maps will also include field relationships of the important hydrogeological features, particularly the locations of the sink points and the inferred and observed flow paths to them. This work complements parallel work planned by the US Geological Survey Field Office in the CNMI in collaboration with the Army Corps of Engineers (Capital Improvement Program) to reinstall a rain gauge in the Sabana Watershed, and new stage gauging instrument in the spring, both of which were destroyed by the typhoon of July 2002. The maps will support future studies of the water budget, including the relationships between rainfall, watershed characteristics, storm water runoff and ponding at the sink points, transport time to the spring, and stage response of the spring. The results of this work will thus provide a basis for assessing the risk to water quality posed by human activities in the Sabana Watershed, along with appropriate strategies for aquifer protection and remediation.

PROJECT SYNOPSIS REPORT

Project Title: Groundwater development and utilization for emergency drinking water, Fais Island, Yap State, FSM

Problem and Research Objectives

The objective of this project is assess of the physical resources and sociocultural factors that must be considered to ensure a reliable source of drinking water to meet emergency needs of the residents of the small (2.6 km^2), remote island of Fais, Yap State, Federated States of Micronesia. Fais's permanent population of about 320 people currently relies almost exclusively on rainwater catchments to meet its potable water needs. However, on average once a decade a major storm destroys or damages existing catchments, most recently in November 2003. In light of the small size and subsistence economy of Fais and the prevailing traditional social organization and land tenure, technical recommendations for development and protection of water resources must be compatible with the island's social traditions, cultural values, and indigenous authority. The central objectives of this study are therefore inventorying and mapping the key karst features that relate to groundwater availability and making an inventory of patterns of usage, storage, and sharing of water from existing rainwater catchments and other sources. These data will be used to developing recommendations for an appropriately balanced approach to management of rain catchment and groundwater resources to meet emergency needs.

Methodology

The study employed the classical methods of geological field investigation, including exploration and mapping of selected geological features. Because no previous geological study has been made and no maps or orthophotographs of Fais have been published, we are building our own base maps for this projects from a set of aerial photos that Dr. Rubinstein has in his collection from previous work on the island. In addition to mapping caves and searching for coastal seeps and springs, we are also mapping major sinkholes, fractures and features that may influence the capture and transport of water in the aquifer. Sociological methods of investigation build upon Dr. Rubinstein's 35 years of association with residents of Fais, assuring excellent access and trust from island leaders. Specific procedures involve participant-observation and open-ended interviewing following semi-structured question protocols, using an opportunity sample of island adults and social leaders.

Principal Findings and Significance

This project has been continued into a second year. Observations from the first year's fieldwork showed that the residents have a strong preference for rain catchment water sources because of the convenience of using and storing it at the household or village catchment source rather than having to carry it from a well. The primary limitation on emergency supply appears to be lack of sufficient storage capacity for rainwater. We are therefore returning to obtain complete information on storage capacity versus actual household requirements under emergency conditions, to include availability of other alternative sources, including coconuts and well water. The current work will also complete the inventory of karst features, to include mapping caves that were not accessible because of weather and surf conditions during the first year.

Persistent Contaminant Assessment of Food Fish from Tanapag Lagoon, Saipan

Basic Information

Title:	Persistent Contaminant Assessment of Food Fish from Tanapag Lagoon, Saipan
Project Number:	2004GU31B
Start Date:	3/1/2004
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	n/a
Research Category:	Water Quality
Focus Category:	Toxic Substances, Water Quality, Non Point Pollution
Descriptors:	
Principal Investigators:	Gary Denton, Peter Houk, Harold Wood

Publication

Project Title: Persistent Contaminant Assessment of Food Fish from Tanapag Lagoon, Saipan

Problem and Research Objectives

Tanapag Lagoon, on the western shore of central Saipan, harbors a rich diversity of marine life and supports a variety of commercial and recreational activities. Over the years, increased urban growth and commercial developments along the adjacent coastline have resulted in a loss of environmental quality, particularly in the southern half of the lagoon. Primary sources of anthropogenic disturbance in these waters include a power station and commercial port (Saipan Harbor), two small boat marinas, a sewer outfall, several garment factories, auto and boat repair shops, wood shops, government vehicle maintenance yards, a commercial laundry, and an acetylene gas producer. There are also a number of old military dumps and disposal sites in the area as well as a 50-year old municipal dump that served as the island's only solid waste disposal site until its closure a little over two years ago. Several streams and storm drains empty into the lagoon during the rainy season and provide a mode of transport into the ocean for any land-based contaminants. Overflows from sewer lines are also commonplace at this time of the year and the whole area is inundated by storm water runoff during periods of prolonged wet weather. The effects of these perturbations on the indigenous biota within the lagoon are largely unknown. Likewise, fundamental data describing the abundance and distribution of persistent and potentially toxic pollutants within the system is also lacking.

Mindful of these shortcomings, a contaminant assessment of surface sediments within Tanapag Lagoon was recently completed (Denton *et al.* 2001) and a bioindicator survey of the nearshore waters is currently underway. The study reported here examined contaminants of potential concern (mercury, arsenic and PCBs) in important food fishes from within the lagoon and is seen as a logical extension of these studies.

The study focused on dominant species with restricted home ranges as well as those that were more roving in their feeding habits. In so doing the study was able to delineated specific areas of enrichment as well as assess the overall condition of the lagoon from a contamination standpoint. Representative species with different food preferences were selected from various trophic levels in order to evaluate the degrees of biological magnification that have taken place so far for each contaminant. Potential health risks associated with the long-term consumption of edible resources surveyed are also being evaluated

Methodology

Fish were taken from seven sites between Muchot Point at the southern end of the lagoon and Pau-Pau Beach in the north. (Fig. 1). Sites 1-4 are impacted by land-based sources of contamination of one sort or another while sites 5-7 are not and serve as useful reference sites (Table 1). Specimens were caught by local fishermen using hook and line, spear gun and Hawaiian sling. They were chilled immediately and transported to the laboratory in insulated containers. The fish examined during the study are identified in Table 2. The trophic level to which each belongs and their movements within the lagoon are also indicated.

In the laboratory, fish were dissected for analysis using high quality stainless steel instruments. Axial muscle was taken from directly under the dorsal fin on the left side of the fish for mercury and arsenic analysis, and on the right side for PCBs. Where possible, liver tissue was also

removed for heavy metal analysis. Most fish were readily identified and processed within a few hours of capture. Those that weren't were deep-frozen as quickly as possible and processed within one month upon returning to Guam. All tissue samples were stored at -20^{o}C until required for analysis. Those for metal analysis were stored in acid cleaned polypropylene vials while those for PCB analysis were individually wrapped in aluminum foil and sealed in Ziploc® bags.

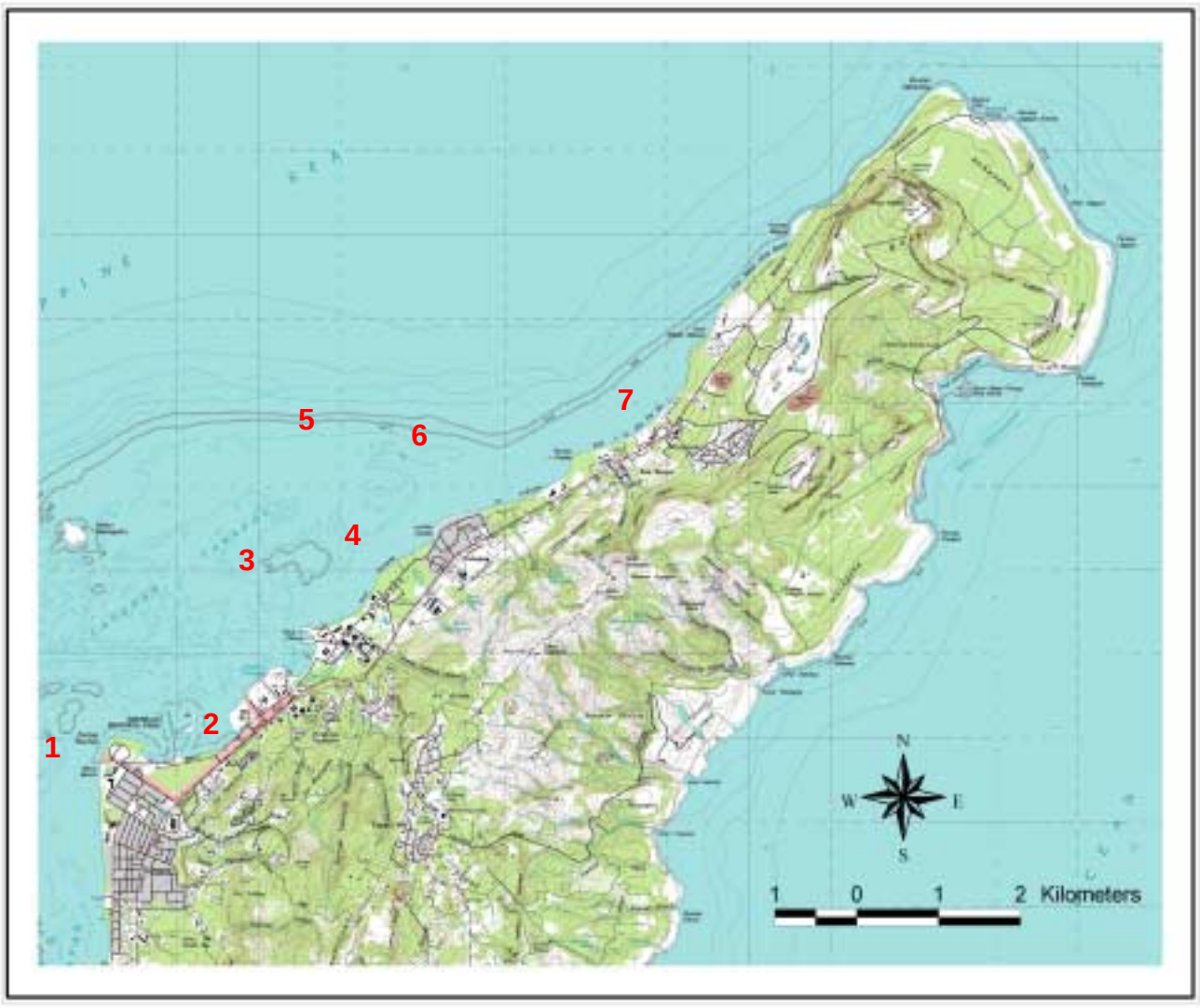


Figure 1: Map of northern Saipan showing fish sampling sites 1-7

To date, all samples have been analyzed for mercury and the arsenic analysis is currently underway. The PCB analysis should be completed within the next 6 months. Analytical protocols for all contaminants of interest are as previously described in Denton *et al.* (1999).

Table 1: Site Identity and Nearby Sources of Heavy Metal and PCB Contamination

Site	Local Name	Nearby Sources of Contamination
1	Micro Beach/Reef	Smiling Cove Marina (metals: boats, antifouling paints)
2	unnamed	Puerto Rico Dump (metals: various, PCBs: transformers)
3	Seaplane Reef	shipping lanes, dry docks (metals: boats, antifouling paints)
4	Tanapag Shoals	PCBs: old transformer storage site in Tanapag village
5	unnamed	none
6	Dankulo Rock	none
7	Pau-Pau Shoals	none

Table 2: Fish Sampled During the Present Survey

Species	Trophic Level*	Micro Beach/Reef	Puerto Rico Dump (seaward edge)	Seaplane Reef	Outer Lagoon Site 1	Outer Lagoon Site 2 (Dankulo Rock)	Tanapag Shoals	Pau-Pau Shoals
Acanthurus blochii	H,DI,R							
Acanthurus lineatus	H, DI, S	22		12		3		2
Acanthurus nigricans	H, DI, R	1					1	
Acanthurus nigricauda	H, DI, R		1				1	
Acanthurus nigrofuscus	H, DI, S		2		1			
Acanthurus olivaceous	O, DI, R					1		
Acanthurus triostegus	H/P, DI, R					1		1
Balistiodes viridescens	C, DI, S		1					
Calotomus carolinus	H, DI, R	2		1				
Caranx melampygus	C, DI, R			2				
Chaetodon ornatissimus	C, DI, S			1				
Cheilinus chlorous	C, DI, R					1		
Cheilinus trilobatus	C, DI, R			2	1		1	
Cheilo inermis	C, DI, R					I		
Chlorurus frontalis	H, DI, R					1		
Chlorurus sordidus	H, DI, R					4	3	
Coris aygula	C, DI, R			1				
Ctenochaetus striatus	H, DI, S	1				2	4	1
Epinephelus maculatus	C, DI, S					1		
Epinephelus howlandi	C, DI, S			2				
Epinephelus merra	C, DI, S			1		1		
Gnathodentex aurolineatus	C, NO, R	1				1	1	1
Halichoeres trimaculatus	C, DI, R					1		
Hemigymnus melapterus	C, DI, R				2			
Heteropriacanthus cruentatus	C, NO, S	1						
Kyphosus biggibus	H, DI, R					1		

Table 2: Fish Sampled During the Present Survey (cont.)

Species	Trophic Level*	Micro Beach/Reef	Puerto Rico Dump (seaward edge)	Seaplane Reef	Outer Lagoon Site 1	Outer Lagoon Site 2 (Dankulo Rock)	Tanapag Shoals	Pau-Pau Shoals
Lethrinus atkinsoni	C, NO, R	2				1		
Lethrinus erythracanthus	C, NO, R					1		
Lethrinus harak	C, NO, R	10	3	5			4	1
Lethrinus obsoletus	C, NO, R	1			1			
Lethrinus olivaceous	C, NO, R					2		
Lethrinus xanthochilus	C, NO, R	3				3		2
Lutjanus fulvus	C, NO, R	1				1		
Lutjanus kasmira	C, NO, R			1		1	2	
Lutjanus monostigmus	C, NO, R	1						
Myripristis amaena	P/C, NO, S	2				1		7
Myripristis berndti	P, NO, S	1	10	2		7	2	1
Myripristis kuntee	P/C, NO, S	1						
Myripristis murdjan	P/C, NO, S	1						
Myripristis pralina	P/C, NO, S	2					4	
Myripristis violacea	P/C, NO, S	7	4					8
Naso annulatus	H, DI, R					1		
Naso lituratus	H, DI, R	4	14	15		1	5	15
Naso unicornis	H, DI, R		1		1		1	1
Naso vlamingii	H, DI, S						1	
Neoniphon argenteus	C, NO, S					1		
Neoniphon opercularis	C, NO, S		1					
Neoniphon sammara	C, NO, S	3						3
Parupeneus barberinus	C, DI, R				1		1	2
Parupeneus multifasciatus	C, DI, R	1	2			1		
Plectropomis laevis	C, DI, R						1	
Pseudobalistes fuscus	C, DI, S					2		
Rhinecanthus aculeatus	O, DI, S						4	
Rhinecanthus rectangulus	O, DI, S			1				
Sargocentron spiniferum	C, NO, S		1	1		1		6
Scarus ghobban	H, DI, R	1		2	3			
Scarus globiceps	H, DI, R				2			
Scarus psittacus	H, DI, R			2		1		
Scarus sp.	H, DI, R			1				
Siganus spinus	H, DI, R		1				1	1
Sphyraena flavicauda	C, DI, R			2				
Sufflamen chrysoptera	O, DI, S					1		
Thalassoma trilobatum	C, DI, R					1		
Triaenodon obesus	C, NO, R			1				
Zanclus cornutus	O, DI, R			1				

* H = herbivore benthic; P = planktivore; C = carnivore; O = omnivore; R = roving/large home range; S = sedentary/small home range
NO = nocternal feeder; DI = diurnal feeder

Principal Findings and Significance

Over 300 fish representing 65 different species were analyzed for mercury during the course of this work. The data are summarized in Table 3 and show strong trophic level dependence. On average, mean mercury concentrations in fish axial muscle were around an order of magnitude higher in carnivores than herbivores. The highest level found was 0.616 µg/g in a specimen of wire-netting cod, *Epinephelus merra*, from Seaplane Reef (site 3). The highest concentration of mercury found in fish liver was 9.131 µg/g in a specimen of soldier fish, *Myripristis berndti*, from the same area.

Mercury levels in sedentary herbivores and carnivores showed distinct inter-site variability with specimens from Micro Beach having significantly higher mean values in their axial muscle compared with specimens from elsewhere in the study area (Table 3). A scatterplot of data sets for the dominant sedentary carnivores, *Myripristis* spp., suggests such difference cannot be fully explained by variations in body weight alone (Fig. 2). The graph is also suggestive of mercury enrichment in the vicinity of the now closed Puerto Rico Dump (site 2), and at Seaplane Reef (site 3). Such enrichment is to be expected given the nature of anthropogenic activities in this part of the lagoon and the general southerly movement of the entrained water masses.

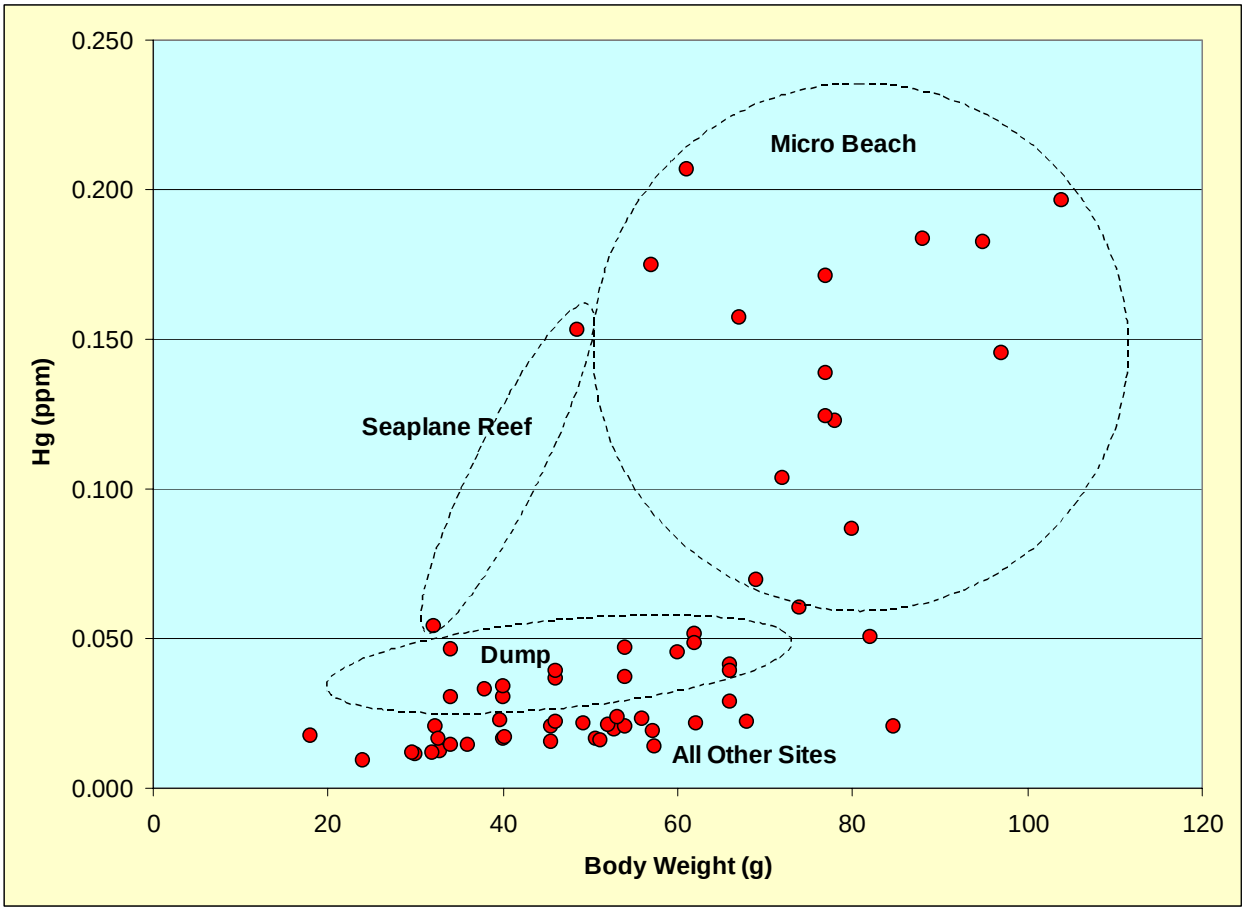


Figure 2: Axial muscle mercury levels vs. wet weight in *Myripristis* spp. from Tanapag Lagoon

Table 3: Mercury in Axial Muscle of Fish from Tanapag Lagoon, Saipan (2003 - 2004)

(all data as µg/g wet weight)

Site	Statistic	Trophic Level*					
		H:S	H:R	C:S	C:R	O:S	O:R
1: Micro Beach/Reef	range	0.004 - 0.109	0.004 - 0.133	0.029 - 0.318	0.010 - 0.212	-	0.017
	median	0.016	0.015	0.161	0.068	-	0.017
	mean	0.019	0.019	0.141	0.078	-	0.017
	# samples	22	9	18	25	-	1
	# species	2	5	8	8	-	1
2: Puerto Rico Dump	range	0.003 - 0.009	0.002 - 0.014	0.030 - 0.297	0.069 - 0.110	-	-
	median	0.006	0.005	0.041	0.079	-	-
	mean	0.006	0.005	0.050	0.085	-	-
	# samples	3	17	17	5	-	-
	# species	2	4	5	2	-	-
3: Seaplane Reef	range	0.003 - 0.114	0.002 - 0.248	0.026 - 0.616	0.016 - 0.396	0.066	0.005
	median	0.005	0.01	0.091	0.084	0.066	0.005
	mean	0.008	0.009	0.097	0.069	0.066	0.005
	# samples	12	21	7	14	1	1
	# species	1	5	5	9	1	1
4: Tanapag Shoals	range	0.002 - 0.010	0.002 - 0.022	0.014 - 0.050	0.010 - 0.161	0.007 - 0.033	-
	median	0.003	0.004	0.018	0.037	0.01	-
	mean	0.003	0.004	0.02	0.04	0.013	-
	# samples	5	12	6	10	4	-
	# species	2	6	2	6	2	-
5: Outer Lagoon Site 1	range	0.007	0.003 - 0.028	-	0.006 - 0.052	-	-
	median	0.007	0.006	-	0.029	-	-
	mean	0.007	0.007	-	0.025	-	-
	# samples	1	6	-	5	-	-
	# species	1	3	-	4	-	-
6: Outer Lagoon Site 2 (Dankulo Rock)	range	0.002 - 0.003	0.001 - 0.006	0.012 - 0.078	0.006 - 0.075	0.018	0.004
	median	0.002	0.002	0.020	0.025	0.018	0.004
	mean	0.002	0.002	0.020	0.024	0.018	0.004
	# samples	5	10	14	12	1	1
	# species	2	7	7	11	1	1
7: Pau-Pau Shoals	range	0.002 - 0.002	0.001 - 0.037	0.009 - 0.063	0.008 - 0.146	-	-
	median	0.002	0.002	0.022	0.018	-	-
	mean	0.002	0.004	0.024	0.022	-	-
	# samples	2	19	27	6	-	-
	# species	1	5	6	4	-	-

* H:S = sedentary herbivore; H:R = roving herbivore; C:S = sedentary carnivore; C:R = roving carnivore; O:S = sedentary omnivore; O:R = roving omnivore; dashes = no data

In non-polluted situations, mercury levels in fish muscle generally lie between 0.001-0.1 µg/g wet weight (Denton and Burdon-Jones 1986) although higher concentrations have been noted in long-lived, predatory species particularly sharks, tuna, marlin and swordfish (Nishigaki *et al.* 1973, Beckett and Freeman 1974, Denton and Breck 1980). In the current study, 86% of all fish examined yielded axial muscle values of less than 0.1 µg/g and 97% had concentrations below 0.2 µg/g. These data suggest that the waters of Tanapag Lagoon are relatively free of mercury pollution. However, one of the problems associated with the current study was that many of the samples analyzed were small, immature individuals as a result of chronic over fishing throughout much of the lagoon in recent years. In all probability, mercury levels are significantly higher in adult fish populations within the region. Nevertheless, the current data are of value because they reflect actual levels currently reaching local consumers who fish these waters on a regular basis. All fish yielding axial muscle mercury levels ≥ 0.1 µg/g are listed in Table 4.

The current FDA food standard for mercury in fish is 1.0 µg/g wet weight, as methylmercury. Methyl mercury is the dominant organic form of mercury in fish and can account for up to 80% of total mercury present (Holden 1973). It is noteworthy, then, that all fish examined during the present study contained methylmercury concentrations that were well below the FDA limit. Unfortunately, this blanket standard does not address variations in consumption rates and so may not adequately protect people living in predominantly fish eating communities like those of the Pacific Islands. The more conservative USEPA risk-based consumption guidelines for methyl mercury in fish are therefore more appropriate here (USEPA 2000). These guidelines are based on an interim RfD of $1x10^{-4}$ mg/kg/d for a person weighing 70 kg. They take into account the methylmercury levels in the fish consumed and indicate the maximum number of 8 oz fish meals that may be consumed each month. Unrestricted consumption (i.e., more than sixteen 8-oz fish meals per month) is recommended only for fish with methylmercury concentrations of 0.029 µg/g wet weight or less.

If we assume that methylmercury accounts for 80% of total mercury present in edible muscle tissue of species captured during the present survey, then, 92% of all herbivores and 88% of all carnivores (including planktivorous species) were edible in unrestricted quantities. Those that exceeded this value were mostly from the Micro Beach area (58% of the total catch from site 1); adjacent to the dump (43% of total catch from site 2); and at Seaplane Reef (35% of the total catch from site 3). Exceedences of the 0.029 µg/g critical value were only evident in 14-18% of the total catch from each of the remaining four sites.

In accordance with the USEPA guidelines, restricted consumption is warranted for all specimens listed in Table 4. Those with a total mercury concentrations ranging from 0.10-0.15 µg/g, for example, should not be consumed (8 oz portion) more than eight times a month while those with levels >0.15-0.3µg/g should not be eaten more than four times a month. Figure 3 illustrates the relationship between total mercury concentrations and size in *Lethrinus harak*, one of the more popular table fish locally. This predatory species contained relatively high levels of mercury in its axial muscle and accounted for ~30% of the listings in Table 4. Zones A-D on the graph indicate the size ranges for consumption rates varying from unrestricted (zone A) to no more than eight 8 oz fish meals/month (zone D). Of course, in the absence of definitive methylmercury data for fish from this region, the predicted size ranges can only be regarded as approximations subject to further verification.

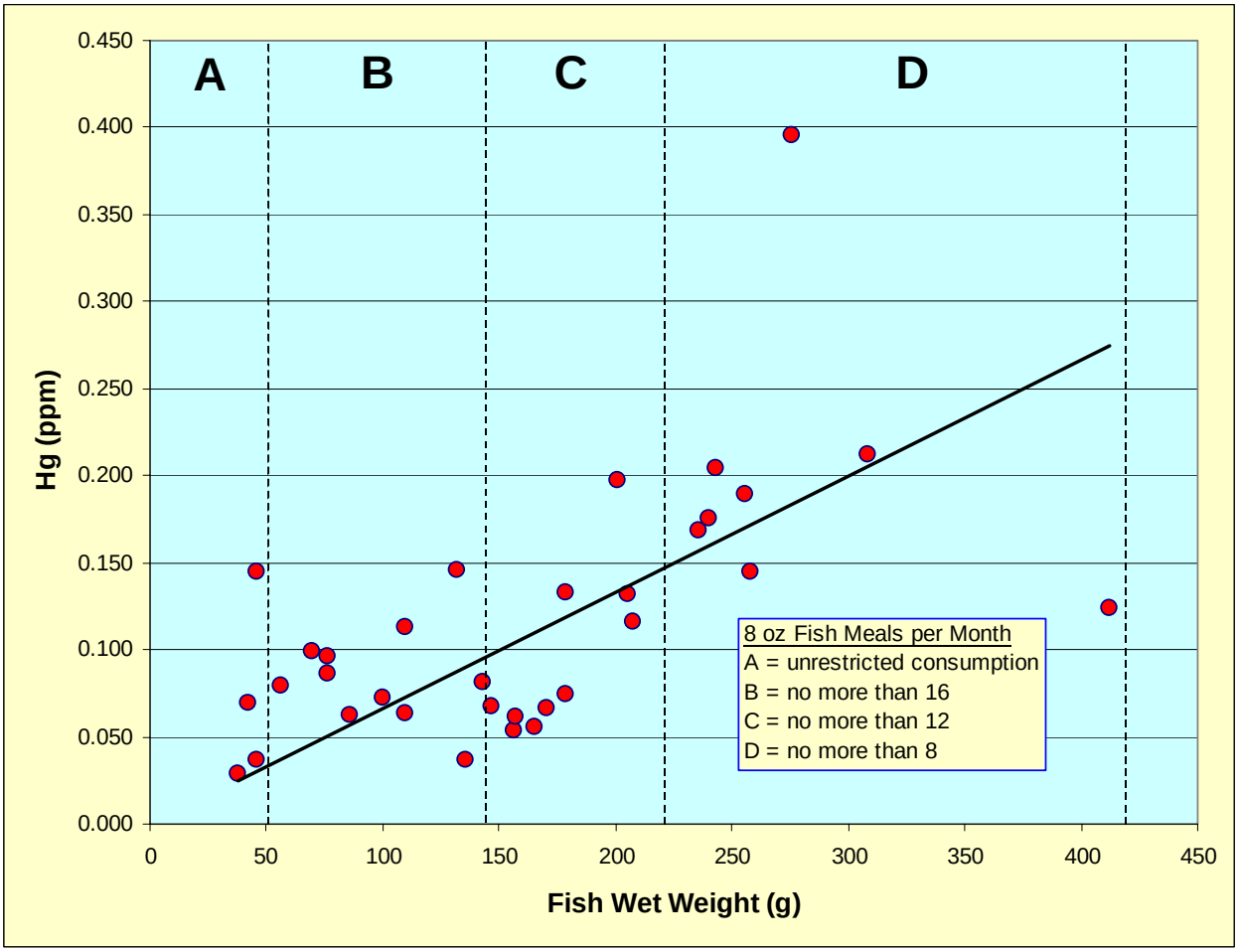


Figure 3: Axial muscle mercury levels vs. wet weight in *Lethrinus harak* from Tanapag Lagoon

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Refining the R-factor and Developing Rainfall Distribution Maps for the Island of Pohnpei

Basic Information

Title:	Refining the R-factor and Developing Rainfall Distribution Maps for the Island of Pohnpei
Project Number:	2004GU36B
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End Date:	2/28/2005
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Focus Category:	Non Point Pollution, Climatological Processes, Management and Planning
Descriptors:	
Principal Investigators:	Shahram Khosrowpanah, Mark Lander

Publication

Project Title:

Refining the R-factor and Developing Rainfall Distribution Maps for the Island of Pohnpei

Problem and Research Objectives

Lack of accurate rainfall data is a common problem throughout Micronesia, making it very difficult for water resources professionals to initiate studies such as watershed management, soil erosion reduction, identifying potential land sliding areas and so on. The slope failure at Sokehs in 1997 that killed 19 people, and the slope failures in Chuuk during tropical cyclone Chata'an in 2002 that killed 47 people are the examples of the need for information on rainfall distribution (e.g., Short-term extremes, and threshold conditions for flooding and slope failures).

The United States Department of Agriculture Natural Resources Conservation Service (USDA/NRCS) has implemented several programs to help manage and reduce soil erosion on the islands. These programs require accurate estimates of annual soil erosion, which is calculated using the Revised Universal Soil Loss Equation (RUSLE). The Universal Soil Loss Equation (USLE) and its updated revision the Revised Universal Soil Loss Equation (RUSLE) are the equations used most commonly to predict soil erosion rates and soil losses in the tropical pacific. In tropical environments, climate, or specifically the volume and intensity of rainfall, is the most significant cause of high soil erosion rates (Foster et al., 1982). This factor is identified in the USLE and RUSLE as the R or rainfall erosivity factor. It is important to have an accurate rainfall record with high time resolution (e.g., 15-minute duration) for calculating R-factor.

The objective of this research project were:

(1) Accurate assessment of the spatial distribution of rainfall on Pohnpei (e.g., isohyets of annual mean rainfall),

(2) some preliminary estimates of the magnitudes of extreme short-term rainfall rates;,

(3) an understanding of the general character of the rainfall (e.g., hourly distribution and month-to-month variability),

(4) develop Rainfall erosivity factor (R-factor) for island of Pohnpei and,

(5) identify the areas having a high potential for a land slide.

Methodology

The Precipitation-elevation Regression Independent Slopes Model (PRISM) analysis (Daly, et al. 1994) for Pohnpei Island predicts that the interior highlands receive much more rain than the coastal perimeter (Fig. 1). The PRISM model indicates that the annual rainfall in the mountainous center of Pohnpei is over twice that of the coastal perimeter. This is an enormous amount of rainfall (~300 inches per year) for the interior, and represents tremendous gradients of mean annual rainfall on this relatively small – 12-mile

diameter – roughly circular island. In addition, to be able to use the PRISM prediction for locating the areas that have potential for land sliding requires calculating the rainfall erosivity factor. The calculation requires having an accurate continuous rainfall record of each storm that might cause the landslide.

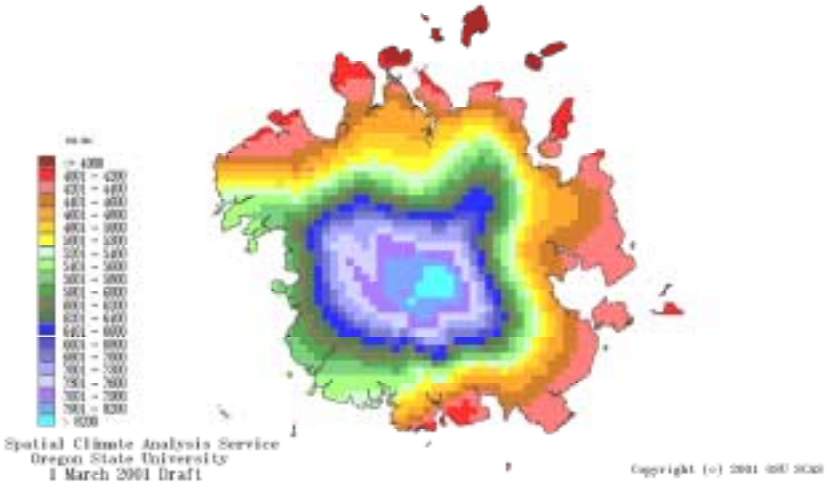


Figure 1. **PRISM**, estimated mean annual precipitation for island of Pohnpei.

The researchers at WERI with the help of Conservation Society of Pohnpei (CSP) installed a transect of manual and electronic rain gages extending from the coast to the highlands of the island. Figure 2 shows the location of WERI and WSO rain gages. Since rainfall is so heavy on Pohnpei (nearly 20 inches per month), simple manual rain gauges that consist of a 56-inch tall 6-inch diameter PVC cylinder capped by a funnel with a debris screen were constructed (Fig. 3a). These are cheap, easy to install and to maintain. Although not highly accurate, these crude manual gauges may be able to accurately measure the differences between rainfalls among the sites. One of the manual rain gauges was collocated with existing accurate recording stations at the WSO Pohnpei. Tipping bucket rain gauges with data loggers were set up at three of the transect sites (Madolenimw Mayor's Office, Nihpit, and Nahna Laud) (Fig. 3b). These allowed a calibration and validation of the rain collected by the manual gages. Two of the manual rain gauges were collocated with WERI/CSP electronic rain gauges at the College of the FSM, and on top of Nahna Laud. Additional electronic rain gauges were placed at the Airport and the College. Manual rain gauges were also placed at the Airport, the College, at a site (Mahnd) along the mountain transect between the Mayor's Office and Nihpit.

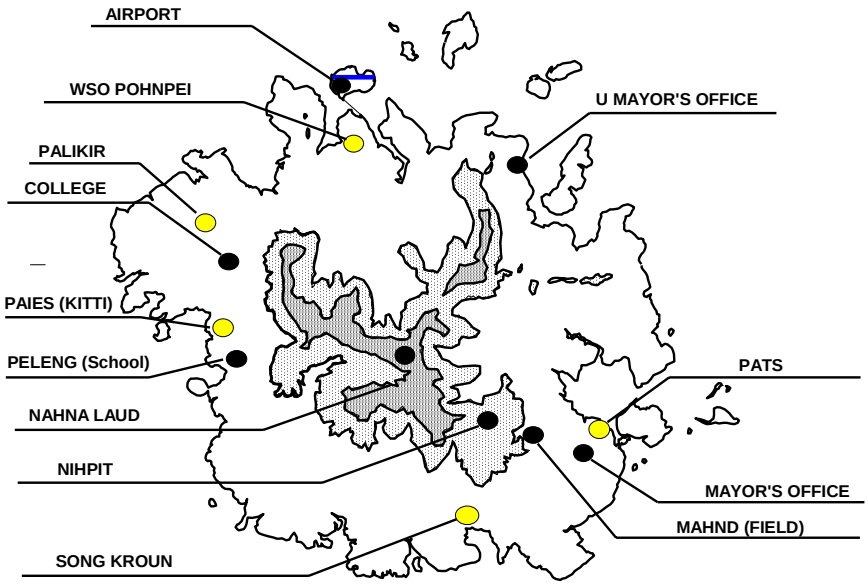
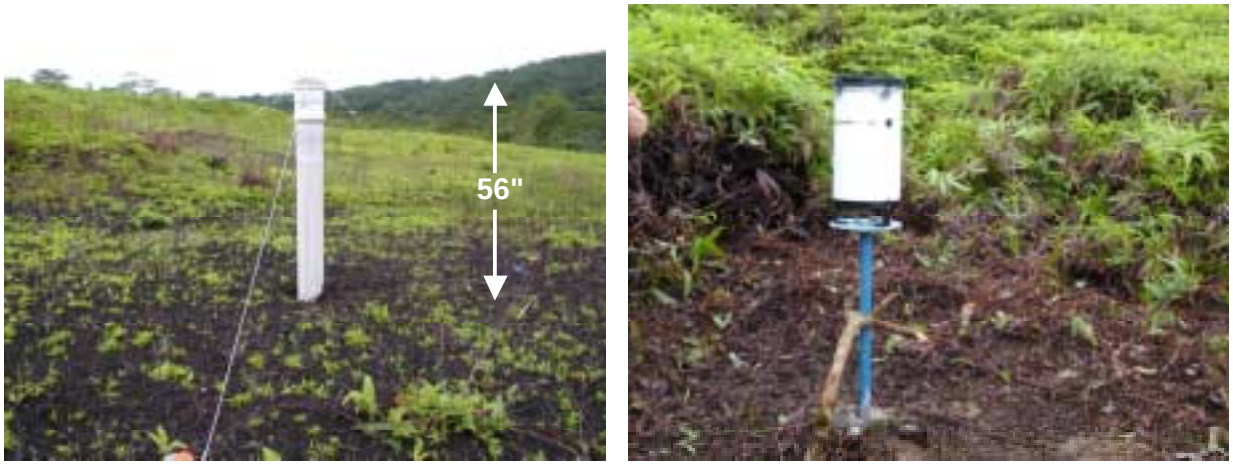


Figure 2. Locations of the raingages, black dots are WERI\CSP network, yellow dots are WSO raingages.



a b

Figure 3. (a) A view of the specially designed 56-inch PVC pipe rain gage assembled in the field at the Mahnd site on Pohnpei Island. (b) A view of the recording tipping bucket rain gage assembled in the field at the Nihpit site on Pohnpei Island.

The top of Nahna Laud was the selected site in the central highlands where two rain gages were set up near one another – one in an open area, and another under the canopy of the rainforest – to assess the impact of fog drip on the water budget of the island. The central highlands of Pohnpei are of sufficient height (~2,000 – 2,600 ft) to often be enshrouded in fog. Deposition of cloud droplets onto leaves, and subsequent coalescence and drip, may enhance the total water budget substantially. This so-called fog-drip is

responsible for a substantial portion of the water budget on portions of the islands of Hawaii. An electronic gage is required at this site to determine the times when it is actually raining at the open-area location. The percent of time the highlands are enshrouded in cloud is itself an unknown.

The WERI project investigators traveled to Pohnpei at least once every three months to perform maintenance on the gages and to collect the data. Personnel at the Pohnpei CSP were contracted to perform readings of the rain gauges and routine maintenance.

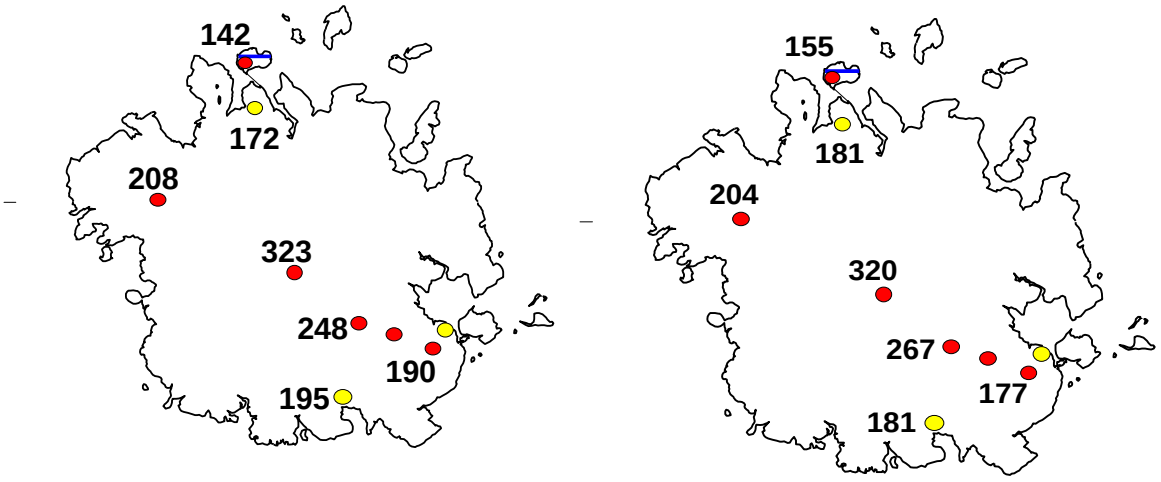
Before field installation, all rain gage equipment was evaluated by setting up a test site at the UOG campus where there already exists a dense network of manual and electronic rain gages: Several 4-inch plastic manual gages, two Qualimetrics tipping bucket rain gages with data logger, a National Weather Service (NWS) HANDAR station that contains a tipping bucket rain gage, and a NWS standard 8-inch brass manual rain gage.

Principal Findings and Significance

SPATIAL DISTRIBUTION OF ANNUAL RAINFALL

According to measurements obtained by the WERI/CSP network, the distribution of rainfall on the island of Pohnpei is strongly affected by the topography, and the annual rainfall totals among recording stations on Pohnpei differed by more than 150 inches. The region in the vicinity of Pohnpei's international airport (Figure 4) received the lowest annual total of 142 inches. The highest measured annual rainfall of 323 inches occurred in the central highlands. The western side of the island is wetter than its eastern side.

The annual rainfall measured on Pohnpei during the first year of operation of the WERI/CSP rain gage network compares favorably with the **PRISM** estimates of mean annual rainfall (Figure 5). Because of this favorable comparison, we feel that the **PRISM** maps are probably the best available estimate of the spatial distribution of the average annual rainfall at this time.



MEASURED JULY 2003 – JULY 2004

PRISM ESTIMATE OF MEAN ANNUAL RAINFALL

Figure 4. Rainfall measured on Pohnpei (left panel) during the first year of operation of the WERI/CSP raingages network, and the mean annual rainfall as estimated by the **PRISM** techniques (right panel).

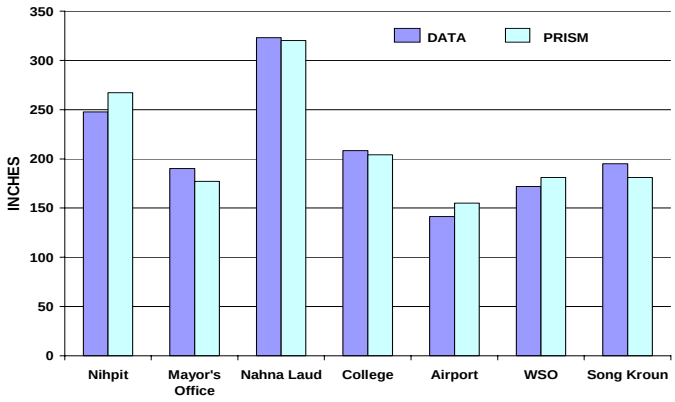


Figure 5. Comparison of measured rainfall to **PRISM** at selected sites on the island of Pohnpei.

HOURLY DISTRIBUTION OF DAILY RAINFALL

Throughout much of the tropical Pacific there is a tendency for more rainfall to occur in the morning hours. Ruprecht and Gray (1976) analyzed 13 years of cloud clusters over the tropical western Pacific and found that over twice as much rain fell on small islands from morning (0700 to 1200L) clusters as from evening (1900 to 2400L) clusters. The heaviest rain fell when it was part of an organized weather system and when diurnal variation was most pronounced. Fu et al. (1990) used satellite infrared images over the tropical Pacific to confirm and refine these findings. Deep convective cloudiness was greatest around 0700L and least around 1900L. The morning rainfall maximum

associated with western Pacific cloud clusters and the early morning instability in the trade winds both originate from the nocturnal radiational cooling of cloud tops. An analysis of the fraction of the rainfall accumulated during each hour of the day shows that there is a tendency for most rainfall to occur between local midnight and sunrise than during other hours, with an absolute minimum in net long-term accumulations contributed during the evening hours (Fig. 6). At most small islands and atolls of Micronesia such as Wake, Majuro and Chuuk, the hourly distribution of rainfall is that which is found to be typical over the open-ocean. This is not the case at Pohnpei, where the island topography distorts the hourly rainfall distribution. The hourly rainfall distribution is more complicated on the larger islands such as Pohnpei, Hawaii, and Guam. On mountainous islands such as Pohnpei and on the Hawaiian Islands, the large diurnal variations in rainfall (not necessarily synchronous with typical open-ocean variations) are driven by mountain- and sea-breeze circulations. Indeed, from personal experience on Pohnpei, during the summer months (May through October) when the winds are light, there is a strong tendency for heavy showers to develop over the mountains by noon. This is confirmed by the WERI/CSP rain gage atop Nahna Laud (Fig. 7). The interior early afternoon showers rain-out and die by evening. At almost all islands, there is an evening minimum of rainfall. ***Pohnpei's extreme amount of rain in the interior appears to derive from day-time convection over the mountains, and not from orographically enhanced rainfall as winds pass over the high terrain (as on many of the Hawaiian Islands).***

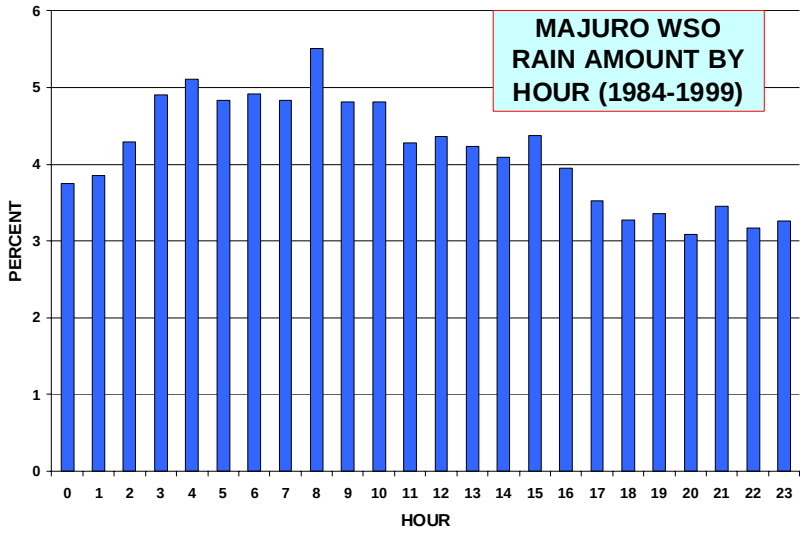


Figure 6. Example of the typical hourly distribution of rainfall in the tropical Pacific Ocean. The example chosen is Majuro Atoll.

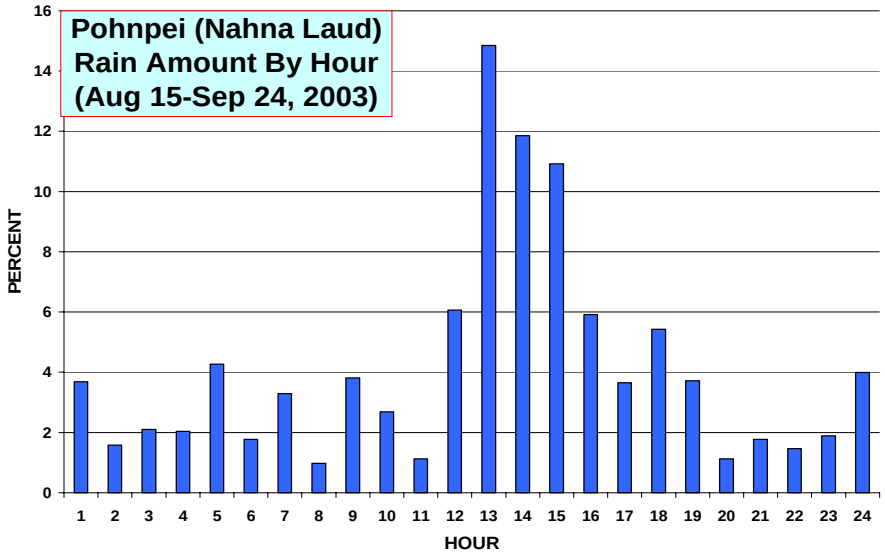


Figure 7. Preliminary data from the Nahna Laud site shows a sharp concentration of rainfall in the four hours of local noon through 4 PM in the afternoon. Convection induced by daily heating in light wind conditions allows for the build-up of thunderstorms nearly every day in Pohnpei's interior.

RETURN PERIODS OF SHORT-TERM HIGH-INTENSITY RAINFALL EVENTS

Since the rainfall records on Pohnpei are so short and/or incomplete, calculations of return periods of extreme rain events may only be crudely estimated. The more complete record of rainfall on Guam allows for a comparison by proxy. Guam, however, experiences direct hits by full-fledged typhoon far more frequently than does Pohnpei. Return-period calculations for Guam's peak annual 24-hour rainfall yield a mixed distribution, with typhoons causing all daily rainfall events in excess of 10 inches. A return-period analysis of the extreme 24-hour rain rates and extreme 1-hour rain rates using Pohnpei's shorter and more incomplete record is shown in Figure 8. Charts of intensity-duration-frequency (IDF) for Pohnpei (Fig. 9 and Table 1) can be derived from extrapolation.

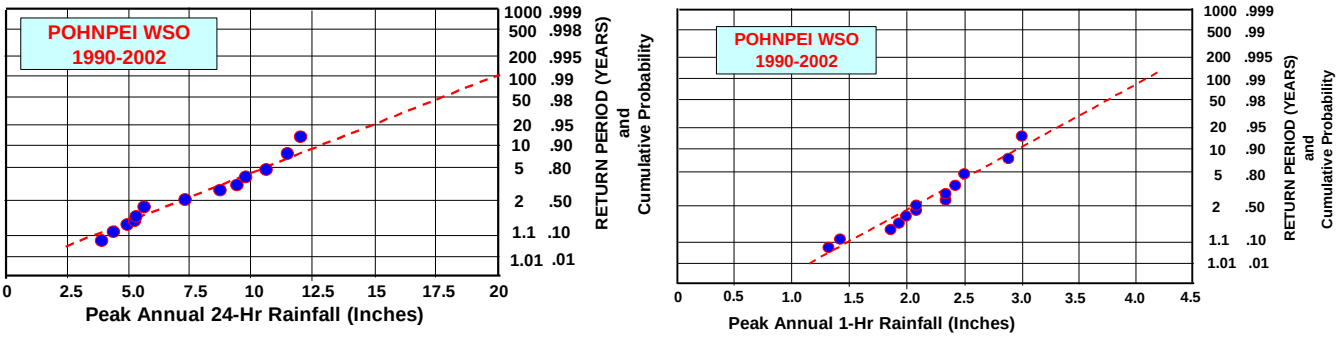


Figure 8. (a) Method-of-moments (ranking method) computations of 24-hour return period extreme rainfall events (left), and 1-hour return periods (right) using Pohnpei WSO data.

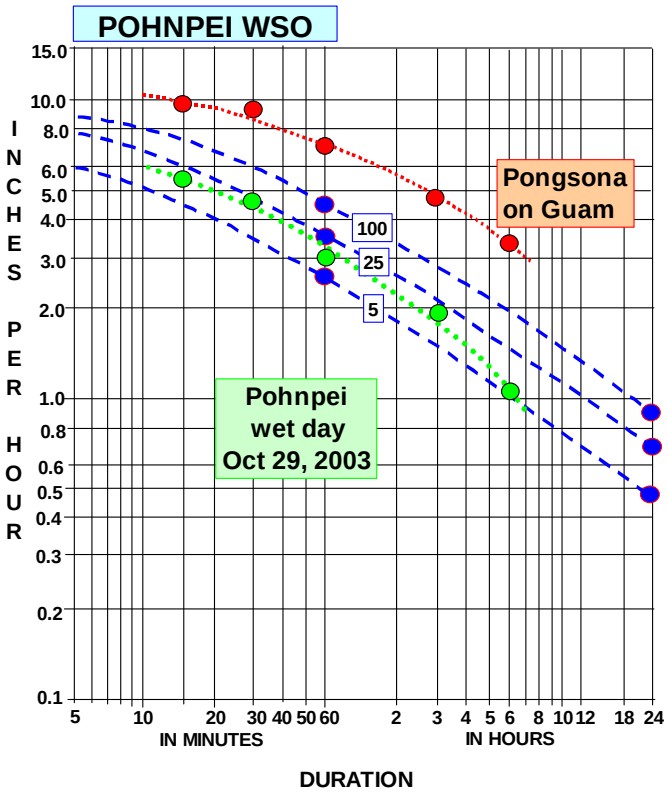


Figure 9. Intensity-Duration-Frequency (IDF) chart of selected return periods at the Pohnpei WSO (blue dots connected by blue dashed lines). For comparison, the IDF values measured during Typhoon Pongsona on Guam (red dots connected by red dotted line) are shown. Also, the highest IDF values measured within the past 9 months by the newly installed WERI/CSP rain gauge network on Pohnpei have been plotted (green dots connected by green dotted line). The Pohnpei event was fairly typical island-wide convection in a tropical disturbance.

TABLE 1. Charts of Pohnpei Rainfall Intensity-Duration-Frequency (IDF). Top panel is total rainfall, and the bottom panel is normalized to rainfall in inches per hour for the indicated return-period and duration.

Return Period	RAINFALL (Inches)								
	15 Minutes	30 Minutes	45 Minutes	60 Minutes (1 Hour)	120 Minutes (2 hrs)	180 Minutes (3 hrs)	360 Minutes (6 Hrs)	720 Minutes (12 Hrs)	1440 Minutes (24 Hrs)
X_{100}	2.13	3.00	3.98	4.60	6.60	8.55	11.70	15.60	20.40
X_{25}	1.98	2.43	3.00	3.70	5.50	6.30	9.60	12.60	16.08
X_5	1.48	1.85	2.12	2.70	3.90	5.10	6.60	7.92	11.76

Return Period	RAINFALL INTENSITY (Inches/Hour)								
	15 Minutes	30 Minutes	45 Minutes	60 Minutes (1 Hour)	120 Minutes (2 hrs)	180 Minutes (3 hrs)	360 Minutes (6 Hrs)	720 Minutes (12 Hrs)	1440 Minutes (24 Hrs)
X_{100}	8.50	6.00	5.30	4.60	3.30	2.85	1.90	1.25	0.85
X_{25}	7.90	4.85	4.00	3.70	2.75	2.10	1.60	1.05	0.67
X_5	5.90	3.70	2.95	2.70	1.90	1.70	1.10	0.67	0.49

SPATIAL DISTRIBUTION OF RAINFALL EROSIVITY FACTOR

The Universal Soil Loss Equation (USLE) and its updated revision the Revised Universal Soil Loss Equation (RUSLE) are the equations used most commonly to predict soil erosion rates and soil losses in the tropical pacific. The five major factors used in USLE and RUSLE to predict soil erosion rates: 1) climate, largely rainfall, 2) soil, its inherent resistance to slaking, dispersion and its water intake and transmission rates, 3) topography, particularly steepness and length of slope, 4) plant cover, and 5) practice factor. Of these, the plant cover, practice and topographic factors are considered management parameters. In contrast, the climate factors and the soil characteristics are normally beyond manipulation by man. In tropical environments, climate or specifically the volume and intensity of rainfall are the most significant cause of high soil erosion rates (Foster et al., 1982). This factor is identified in the USLE and RUSLE as the R or rainfall erosivity factor. The numerical value used for the R-factor in the soil loss equation must quantify the raindrop impact effect and must also provide relative information on the amount and rate of runoff likely to be associated with the rainfall regimes (Lal, 1994). The storm erosion index or Storm EI_{30}, derived by Wischmeier appears to meet these requirements better than any other of the many rainfall parameters. The relationship is expressed by the equation (Lal, 1994),

$$Storm\ EI_{30} = \left\{\sum 1099 \times \left[1 - 0.72 \times Exp\left(-1.27 \times I_r\right)\right] \times R_r\right\} \times I_{30}$$

Where I_r is the rainfall intensity (inch/hour) for a 30-minutes interval during the storm, R_r is the rainfall amount (inch) during this same time interval. These values are input into the equation shown above for each time interval of the storm. The sum of the computed values is called the storm energy or E value. The E value is multiplied by the $I_{30,}$ which is the maximum 30-minute intensity during the storm. The product is called the Storm $EI_{30.}$ It is expressed in hundreds of foot-ton inches per acre-hour (Lal, 1994). The sum of the storm EI_{30} values for a given period is a numerical measure of the erosive potential of the rainfall within the period. The average annual total of the storm EI_{30} values in a particular locality is the rainfall erosion index (R-factor) for that locality (Lal, 1994). To calculate the Storm Erosivity EI_{30}, requires having 30-minute duration rainfall intensity. The annual storm erosion index (R-factor) was calculated for each raingage site. In order to determine the R-factors at un-gauged sites, a correlation of R-factors versus average rainfall was determined as shown in Figure 10.

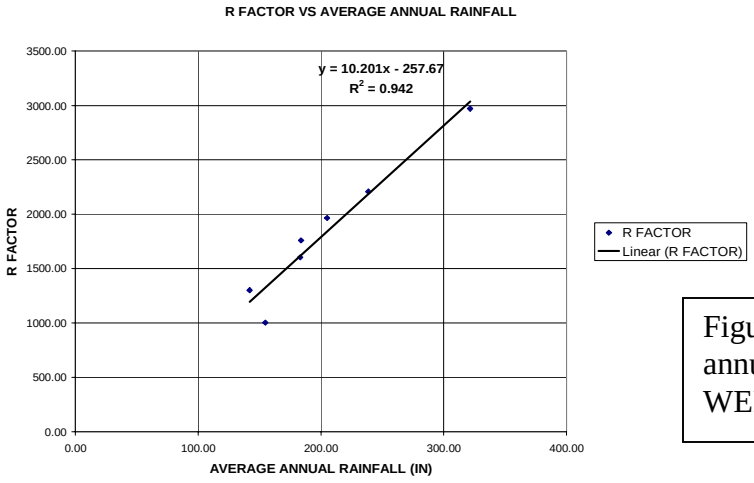


Figure 10. Linear trend of average annual rainfall and R-factor from WERI/CSP raingages.

The next step was to develop a GIS implementation of the average annual rainfall versus R-factor correlation. This required having a spatial distribution of average rainfall as a starting point. The **PRISM** data (Figure 2) was used for the annual rainfall distribution. The **PRISM** map was scanned and the digital files were geo-referenced to the Pohnpei's base map. Rainfall contours were developed from the scanned image. Next a geo-referenced rainfall Triangulated Irregular Networks (TIN) and appropriate average rainfall grid file and rainfall contours were developed as shown in Fig. 11.
The spatial distribution of R-factor was developed by applying the R-factor versus average annual rainfall correlation to each of the cells in the average annual rainfall map. R-value contours were next developed from the girded values and are shown in Fig. 12.
In order to develop maps of high erosion potential or land slides we developed a modified version of the USLE using only the R factor and slope factor components. The modified equation does not predict the amount of sediment production, but it indicated the areas where high potential for erosion exist. It does not account for plant coverage, management practices, and soil types. Using a spatially comparable digital elevation model (DEM) we developed a girded slope distribution map for the entire island of Pohnpei.
We applied the following relationship between the slope and length as expressed by (V. Novotny and Chesters 1981) to each of the girded slope values to obtain a new grid of the spatial distribution of the USLE slope factor.

$$LS = L^{1/2}\left(0.0138 + 0.00974 \times S + 0.00138 \times S^2\right)$$

Where L is the length in meters from the point of the origin overland flow (length of each cell), S is the average slope (%) over the runoff length. The final step was to spatially multiply the USLE slope factor by the previously obtained girded map of the R-factor. The resulting erosions potential map is shown in Fig. 13.

Figure 11. Average annual rainfall distribution map for Pohnpei Island.

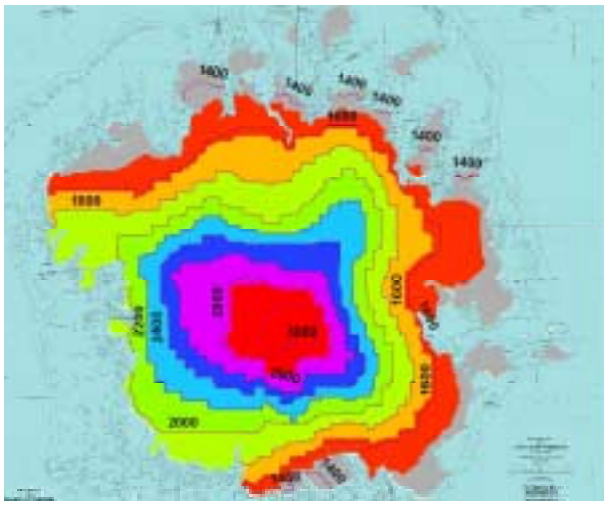


Figure 12. R-factor distribution map for Pohnpei Island.

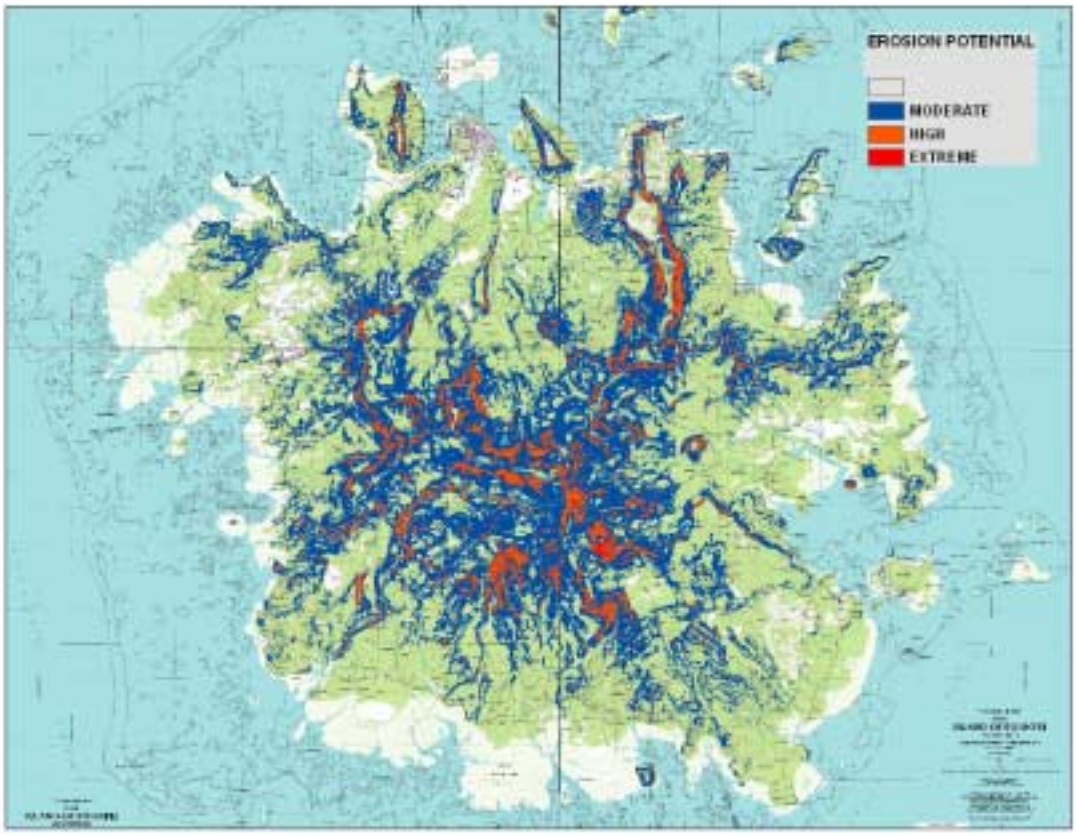


Figure 13. Areas with high erosion potential, Pohnpei Island.

Summary of Findings

The Preliminary results of the measured rainfall for the island of Pohnpei indicated that: (1) the distribution of rainfall on Pohnpei is affected by the topography, and the measured annual rainfall totals among recording stations on Pohnpei differ by over 150 inches; (2) Pohnpei's international airport received the lowest annual total of 142 inches. The highest measured annual total of 323 inches occurred on top of Nahna Laud in the highland rainforest of Pohnpei's interior; and (3) earlier charts of Pohnpei's mean annual rainfall using **PRISM** were comparable to the values measured at the WERI/CSP raingages.

The resulting erosion potential maps are a good first order identification of areas that bear close monitoring for high erosion potential and possible landslide activities. As more long term data is available, improvements on the existing annual rainfall distribution and the relationship between annual rainfall and calculated R-factor will be made. These improvements can be easily implemented within the existing GIS structure developed for this project. The preliminary maps that developed by this project will allow governmental managers to warn private citizens of possible high risk development areas and to developed management strategy to minimize the impact of soil erosion and land slide areas and watershed protection plan.

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. Groundwater Development and Utilization for Emergency Drinking Water Supply on Fais, Yap State, FSM

Basic Information

Title:	. Groundwater Development and Utilization for Emergency Drinking Water Supply on Fais, Yap State, FSM
Project Number:	2004GU37B
Start Date:	3/1/2004
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	n/a
Research Category:	Social Sciences
Focus Category:	Groundwater, Water Use, Drought
Descriptors:	
Principal Investigators:	john jenson, Donald Rubinstein

Publication

1. MacCracken, R.S. 2005, Creating a GIS of Fais Island, College of Liberal Arts & Social Sciences Annual Conference, University of Guam, Mangilao, Guam.

Project Title: Groundwater development and utilization for emergency drinking water, Fais Island, Yap State, FSM

Problem and Research Objectives

The objective of this project is assess of the physical resources and sociocultural factors that must be considered to ensure a reliable source of drinking water to meet emergency needs of the residents of the small (2.6 km^2), remote island of Fais, Yap State, Federated States of Micronesia. Fais's permanent population of about 320 people currently relies almost exclusively on rainwater catchments to meet its potable water needs. However, on average once a decade a major storm destroys or damages existing catchments, most recently in November 2003. In light of the small size and subsistence economy of Fais and the prevailing traditional social organization and land tenure, technical recommendations for development and protection of water resources must be compatible with the island's social traditions, cultural values, and indigenous authority. The central objectives of this study are therefore inventorying and mapping the key karst features that relate to groundwater availability and making an inventory of patterns of usage, storage, and sharing of water from existing rainwater catchments and other sources. These data will be used to developing recommendations for an appropriately balanced approach to management of rain catchment and groundwater resources to meet emergency needs.

Methodology

The study employed the classical methods of geological field investigation, including exploration and mapping of selected geological features. Because no previous geological study has been made and no maps or orthophotographs of Fais have been published, we are building our own base maps for this projects from a set of aerial photos that Dr. Rubinstein has in his collection from previous work on the island. In addition to mapping caves and searching for coastal seeps and springs, we are also mapping major sinkholes, fractures and features that may influence the capture and transport of water in the aquifer. Sociological methods of investigation build upon Dr. Rubinstein's 35 years of association with residents of Fais, assuring excellent access and trust from island leaders. Specific procedures involve participant-observation and open-ended interviewing following semi-structured question protocols, using an opportunity sample of island adults and social leaders.

Principal Findings and Significance

This project has been continued into a second year. Observations from the first year's fieldwork showed that the residents have a strong preference for rain catchment water sources because of the convenience of using and storing it at the household or village catchment source rather than having to carry it from a well. The primary limitation on emergency supply appears to be lack of sufficient storage capacity for rainwater. We are therefore returning to obtain complete information on storage capacity versus actual household requirements under emergency conditions, to include availability of other alternative sources, including coconuts and well water. The current work will also complete the inventory of karst features, to include mapping caves that were not accessible because of weather and surf conditions during the first year.

Qualitative examination of groundwater from Yap and some of its neighboring islands

Basic Information

Title:	Qualitative examination of groundwater from Yap and some of its neighboring islands
Project Number:	2004GU50B
Start Date:	3/1/2004
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	n/a
Research Category:	Water Quality
Focus Category:	Water Quality, Water Supply, Water Use
Descriptors:	
Principal Investigators:	Vazhaveli Murukesan, Tim Scheidt, Leonard Yinug

Publication

Project Title
Qualitative examination of groundwater from Yap and some of its neighboring islands

Problem and Research Objectives
Yap receives over 100 inches of rain annually and much of the rainwater seep into the ground. The groundwater provides drinking water for about half of the Yap population. Yet, no scientific data is currently available on the quality of water sources. No qualitative examination of groundwater samples has ever conducted owing to the economic and other infrastructure constraints of Yap State Public Service Corporation (YSPSC), the establishment responsible for water treatment and distribution. Consequently, groundwater contamination caused by pathogen or chemicals remains undetected. Current treatment facility at Colonia (Central Water System) is able to supply nearly 500,000 gallons of treated water daily for a population of about 3500. Declining Compact Grants from United States in recent years and lack of necessary infrastructure facilities and trained work force makes it difficult for YSPSC or Yap State Environmental Protection Agency (EPA) to conduct periodic monitoring of water sources. The limited number of water reservoirs in the State that exist close to the human habitation makes it a very likely source of contamination and thereby water borne diseases.

On Yap, potential sources of groundwater pollution include human and animal feces, leachate from garbage dump, abandoned motor vehicles and corroded World War relic armaments lying all around the island. According to Yap State Census Report, 76 percent of the population does not have proper toilet facilities whereas in its neighboring islands 96 percent of the population relies on 'other means' of waste disposal. Recent tests on groundwater from Southern Water System showed elevated levels of nitrate. Similarly there are reports of polluted groundwater lens in Ulithi. Here, island inhabitants use open toilets resulting that the available groundwater lens is heavily contaminated with fecal coliform bacteria. These information calls for immediate intervention and thorough examination of the groundwater sources to come up with necessary mitigation strategies.

Therefore, our objectives in this study are to (i) conduct a quality assessment of groundwater samples collected from different localities of Yap State including three of its main inhabited neighboring islands (ii) establish baseline information on the present conditions of the vital resource, and (iii) train YSPSC and Yap State EPA personnel in carrying out various water qualities testing procedures.

Methodology
Set of portable equipments coupled with commercially available test kits and laboratory exercise are mainly used to analyze water samples for microbiological and chemical qualities. Colilert and Enterolert reagents from Idexx are being used for the identification of coliforms, *E.coli* and Enterococci. An advanced portable laboratory test kit from Hac (CEL/890 Advanced Portable Laboratory) is being used to carry out basic tests such turbidity, hardness, pH, alkalinity, nitrate, sulfate, phosphate, potassium etc. Service of Intertek Laboratory (Manila) is being sought to analyze inorganic constituents and disinfection by- products.

A total of five sampling sites (from Yap proper and neighboring islands, Falalop-Ulithi and Woleai) are selected based on various source waters (groundwater wells, surface waters, rain catchments i.e.), on the recognized utilities providing water to consumers (Yap State Public Service Corporation, Southern Yap Water System, Gagi-Tomil Water System, and waters that have been treated with chemicals (YSPSC).

Principal Findings and Significance

As part of the capacity building component of the project, two staffs from Yap State Public Service Corporation and Yap State Environmental Protection Agency received one week training at WERI on various testing procedures.

Tim Scheidt, has been carrying out series of workshops on water sampling, testing, reporting and documentation. Employees of YSPSC Water Division, Yap State EPA, Yap State Health Services, Gagil-Tomil Water System (GTWS), Southern Yap Water System (SYWS) is attending this seven week long lecture cum hands on. During first week of this education series, lecture and discussion on sampling coliform bacteria conducted. Each participant was provided with a copy of the skill package written for this activity. In addition, each received a copy of the exercise "pre job planning" to assist in preparation of field activity. A brief overview of YSPSC Water Distribution System, including all source waters, was presented, and the class used the map of the system to determine the appropriate sampling sites. The class then discussed proper sample collection techniques, and proper documentation procedures, before collection and analysis at Yap State EPA laboratory.

Three distribution system samples were positive for Coliform, but not for *E.coli*. Repeat samples were taken on the following week to continue testing. Further, the group met at GTWS Office and reviewed the map of the GTWS system, identified sampling sites. Here, a total 29 samples were collected from source to various distribution points. Twenty eight out of 29 samples tested positive for coliform bacteria. A majority of those samples were positive for *E.coli*, including the source water (well#2), and the storage tank. One sample was negative for bacteria. The class then discussed the meaning of these results as they applied to the public health. The 'Public Notification' section of the skill package was reviewed, including the representative notice form provided. The group then devised a plan of action to correct the problem. It was determined that the GTWS Operator would inform the board of directors immediately of these findings, and to present the suggested plan of action to address the matter. A brief summary of the proposed plan taken is as follows:

1. Inform the general public according to the procedures outlined in the skill package.
2. Shut down #2 well. Run the other three wells a bit longer each day to compensate
3. Disinfect the well according to proper well disinfection procedures.
4. Drain, clean, inspect and disinfect the storage tank.
5. Flush the system with chlorinated water.
6. Resample the system.

Yap State EPA has assigned to assist GTWS with resampling and further discussion with the Board of Directors regarding the situation. The Board of Directors of the GTWS has responded favorably to the group's recommendations, and is directing the operations staff to commence with the recommended activities. The Yap State has also been instrumental in this effort by providing the additional sampling and analysis. The system has been flushed, and the storage tank is scheduled for draining, cleaning, inspection, and repair.

On a following week course, the group discussed the methods of reporting principal findings to the public and the specifics associated with that. The group reviewed example of a "Consumer Confidence Report" from a typical water service provider in the US, and considered creating one for each of the public water supplies on Yap.

Similar exercise on sampling, analysis and discussion is currently underway for other sampling sites including neighboring islands.

A water quality study of river and ground water resources in Kosrae, FSM.

Basic Information

Title:	A water quality study of river and ground water resources in Kosrae, FSM.
Project Number:	2004GU51B
Start Date:	3/1/2004
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	n/a
Research Category:	Water Quality
Focus Category:	Water Quality, Water Supply, Water Use
Descriptors:	
Principal Investigators:	Puthiyaparambil Josekutty

Publication

Project Title
Qualitative examination of groundwater from Yap and some of its neighboring islands

Problem and Research Objectives
Annual rain fall in Kosrae, FSM has declined from over 350 inches, 20 years ago to less than 200 inches in recent years. The population of the FSM is growing at 3% per annum. Population pressure is affecting the natural forests and watershed areas. As a result of the climatic change and human impact on the forests, some streams that traversed Kosrae have disappeared and others have limited water flow. The majority of the people of Kosrae still rely on surface water for their domestic requirements. Although, compact funds and other assistances from the US Government have established water catchments and safe toilets with septic tanks, water quality assessment and assurance programs are not yet in place in Kosrae. Only a part of one out of the four municipalities in Kosrae has an established ground water supply. However, the ground water quality has never been determined. A previous study has shown high levels of mercury from some water samples in Kosrae. Trained manpower and other resources like equipment and supplies are in short supply in Kosrae limiting the water quality analysis and assurance plans. Apparently very little qualitative data is currently available to formulate necessary treatments required.

Reduced rainfall and low rate of water flow may be making concentration of dissolved chemicals in the river water high. Abundance of rodents and wild pigs in the forests of Kosrae is a sure source of contaminating nutrients and fecal bacteria in to the river water. Waste from piggeries and other agriculture activities (chemical fertilization and pesticide application) are other known sources of water pollution.

The objectives of this study were to (i) conduct a quality assessment of water sources collected from different localities of Kosrae State (ii) establish baseline information on the present conditions of the vital resource, and (iii) train Kosrae State EPA personnel in carrying out various water qualities testing procedures.

Methodology
Samples from household systems supplied by municipal supplies or roof catchment, major rivers and dams in four municipalities in Kosrae were subjected to testing for total coliform, E. coli and Enterococci. This testing was done using the Idexx Colilert™ system for coliform and E. coli. And Idexx Enterolert™ for Enterococci. Results were reported in most probable number (mpn) units. The actual water analyses were performed at the Agricultural Experiment Station Laboratory (MPPRC) in Kosrae. A total of 265 samples were analyzed with results as shown in figure 1.

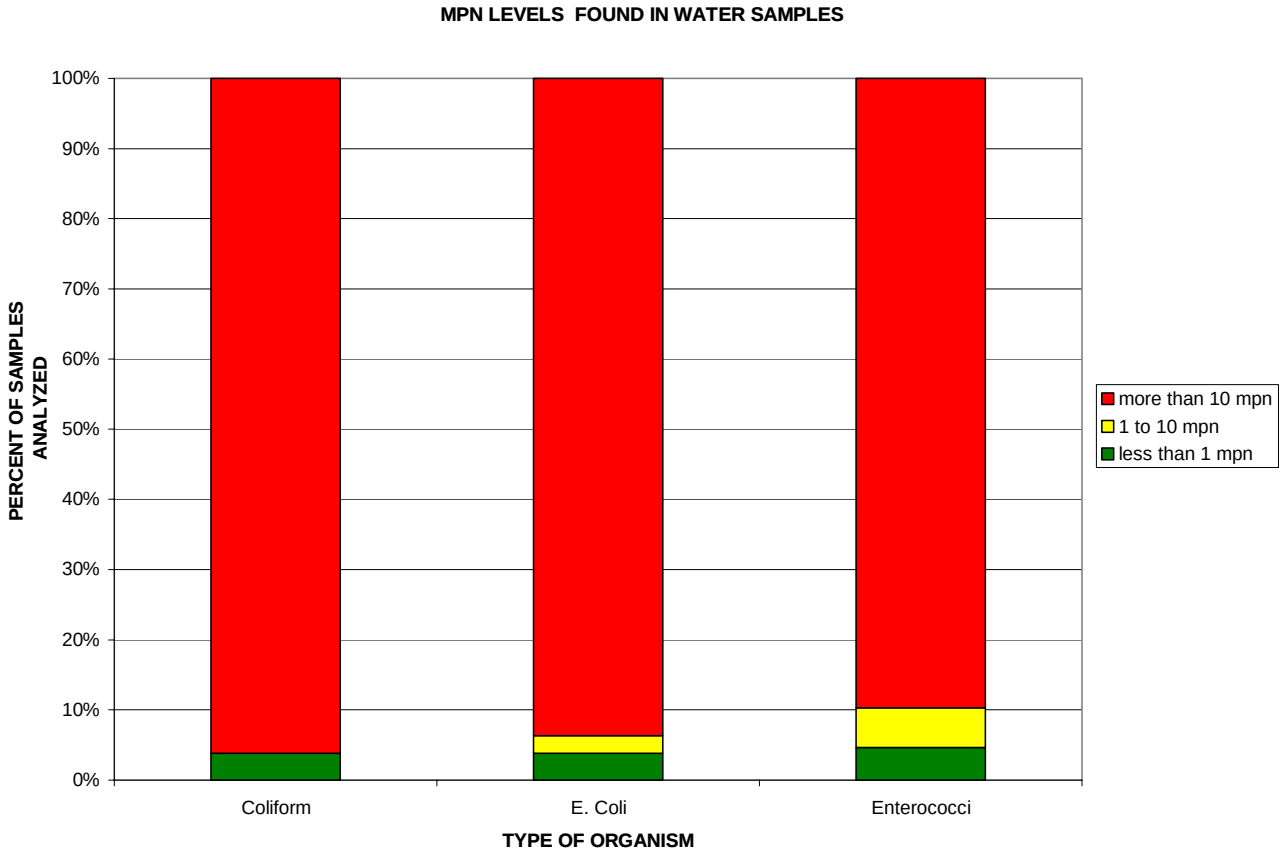

Figure 1. Levels of Coliforms and Enterococci found in the samples tested

Principal Findings and Significance

The relative safety of a water supply can be classified based on bacterial contamination level. A high quality system would have bacterial levels less than 1 mpn, a, medium quality system would have levels in the range of 1 to 10 mpn, and a low quality system would have levels greater than 10 mpn. The testing so far has shown that 96% of the water supplies tested showed total coliform levels greater than 10 mpn (lowest quality), with none of the tests falling in the 1 to 10 mpn (medium quality) range. Only 4 % fell in the less than 1 mpn (high quality). range. The E. coli testing so far has shown that 94% of the water supplies tested showed total coliform levels greater than 10 mpn (lowest quality), with 2% of the tests falling in the 1 to 10 mpn (medium quality) range. Only 4 % fell in the less than 1 mpn (high quality). range. The enterococci testing so far has shown that 90% of the water supplies tested showed total enterococci levels greater than 10 mpn (lowest quality), with 5% of the tests falling in the 1 to 10 mpn (medium quality) range. Only 5 % fell in the less than 1 mpn (high quality). Range. These results

indicate that a vast majority of the drinking water supplies may be unsafe for human consumption under untreated conditions. Since none of the water supplies in Kosrae are treated one can say that the vast majority of water presently being consumed by local residents may be unsafe for human consumption. The results so far indicate that the government/utility needs to implement a disinfection program (chlorination) for distributed water supplies. Lacking that, and in the case of individually collected sources, the people need to institute personal disinfection programs such as chlorination with Clorox™ or boiling

This study yielded important water quality data for different regions of the island. The results will be useful for Kosrae State Administration/ Department of Health formulate appropriate treatment systems required. Since little water quality data exists for in Kosrae, this project was a major step forward in providing a database for future comparative purposes. The data will be useful for people and policy makers alike to come up with better solutions for the supply of potable water to the public. This will be a useful step to reduce the physical hardship of the people suffering from water borne diseases. It will also reduce the financial burden of the local government in providing health care both on and off island to those suffering from water borne diseases. The outcome and further action by the concerned department will help to provide necessary advise to tourists on the water quality in Kosrae (mostly Americans) visiting the island every year.

Information Transfer Program

Information Transfer

Basic Information

Title:	Information Transfer
Project Number:	2004GU44B
Start Date:	3/1/2004
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	n/a
Research Category:	Not Applicable
Focus Category:	Education, Management and Planning, None
Descriptors:	water resources, information transfer
Principal Investigators:	Leroy F. Heitz

Publication

WERI's mission involves a large information transfer-dissemination component. Key elements include written forms such as brochures and pamphlets, a web site, technical reports, journal articles, newspaper columns, and book chapters. The audience for the results of USGS sponsored research is widely varied geographically and by education level. It is important that WERI make this information available in a very widely distributed form.

This project funded the design, layout and printing of five technical completion reports resulting from USGS funded research projects. One hundred (100) hard copies of each report were printed and the reports were prepared for publication on WERI's Web page and entered into WERI's on-line searchable Technical Reports Data Base.

WERI's Web page, shown below, is located at http://weriguam.org/home/index.htm, and is the Institute's focus for Information Transfer/ Dissemination.

WERI Web Page

It is very important that WERI's Web page be updated and optimized on a regular basis. To provide this a professional web maintenance firm was contracted to provide maintenance to the WERI Web page on a regular basis. This year the firm continued work on digitizing and entering all newly completed WERI technical completion report into the database search engine for accessing the technical completion reports on line.

Because of Guam's remote location it is difficult and quite costly for researchers to present their findings at technical conferences and symposiums. This project funded a portion of off-Island travel expenses for PI's and graduate students presenting refereed professional papers summarizing all or a portion of current or past 104-B research projects.

Information Management

Basic Information

Title:	Information Management
Project Number:	2004GU45B
Start Date:	3/1/2004
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	n/a
Research Category:	Not Applicable
Focus Category:	Climatological Processes, Hydrology, Management and Planning
Descriptors:	water resources, information management
Principal Investigators:	Leroy F. Heitz, Leroy F. Heitz

Publication

INFORMATION MANAGEMENT

WERI's mission involves maintaining and providing water resources related data to researchers, water resources managers, educators and the general population of the islands of the Western Pacific. This project was used to provide funding to maintain subscriptions to a wide variety of data sources dealing with meteorology, climatology and hydrologic data. These resources are maintained at WERI and made available to researchers, water managers, educators and the general public throughout the region. Communication and information exchange between experts in the area of water resources is vital to the improvements in the wise use of this resource.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	5	0	0	0	5
Masters	5	0	0	0	5
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	10	0	0	0	10

Notable Awards and Achievements

The research project, Refining the R-factor and Developing Rainfall Distribution Maps for the Island of Pohnpei was the first of its kind to develop comprehensive rainfall distribution maps and maps identifying the location of potential landslide areas for the island of Pohnpei. Before this project, there were only two continuously recording rain gages on Pohnpei, one at the weather station and one at the hospital. These gages were located in close proximity of each other on the western side of the island with very limited data being available.

Researchers on this project installed a transect of manual and electronic rain gages extending from the coast to the highlands of the island. The personnel from the Conservation Society of Pohnpei (CSP) were trained to read and maintain all of the raingages. Areas of high potential for landslides were identified. These maps will help the local government prevent future disasters such as the slope failure at Sokehs in 1997 that killed 19 people.

Publications from Prior Projects

1. 1999GU11B ("Island karst hydrology of Guam and its incorporation into a general carbonate island karst model") - Articles in Refereed Scientific Journals - Taboroi, D., J.W. Jenson and J.E. Mylroie. 2005. In press. Karst features of Guam. Micronesica. University of Guam Press, University of Guam, Mangilao, Guam.
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5. 2002GU5B ("Inventory of Karst Features Relating to Past and Present Groundwater Flow on Tinian, CNMI, in Terms of the Carbonate Island Karst Model") - Articles in Refereed Scientific Journals - Stafford, K.W., J.E. Mylroie, D. Taboroi and J.W. Jenson. Accepted. Eogenetic karst development on a small, tectonically active, carbonate island: Aguijan, CNMI. Cave and Karst Science.
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9. 2002GU5B ("Inventory of Karst Features Relating to Past and Present Groundwater Flow on Tinian, CNMI, in Terms of the Carbonate Island Karst Model") - Dissertations - Stafford, K.W. 2003. Structural Controls on Megaporosity in Eogenetic Carbonate Rocks: Tinian, CNMI. MS Dissertation. Mississippi State University, Mississippi. 340 p
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