Guam Water Resources Research Center

Annual Technical Report

FY 2000

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 25th 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 2001 WERI faculty will be involved as Principal Investigators on eighteen research and training projects. Funding sources include US Geological Survey, US Weather Service, NASA, local agencies such as Guam Environmental Protection Agency and Guam Bureau of Planning, and direct appropriations from the Guam legislature.

Currently WERI has a fulltime director who is also a UOG faculty member, five regular research faculty, two adjunct research faculty, a water analysis laboratory manager and technician, two office staff, as well as six graduate research students who are completing their MS degree in the Environmental Sciences program During the 1999-2000 interval, WERI faculty and staff taught 12 graduate courses and five undergraduate courses in the Environmental Science MS program and the undergraduate science and pre-engineering curriculums respectively. At the same time WERI faculty were first or second authors on twenty-five refereed journal articles or conference proceedings, fourteen technical reports, and twenty-two professional presentations. Currently WERI faculty members serve as committee members on, or chairs of about 30 MS research theses in the Environmental Sciences and Biology graduate programs.

NON USGS Funded Projects

NASA Ground Based Radar Rainfall Estimation Project: Guam TRMM Validation

NATIONAL WEATHER SERVICE Pacific ENSO Applications Center

GUAM WATERSHED PROJECTS GUAM Environmental Protection Agency

The Spatial Variability of contaminants from Septic Tanks in Northern Guam

Potential Impact of Current Landscaping Practices in the Tumon Basin on the Nutrient Status of Tumon Bay

Restoring the Northern Guam Watershed by identifying Groundwater Nitrate-Nitrogen Anomalies and their Sources

Contaminant and Restoration Assessment of Agana Swamp and Adjacent Waters

GUAM BUREAU OF PLANNING

Baseline Environmental Study of the New Municipal Landfill Site at the Big Guatali Watershed Southern Guam

Contaminant and Restoration Assessment of Agana Swamp and Adjacent Waters

DIRECT LOCAL FUNDING

Guam Hydrologic Survey

Water Resources Monitoring Program

Research Program

Basic Information

Title:	Nutrient Levels in Tumon Bay
Project Number:	
Start Date:	3/1/2000
End Date:	2/28/2001
Research Category:	Biological Sciences
Focus Category:	Non Point Pollution, Surface Water, Wetlands
Descriptors:	wetlands
Lead Institute:	University of Guam
Principle Investigators:	Gary Denton, Harold Wood, John W. Jenson

Publication

1. Denton, Gary, & Leroy Heitz, 2001, Potential Impact of Landscaping Activities on the Nutrient Status of Tumon Bay, Guam, in The Integration of Natural and Social Sciences in the New Pacific Millennium, Proceedings of the 10th Pacific Science Inter-Congress, University of Guam Graduate School & Research, and Pacific Science Association, Mangilao, Guam. p. 97.

PROJECT SYNOPSIS REPORT

Project Title: Nutrient Levels in Freshwater Seeps, Springs and Subterranean Flows of Tumon Bay and their Potential Impact on the Growth and Proliferation of the Green Alga *Enteromorpha clathrata*

Problem and Research Objectives:

The lower Tumon basin, on the western shore of northern Guam, is the tourist Mecca of the island. Some 25 hotels are located in this area together with a vast array of shopping outlets, restaurants, and recreational facilities. The entire commercial complex borders Tumon Bay, a premier location and major attraction to overseas visitors. In fact, Tumon Bay and its associated developments represent the lifeblood of the tourist industry on Guam. Maintaining the natural beauty of Tumon Bay is, therefore, tantamount to maintaining a healthy economy and has become a top priority in recent years. For this reason, the presence of the highly visible and aesthetically unappealing stands of green alga along the shoreline of Tumon Bay is of major concern. The alga, *Enteromorpha clathrata,* is not a recent invader. On the contrary, it occurs naturally on Guam although it's increased presence and abundance in Tumon Bay appears to have paralleled the commercial developments that have occurred in the area over the last 30 years.

Several major springs and numerous small seeps flow into Tumon Bay directly from the northern lens, the islands sole source aquifer. These groundwaters are naturally enriched with nitrate – the nutrient traditionally believed to be responsible for the algal problem in Tumon Bay (Fitzgerald 1976). Unfortunately, the nitrate enrichment theory does not explain why *E. clathrata* has become more abundant in recent years. An alternative explanation is that phosphorus is the nutrient of primary concern. Under natural conditions phosphorus levels in Guam's groundwater are probably low enough to limit algal growth in the Bay for much of the year. However, with the advent of bayside hotels and concomitant increases in landscaping activities, phosphorus enrichment associated with excessive fertilizer applications is suspected to have occurred in this area. With this in mind, a study was carried out to determine whether levels of phosphorus (and other nutrients) in freshwater seeps and springs entering Tumon Bay were significantly different from levels encountered in the aquifer. The objectives of the study were:

1. To determine the distribution and abundance of primary nutrients in freshwater seeps, springs, and subterranean flows within the intertidal region of Tumon Bay.

2. To delineate nutrient concentration gradients along the beach and identify areas of temporary and chronic enrichment if they exist.

3. To identify those nutrients that are present in excess and those that are limiting, relative to the needs of *E. clathratus* for optimum growth and photosynthesis.

4. To initiate the provision of a sound database with which future levels may be compared and evaluated.

5. To identify permanent monitoring sites for future nutrient surveillance work.

Methodology

The freshwater seeps and springs entering Tumon Bay were sampled monthly during the extreme daytime low-tides that occurred in June, July and August of 2000. The samples were carefully removed from the intertidal zone using a pre-cleaned 50-ml polyethylene syringe. Each sample was immediately passed through a 0.45 µm in-line filter into a 50 ml polypropylene, screw-cap tube, labeled, and rapidly cooled on icepacks in an insulated container. Samples were taken at 50-m intervals along the entire beach, with 70 samples collected in duplicate on each occasion.

In the laboratory, samples were stored overnight at 4^{o}C and analyzed for nutrients the following day using a four-channel, automated, flow injection ion analyzer (Lachet). Relatively unstable, reactive phosphorus (orthophosphate-P), nitrite nitrogen (NO_2-N), ammonium (NH_4^+) and silica (Si) were analyzed first followed by nitrate nitrogen (NO_3^+) and chlorides using the manufactures recommended QuickChem® methods. Total N and P were determined later following persulfate oxidation. Iron and manganese were determined on acidified subsamples (~pH 1) by conventional flame atomic absorption spectrophotometry using a deuterium lamp to correct for non-atomic absorption.

Representative aquifer samples were taken from 97 Guam Waterworks Authority (GWA) drinking water production wells in the northern half of the island between June 2000 and April 2001. Samples were collected from the well head directly into 50-ml polypropylene, screw-cap tubes. Other than the fact that they were unfiltered, they were treated in precisely the same way as described above for spring and seep samples.

Baseline levels of reactive P, nitrate-N and ammonium were also established for Tumon Bay waters between February and May 2001. In this instance, daily seawater samples were collected directly in front of nine bayside hotels and one beach bar between 6-9 am each morning. At each site, one sample was collected at the top of the surf zone and the other offshore in waist deep water. All samples were filtered and treated in the same manner as described earlier.

Principal Findings and Significance

A summary of the nutrient data for all water types analyzed over the course of the study period is given in Table 1 below. All data are expressed as µg/l (parts per billion).

TABLE 1: NUTRIENT STATUS OF TUMON BAY AND GWA PRODUCTION WELLS

Water Type	Ortho-P	Nitrate-N	Nitrite-N	NH_4^+	Si
TUMON BAY					
Major Springs	13.3-25.6	1,534-3,242	<1.00-9.00	<1.00-11.8	752-2,464
Seeps	1.20-32.0	0.90-7,944	<1.00-414	<1.00-387	417-3,781
Seawater (surf zone)	0.18-10.3	18.4-1,873	nd	<2.49-216	nd
Seawater (offshore)	0.10-5.99	9.90-397	nd	<2.49-29.7	nd
GWA WELLS	6.70-38.5	793-5,779	all <1.00	<1.00-30.7	561-15,023

Orthophosphate-P accounted for virtually all total-P estimates (>95%) in all samples. Likewise, nitrate-N accounted for almost all total-N estimates. Iron and manganese were consistently below analytical detection limits of 24 µg/l and 13 µg/l respectively.

The nutrient requirements of *E. clathrata* are not well known. One local study showed that optimum growth requirements for this species were met when nitrate-N and orthophosphate-P concentrations were held at 2,100 µg/l and 1,178 µg/l respectively (Fitzgerald 1976). If such is the case, there is clearly sufficient nitrogen in local spring and seep water to meet these demands whereas levels of available P are considerably lower and more limiting.

An analysis of the seawater data for reactive P and nitrate-N indicates a significant negative correlation with salinity for both nutrients (Fig.1). The relationship is especially strong in the surf zone where mixing predominates. Of particular interest is the fact that nitrate-N concentrations appear to act conservatively, affected only by the physical process of dilution with seawater. On the other hand, reactive P concentrations entering the bay respond to increasing salinity in a non-conservative fashion, presumably as a result of additional chemical and biological processes.

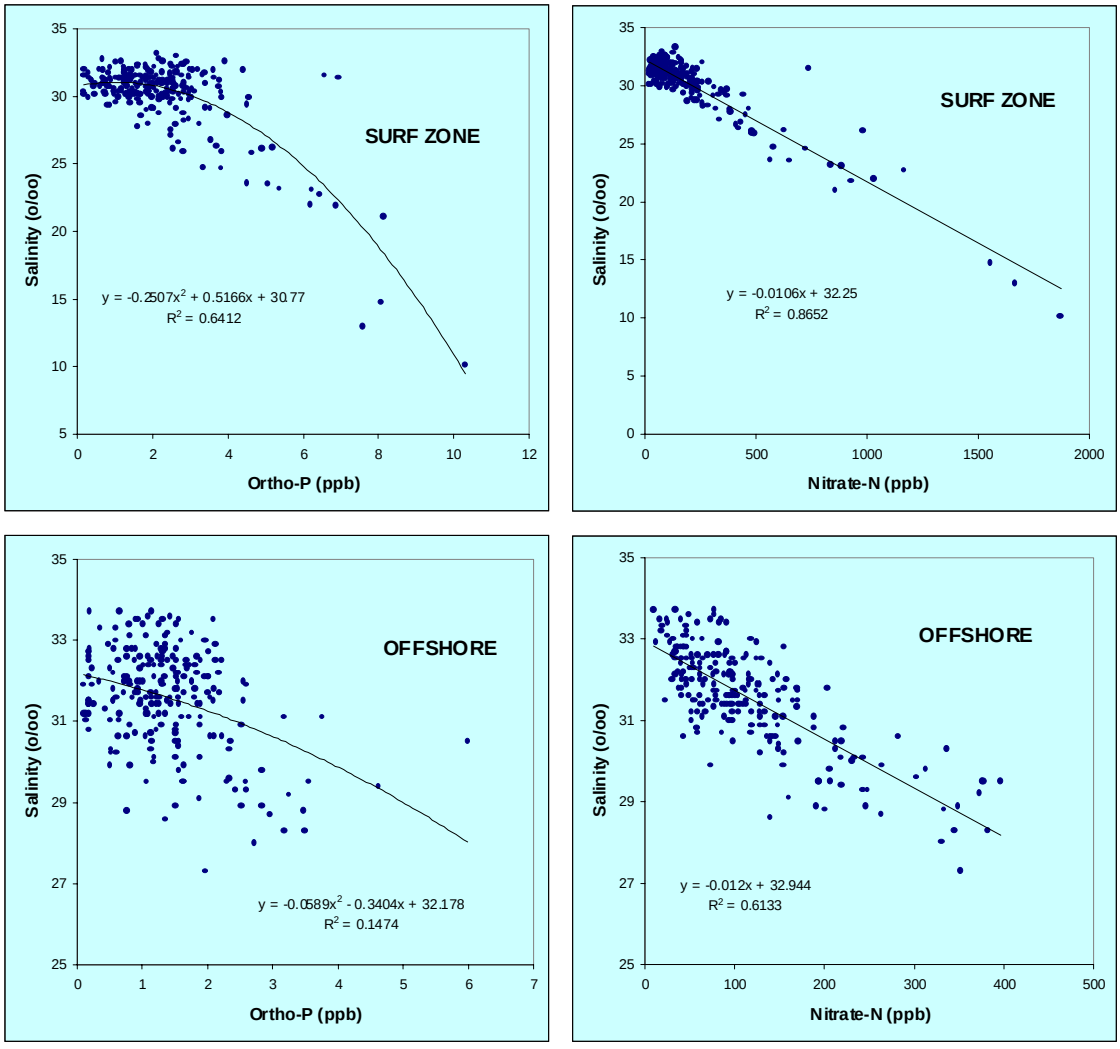

Figure 1: Orthophosphate-P and nitrate-N concentrations (µg/l) vs. salinity in the surf zone and in waist deep water ~50m offshore in Tumon Bay (April - May 2001)

Studies on the Great Barrier Reef suggest that algae do not do well in waters where reactive P concentrations are less than 0.1 µg/l (Furnas *et al* 1995). Threshold levels of reactive P, above which macroalgae blooms have been observed on coral reefs elsewhere, are around 3 µg/l (Lapointe *et al.* 1993, 1997, Bell 1992). This value closely approximates mean reactive P values determined in the higher salinity waters offshore in Tumon Bay during the present study (Fig 1). However, the equivalent threshold level for *E. clathrata* blooms has yet to be determined and, in all probability, is higher than 3 µg/l given the fact that this species does not grow in abundance within the lagoon itself.

Reactive P levels determined in Tumon Bay seeps and springs during this study are summarized graphically in Figures 2 and 3 respectively. Noteworthy is the fact that seep concentrations of reactive P show considerably more within-site variability than the eight major springs located within the bay. Such variability was not related to salinity fluctuations and may have been REDOX mediated as a result of depressed oxygen levels in beach sediment. Episodic nutrient inputs associated with landscaping activities along the waterfront are also a possibility since irrigation runoff would likely show up on the beach in small, shallow seeps rather than in the larger springs.

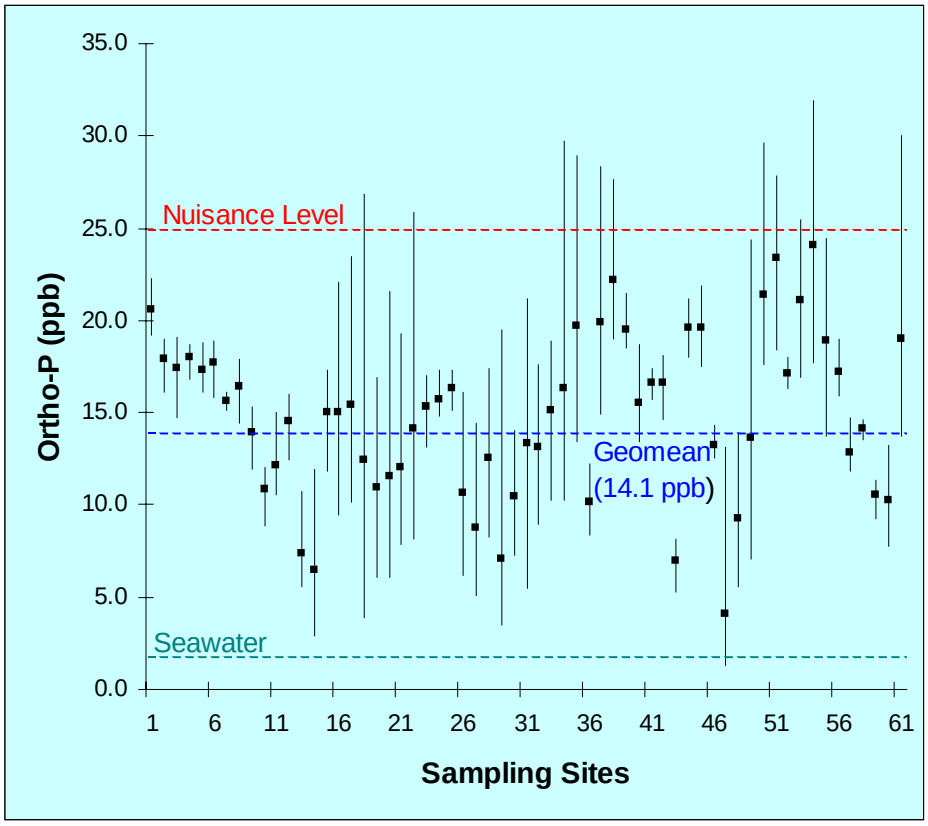

Figure 2: Orthophosphate-P levels (µg/l) in Tumon Bay seeps (June-August 2000)

According to the U.S.EPA (1986), nuisance algal growth occurs when reactive P levels exceed 25 µg/l and is based on observations in freshwater environments. Guam EPA has adopted this value as its surface water quality standard for all marine and freshwater environments classified as excellent. In our opinion this standard is insufficient for

marine waters where algae have adapted to typically lower levels of available P compared to their freshwater counterparts. We therefore propose that the standard be amended at least to 20 µg/l and perhaps even lower.

Overall geometric mean levels of reactive P levels found in Tumon Bay seeps and springs were 14.1 µg/l and 16.8 µg/l respectively. The significantly higher levels found in two adjacent springs between the *Seahorse Restaurant* and the *Pacific Star Hotel* are of interest and clearly represent aquifer source waters that are chemically different from those feeding the other springs along the beach. It is noteworthy that *E. clathrata* is especially abundant in this region of the bay.

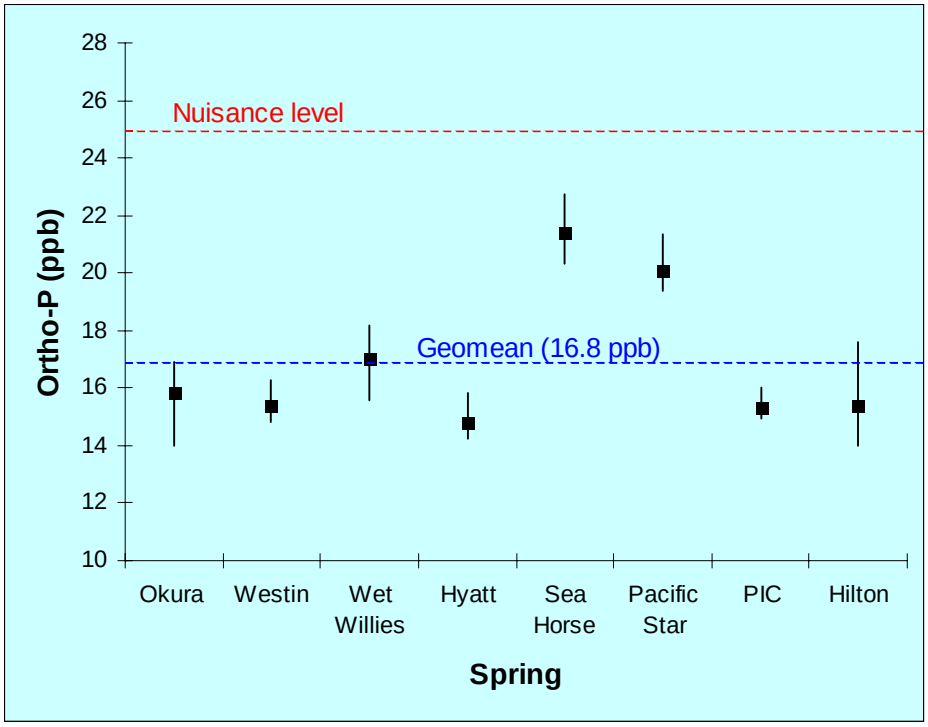

Figure 3: Orthophosphate-P levels (µg/l) in Tumon Bay springs (June-August 2000)

Approximately, 40 million gallons of fresh water flows from the aquifer into Tumon Bay each day (Jocson 1998). This translates to a total daily input of 2.3 kg of reactive P and 378 kg of nitrate-N, assuming a mean groundwater value of 15 µg/l and 2,500 µg/l for each nutrient respectively.

Reactive P levels in the GWA drinking water production wells are shown in Fig. 4. Some considerable variability was noted particularly in the A-, D- and M-wells. Overall, 10 wells yielded reactive P levels greater than 20 µg/l and four exceeded the Guam surface water quality standard of 25 µg/l. Much of the groundwater entering Tumon Bay flows along the Yigo-Tumon Trough, a natural valley formed by the basement volcanics to the northeast (Jenson *et al.* 1997). Only four of the 40 or so wells in this region had reactive P levels above 20 µg/l. Of these, only two exceeded 25 µg/l. The geometric mean reactive P level for all wells sampled island-wide was 12.7 µg/l, identical to that calculated for wells within the Yigo-Tumon Trough.

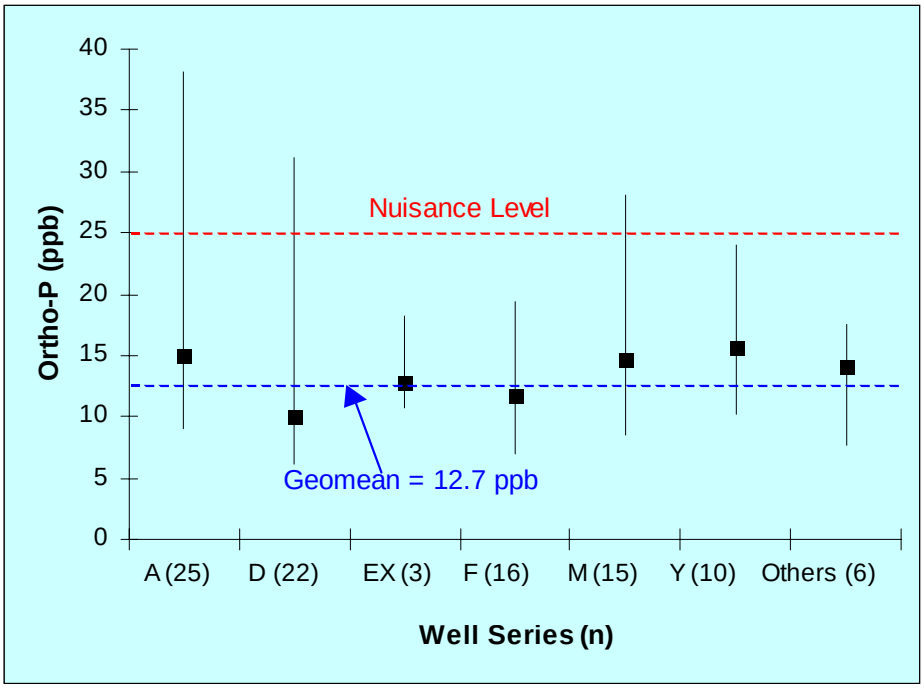

Figure 4: Orthophosphate-P levels (µg/l) in GWA wells (June 2000 - April 2001)

The frequency distribution histograms for reactive P levels in Tumon Bay seeps and springs vs. GWA production wells are compared in Fig. 5. In both instances, the distribution of frequencies for the various concentration categories was essentially normal. However the shifting of central tendency to the right in the Tumon samples is a clear indication that the aquifer is not the only source of reactive P entering the bay.

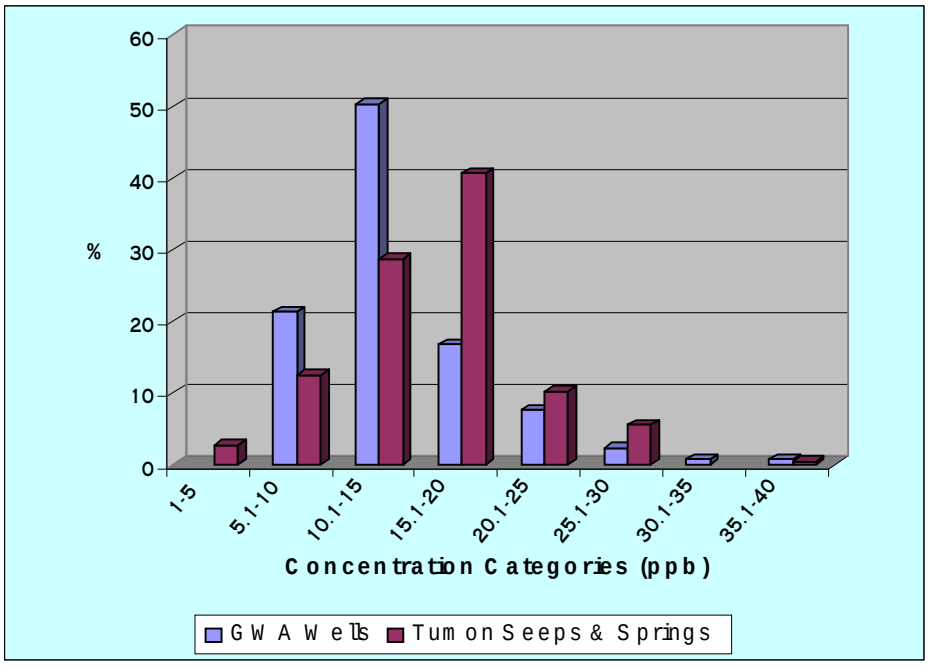

Figure 5: Frequency distribution histograms for orthophosphate-P levels in Tumon Bay seeps and springs and in GWA drinking water production wells.

On the strength of these findings, a follow-up study has recently been initiated to evaluate the landscaping practices currently employed by groundskeepers of all waterfront hotels in the Tumon Bay area. Information gathered by questionnaire and personal interview will be assessed by horticultural experts to determine the appropriateness of current fertilizer and irrigation regimes relative to the needs of the landscaped areas.

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Furnas, M.J., A.W. Mitchell, and M. Skuza (1995) Nitrogen and Phosphorus Budget for the Central Great Barrier Reef Shelf. Research Publication No. 36, Great Barrier Reff Marine Park Authority, Townsville, p 1-94.

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Jocson, J. M. U. (1998). *Hydrologic Model for the Yigo-Tumon and Finegayan Subbasins of the Northern Guam Lens Aquifer, Guam*. Masters Thesis, University of Guam, 95 pp.

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Basic Information

Title:	Quality of Formula Preparation Water and Incidence of Waterborne Diseases Associated with Artificial Infant Feeding in Chuuk State, Federated States of Micronesia
Project Number:	B-04
Start Date:	3/1/2000
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Water Quality, Water Use, None
Descriptors:	Water Quality, Breastfeeding Incidence
Lead Institute:	University of Guam
Principle Investigators:	Kathy Wood, Andita Meyshine

Publication

Basic Information

Title:	The effect of education and increased training in operation and maintenance and improved water quality analysis on water consumption within a small water supply system
Project Number:	B-05
Start Date:	3/1/2000
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Water Quality, Education, Surface Water
Descriptors:	water quality, education , surface water
Lead Institute:	University of Guam
Principle Investigators:	Arthur Jonas

Publication

Malem Water System Project

PROJECT SYNOPSIS REPORT

June 20, 2001

Introduction:

The site for this study project (Malem Water System) was recommended and approved by the project advisory committee consisting of the following individual volunteers, Patti Brewer which is working as a legal counselor for the Kosrae State Legislature, Robert Nelson, the Kosrae Utility Authority Manager, Bruce Howell, Kosrae State Public Works Director, and of course the Project Investigator. The intention of this project is to break down the barriers against water quality improvement, use water wisely without wasting it, developing positive attitudes toward maintaining the system, and to motivate today's children especially High School and College to seek further studies in such field related to water or the importance of water and how to maintain to a level that can provide the needs of every home in a community.

Malem Small Water System is located in the middle of the municipality which serves two hundred some houses. The system source is about 2-3 miles from town toward the mountain site. The main pipes run from the source to town are 6" metal pipes with some 4" plastic pipes extended to both ends of the municipality. The secondary pipe lines to each residential home are ¾" and ½" plastic pipes. This project was operated under the supervision of the Project Investigator and the advisory committee with the help of one research assistant and 4 college students from the College of Micronesia Kosrae Campus.

Project Title:

The effect of education and increased training in operation and maintenance and improved water quality analysis on water consumption within a small water supply system.

Problem and Research objectives:

Kosrae State residents are served by several independent municipal water systems. All of these systems currently use untreated, unfiltered surface waters. Contamination of these surface water sources is a frequent problem due to sedimentation during periods of heavy rain and bacterial contamination from animal waste (i.e. E. coli and leptospirosis). It is strongly suspected by the medial community that many health problems experienced by Kosrae residents can be traced, at least in part, to the poor quality of the water provided by the public water system. Nonetheless, repeated attempts to pursue projects to improve the water quality to potable standards (e.g. construction of a modern water filtration plant) have failed because of a widespread public perception that improved water quality is not worth the cost.

This demonstration project will help break down the public barriers against water quality improvement programs and build public confidence in the need for water system improvements. The project will provide evidence of the scope of contamination of Kosrae's untreated water supply and also determine the potential for a modern maintenance program to reduce wasted water and thereby minimize the increased cost of providing public water with a treatment/filtration system. The interim results of the study will be used to educate the public about the importance of safe water and the necessity for routine maintenance of water systems.

The major objectives of this study are to determine the effect of improved maintenance on the municipal water systems and to educate the public about the need for clean, safe water. Specific objectives are:

1. **To determine the current water use and to determine**

   Water use rates after improved maintenance;

2. **To educate the public about the importance of proper**

   Maintenance of the water supply system within the home;

3. **To monitor and determine the specific water quality**

   Problems for each of the municipal systems;

4. **To educate the public about the importance of safe**

   Water;

5. **To prepare the public for a move to safe water systems;**

   And

6. **To prepare those persons operating the water systems**

   For the move to safe water systems by stressing proper

   Installation and maintenance procedures.

Methodology:

The following methods were used to determine the Project's Goals and Objectives:

Determination of Water used:

Smaller meter devices were used to determine the water used within each target home. Meter reading was collected and recorded every week throughout the duration of the project. Prior to this meter reading task, the pipe lines of the target homes were fixed. Other leaks in the main pipes were also fixed as the Project operation continued. Result of this water project was revealed to the public.

Determination of current quality of available water:

Water samples were collected each week throughout the duration of the project. These samples were tested and analyzed for disease causing bacteria. The system tested was found to have a lot of fecal coliforms. Other sources of water as in rain water was also tested for comparison purpose.

Educating the Public About Safe Drinking Water:

Brochures were developed to provide information about the project and to teach the public about the importance of water as well as safe drinking water. Publication of project results were also developed in Kosraen and distributed to the public.

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Principal Findings and Significance:

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This particular project was found to be helpful and effective to the community which serves by the system. It gives awareness to the people to maintain the system, use the water without wasting it, keep the water clean without polluting or contaminating it and most of all they are now aware that the current available water in this system cannot be used for drinking as well as washing dishes and brushing teeth.

We also purchased one big meter device to measure the amount of water consumed at a certain period of time. Unfortunately, we were unable to install it due to a couple of reasons: First, the Mayor of this municipality advises us to hold on to it so he could seek for funds to continue the service since we experienced some problems with the smaller meter devices installed previously in the homes study as in clogging or blocking of the devices which caused problem to the flow of water. This usually happened during heavy rain. Proper equipment and a person with appropriate skill is needed to do this service. We will do follow up on this and complete the task as soon as practical. The meter device is with Bruce Howell.

Basic Information

Title:	Indicator potential of Caffeine and its Metabolites
Project Number:	B-06
Start Date:	3/1/2000
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Water Quality, None, None
Descriptors:	Indicator Potential
Lead Institute:	University of Guam
Principle Investigators:	Harold Wood

Publication

PROJECT SYNOPSIS REPORT

Project Title: Indicator Potential of Caffeine and its Metabolites

Problem and Research Objectives

The usual bacteriologic indicators of sewage / fecal pollution and contamination, including the thermotolerant coliforms and enterococcus, have been found to not be very good indicators of health risk. This is especially true of health risk due to recreational exposure to fecally transmitted viruses and protozoan pathogens in tropical marine waters.

Other bacteria, viruses, phages and chemicals have been advocated as potentially useful for indicating health risk. Caffeine has been proposed in this respect. However, most of a caffeine dose is metabolized producing a variety of metabolites that are excreted, primarily in the urine. Thus, less that 3% of an administered caffeine dose is excreted unchanged as caffeine. Because of dilution after entering receiving waters, this reduces the sensitivity of using caffeine as an indicator and it is felt that other metabolites may be better suited fur use as indicators.

Methodology

Methods were modified developed for the extraction and analysis of caffeine and certain metabolites from environmental waters. This included solid phase extraction on sorbants (carbopak) and liquid liquid extraction with dichloromethane.

Analysis for caffeine and its methylated xanthine metabolites was performed with HPLC using a tertiary gradient of water (0.25% Triflouricacetic acid)/methanol/acetonitrile and diode array detection.

Principal Findings and Significance

Methodology was developed but difficulty was uncounted with the methylated uric acid metabolites. Analysis concentrated on the demethylated xanthine metabolites of caffeine. Preliminary results suggest that several of the demethylated xanthines show some promise, particularly the 1,7 dimethylxanthine and 1-methylxanthine demethylated metabolites. We would to evaluate metabolite ratios thru the wastewater treatment process.

Basic Information

Title:	Teachers Guide: Island Ecology/Resource Management Text
Project Number:	B-07
Start Date:	3/1/2000
End Date:	2/28/2001
Research Category:	Social Sciences
Focus Category:	Education, Ecology, Methods
Descriptors:	TEACHER'S MANUALSTUDENT ACTIVITY MANUALISLAND ECOLOGYISLAND RESOURCE MANAGEMENT
Lead Institute:	University of Guam
Principle Investigators:	John Fury

Publication

1. Furey, John F. ; Alan Davis, Lynwood Sievers, Diane Greenough, Ph.D, 2001,Island Ecology & Resource Management: Commonwealth of the Northern Mariana Islands, Teacher's Manual/Student Activity Guide, Northern Marianas College) 125pp

PROJECT SYNOPSIS REPORT

Project Title: Teachers Guide: Island Ecology/Resource Management Text

Problem and Research Objectives:

Ecological researchers and teachers in the US Commonwealth of the Northern Mariana Islands identified the need to develop a teacher's manual/activity activity guide to supplement a newly developed island-based textbook on ecology and resource management.

An instructor's manual was needed to orient both new and experienced teachers to the new textbook and to assist them in designing their environmental science and natural history courses to take best advantage of the new book as a teaching tool. Students, as well, needed to have an organized activity guide to properly orient them to experimental procedures, field trip features, laboratory and field safety tips, etc.

This project sought to begin to address these needs. It was anticipated that additional funding would also be needed beyond the limits of the USGS proposal and that the funding of this sub grant would hopefully 'leverage' other funding sources. This proved successful.

Methodology:

The principal investigator was the textbooks' lead author and editor. As was done with the Island Ecology/Resource Management textbook project, the principal investigator contacted persons known to be knowledgeable in the chapter subjects. Each author consulted with the PI regarding the scope and sequence of their activity write-ups.

Planned activities were not to be exhaustive. They did however need to be well developed and be clear in their instruction to these islands' average students.

Each activity has a section on:

- Title
- Purpose(s) Statement
- Materials Needed Statement
- Methodology
- Results/Analyses/Discussion Statement

One third of all laboratory activities were to have a component of determining, working with, and interpreting the meaning of quantitative data. The use of the Internet for research and reference was also emphasized.

Like the textbook chapters, the activities were to be 'in the public domain' for all interested parties to cut and paste from as necessary. Permission was expressly given and digital copies are being provided to facilitate users (teachers) to improve upon them over time.

Additionally, the project provided a small working fund ($1,500.00) for each island's group of teachers to obtain classroom and field consumable supplies and to obtain small purchase materials for their use in the field and in the laboratory. Anticipated field items include backpacks, magnifying lenses, rock hammers, topographic maps, Ziploc plastic bags, 3x5 index cards, measuring tapelines, etc. Anticipated laboratory items include sterile petri dishes & nutrient media, herbarium paper & mothballs, indicator reagents &

other chemicals such as methyl cellulose for slowing protists, ethyl alcohol and 'Carosafe' chemicals for specimen preservations, specimen bottles, graph paper, etc.

Principal Findings and Significance:

The project successfully resulted in the development of a good quality working draft Activity Manual (125 pages) that is ready for testing in the coming School Year. As delivered, the activity guide provides the teachers both hard copy and digital (Microsoft Word) formatted references for carrying out their classes' environmental science activities. The project initiates the use of the Internet through the addition of an average of six and one half hyperlinked Universal Resource Locators for each of the textbook's 41 chapters for a total of 268 websites. The number of activities in the working draft number 156, or an average of 3.8 per chapter.

By providing instructional methodologies and reference resources, the activity guide addresses a critical unmet need of the Commonwealth's school system. There were four project writers, including the lead author/editor.

Per the original project plan, the PI's were successfully able to leverage additional materials and supplies for the Northern Marianas College's Science and Mathematics Department via the participation of the main Principal Investigator in the NOAA Sea Grant proposal development process. Key supplies and equipment have been procured and more are on the way.

Due to active work schedules, the participating writers had to use all of the available project time to carry out the writings and the final project should be considered as a working draft as it has not yet been fully test-tried. This will occur during the coming Fall Semester when the final edited activity book and digital CD's will be provided to the teachers. Supply funds will also be provided to the teachers at the start of the school's Fall 2001 Semester. The Principal Investigator will oversee and participate in this test trial.

The project participants developed two additional products for the new teachers that were not originally proposed. One is a set of Compact Discs (3) that includes all of the graphics in the textbook (numbering over 2000 images). Second is a set of CD's that contains chapter-specific Microsoft PowerPoint presentations developed by the PI and by students from his Northern Marianas College's science classes. These are tremendously valuable should the new teacher have access to a Multimedia projector.

The significance of this project cannot be overemphasized. For the first time an island-appropriate activity guide has been developed, albeit in working draft form.

Teachers now have a manual that helps them take the principles and terminologies of the new *Island Ecology & Resource Management: Commonwealth of the Northern Mariana Islands* textbook and apply them to hands-on classroom exercises with their students. Students now have needed references and methods to guide them in investigating their island ecosystems.

Basic Information

Title:	Determination of Rainfall Erosivity Factors for Selected Islands in the Federated States of Micronesia Accounting for Climate Variability
Project Number:	B-08
Start Date:	3/1/2000
End Date:	2/28/2001
Research Category:	Climate and Hydrologic Processes
Focus Category:	Non Point Pollution, Hydrology, Management and Planning
Descriptors:	Soil Erosion, Rainfall, Water Quality, Rainfall Runoff Processes
Lead Institute:	University of Guam
Principle Investigators:	Shahram Khosrowpanah, Leroy F. Heitz

Publication

1. Khosrowpanah, Shahram, and Leroy Heitz, 2001, Rainfall Erosivity Factors for Selected Islands in the Federated States of Micronesia (FSM), Water and Environmental Research Institute of the Western Pacific, University of Guam, UOG Station, Mangilao, Guam, Report No. 92, 50pp.
2. Khosrowpanah, Shahram, and Leroy Heitz, 2001, Determination of Rainfall Erosivity Factors for Selected Islands in the Federated States of Micronesia (FSM), The Integration of Natural and Social Sciences in the New Pacific Millennium, 10th Pacific Science Inter-Congress, Guam, June 6-11.

PROJECT SYNOPSIS REPORT

Project Title: Determination of Rainfall Erosivity Factors for Selected Islands in the Federated States of Micronesia Accounting for Climate Variability

Problem and Research Objectives

Soil erosion is a major source of pollution in tropical islands. These islands are small, with limited resources, and are heavily dependent on a high quality marine environment both as a source of food and as an attraction for tourism, which is a major source of income for the islands. In the Federated States of Micronesia (FSM) soil erosion has already degraded the fishing within the reef and has created major water quality problems. For example, the island of Kosrae has one of the world's highest rates of water born disease. A recent study indicated that high turbidity in streams is a major factor in the cause of the problem (US EPA, 1986, Assessment of Water Supplies and Their Impact on Public Health in the Trust Territory of the Pacific Islands).

Soil erosion and its effects had been extensively studied for many years, but most quantitative information gathered has resulted from research in subtropical and temperate areas. Attempts to extrapolate this information for use in the tropics are seldom satisfactory. Recent studies (Khosrowpanah, Sh., and Peter-Pual G. Dumaliang, 1998, Soil erosion in Micronesia: Guam a case study. Proceeding of the International Symposium on Tropical Islands, Puerto Rico, 111-116 pp) indicate that the soil erosion rates predicted for the island of Guam could be as much as 45 % in error when using the extrapolated data compared to soil erosion rates based on actual local climatic conditions. In addition to the obvious lack of knowledge and information concerning the basic parameters governing erosion, the predictive capabilities for soil losses are further limited by the large variability of climate, soils, and topography in tropical regions.

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. This factor is identified in the USLE and RUSLE as the R or rainfall erosivity factor. It is important to have an average annual R-factor and its monthly variation that represents the local climate if successful erosion control plans are to be implemented.

The objective of this study was to develop average annual rainfall erosivity (R-values) for selected rainfall stations in the FSM by using local rainfall data for each station. The

rainfall stations that were considered were those that had long-term rainfall data with 30 or 60 minutes interval.

Methodology

The first step was rainfall data collection. The available rainfall with 15, 30, or 60 minutes interval was gathered from US Weather Service Stations in Pohnpei, Chuuk, and Yap. Kosrae was not included in this study because of the lack of hourly rainfall data.

The second step was to translate all the rainfall data into 30-minutes intervals. When 15-minute data was available (such as the two Pohnpei Stations) we simply summed the first two 15-minute values of the hour to get the first 30-minute value and summed the third and fourth 15-minute values of the hour to get the second thirty-minute value.

For stations where only 60-minute data was available a different technique was applied. A correlation was developed between I_{30} and I_{60} for two gages with long 15-minute rainfall was available (Piti, Guam and Capital Hill, Saipan). This I_{30}-I_{60} relationship was used to generate a record of 30-minute rainfalls from the existing 60-minute rainfall records.

The derived 30-minute rainfall record for each station was split into rainstorms. A new rainstorm was started every time there was a continuous no precipitation period of 6 hours or more (6hr breakpoint). The R-factor for each storm were then calculated and summed to come up with monthly and annual R-factors. The average annual and average monthly rainfall factor were calculated for each station. The last step was to apply a weighting factor in order to account for missing rainfall data. Some of the rainfall station such as Yap rainfall station had up to 60 percent missing rainfall data for some month of the year. In order to have a good representation of R-factor we did a weighted average for each day of the data set.

Principal Findings and Significance

The computed average annual R-factors for island of Pohnpei, Chuuk, and Yap is shown in Table 1.

Table 1. Average Annual R-Factor for Islands of FSM

Island	Average Annual Rainfall (inches)	Average Annual R-factor
Pohnpei Hospital	255	2354
Pohnpei WSO	224	1965
Chuuk WSO	174	1326
Yap WSO	122	970

Monthly variation of the percentage of annual R factor and accumulated R factor for Pohnpei, Chuuk and Yap state has been developed. Figure 1, and 2 shows this variation for the island of Pohnpei.

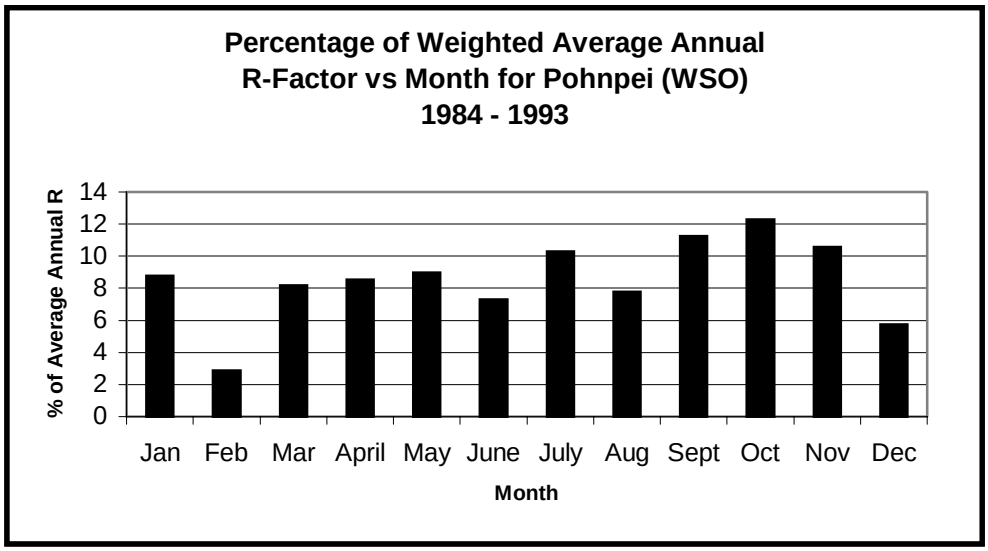

Figure 1. Percentage of weighted average annual R-factor vs. month for Pohnpei WSO

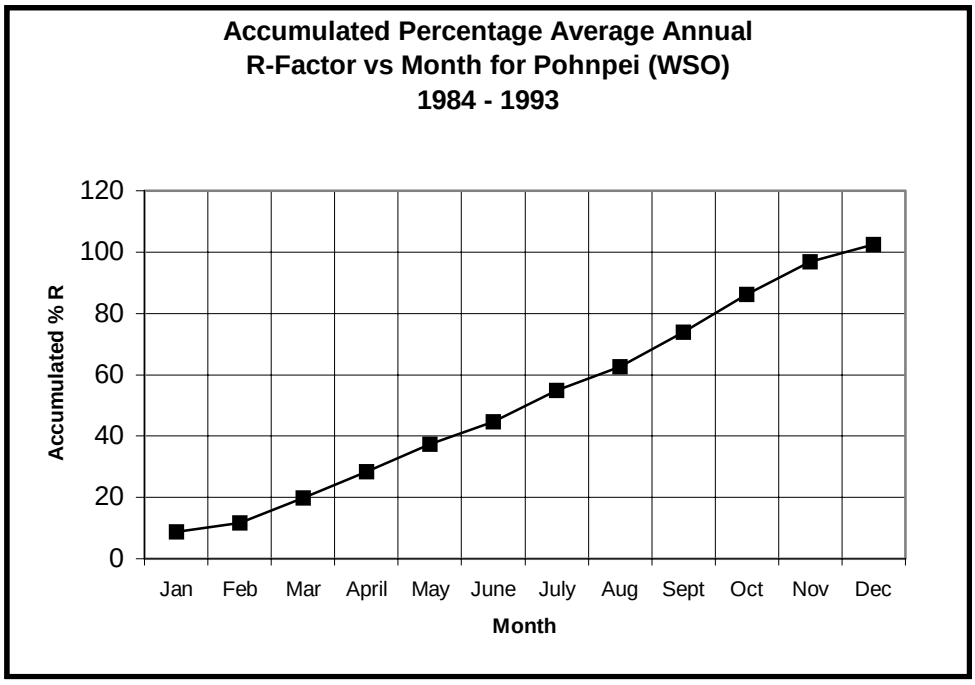

Figure 2. Accumulated percentage average annual R-factor vs. month for Pohnpei WSO

Basic Information

Title:	Erosion and Sedimentation Processes in Southern Guam
Project Number:	B-09
Start Date:	3/1/2000
End Date:	2/28/2001
Research Category:	Climate and Hydrologic Processes
Focus Category:	Water Quality, Water Quantity, Management and Planning
Descriptors:	Soil Erosion, Runoff, Geographic Information Systems, Watershed Management
Lead Institute:	University of Guam
Principle Investigators:	Shahram Khosrowpanah, Leroy F. Heitz

Publication

PROJECT SYNOPSIS REPORT

Project Title: Erosion and Sedimentation Process in Southern Guam

Problem and Research Objectives

Surface runoff and sediment losses from soil erosion are major contributors to reduction in surface water quality in Southern Guam. A study of the Ugum watershed on Guam indicates that soil erosion from vegetated savanna grassland in the watershed is approximately 70 tons ha^{-1} yr^{-1} but can be as high as 547 tons ha^{-1} yr^{-1} in unvegetated sloping sites known as "badlands" (Natural Resources Conservation Service, 1996, Resource Assessment: Ugum Watershed, Guam, U.S. Department of Agriculture, Agana, Guam). Agricultural lands in the Ugum watershed were estimated to have an average soil erosion loss of 45 tons ha^{-1} yr^{-1}. Additional problems associated with soil erosion include loss of soil productivity at the eroded site, reduced water storage capacity in streams and lakes, and loss of wildlife habitat. The negative impact of sediment loading on the aquatic environment of Guam has been recorded by several researchers (Rogers, C.S. 1990. Responses of coral reefs and reef organisms to sedimentation. Marine Ecology Progress Series 62:185-202). These researchers observed that coral reef decline, due to sediment deposition, are directly linked with reduction in the quantity and quality of solar radiation in part due to the sediment load from stream runoff. Concerns over degradation of coral reef include negative impacts on fish populations and tourism.

Effective land use planning and proper erosion control is a two-part process. First we must obtain a basic understanding of runoff and erosion rates at the plot, on hill slopes, and at small catchment scale and how these vary across the landscape. Next we must have a means to identify areas that have the potential for high erosion so that corrective actions can be taken to reduce sediment production from these areas.

The objectives of this study was; 1) to develop a GIS based erosion simulation model suitable for predicting soil erosion for the soils, vegetation and climate conditions of southern Guam, and 2) to examine the relationship between actual sediment production and hydrologic factors such as stream flow and rainfall.

Methodology

The project was divided into two phases. Phase I was to develop and apply a GIS based erosion simulation model to a southern Guam watershed. Phase II was to examine and develop relationships between the measured sediment yield at the watershed outlet and measured stream flow and rainfall within the watershed.

La Sa Fua River basins in Southern Guam was selected for monitoring and applying the erosion GIS base model. This watershed is located near the village of Umatac in southern Guam. Recently, as part of the USGS/WERI cooperative data network, the USGS Hawaii District office has installed stream flow and continuous sediment load

monitoring equipment at the outlet of this watershed. In addition, a continuous recording rain gage has been installed in the headwater of the La Sa Fua basin.

The actual erosion model that we selected for this study was a GIS implementation of the Universal Soil Loss Equation (USLE). The USLE is an empirical equation that was developed and established at the National Runoff and Soil Loss data Center in 1954 by the Science and Educational Administration. The USLE, derived empirically is

$$A = RxKxLSxCxP$$

A is the estimated sheet and rill erosion for a watershed in tons/acre-year. R is the rainfall erosivity factor that accounts for differences in rainfall intensity, volume, duration, and frequency at different locations. K is soil erodibilty factor that includes the combined effects of soil's characteristics that influence water intake and its ability to resist detachment and transport by rainfall and runoff. C is cropping management factor that accounts for effects of plant or mulch cover. P is management factor that accounts for the effects of conservation practices such as interceptor terraces and contour strips of vegetation. SL is slope length that accounts for length of the watershed.

The GIS implementation of the USLE uses the ArcView GIS program. The model was developed by inputting the USLE parameters describing the erosion process and performing the required calculation between these parameters. USGS Digital Elevation Models (DEM) maps were used to develop the parameters dealing with slope. NRCS Soil maps were used to develop soil type coverages. Ortho photos developed for the Guam Bureau of planning were used to develop coverages of plant type and cover factors.

As part two of this activity, sediment, stream flow, and rainfall gages have been installed within the La Sa Fua watershed. The sediment data has been collected at the newly activated USGS sediment gage on La Sa Fua River for the last eight months. Stream flow values have been obtained from the same site. A new rainfall gage station has been installed in the headwaters of the basin. The information on the amount of the sediment that leaves the watershed and the rainfall and stream flow will be use to calibrate the model. Also it will help us to develop a relationship among these hydrological factors.

Principal Findings and Significance

One of the most important outcomes of this project is that now we have a well-defined watershed in the southern Guam that is equipped with sediment, rainfall, and stream flow gages. This will enable us to easily carry out further erosion studies. The second outcome is the GIS erosion model that has been developed as part of this activity. The model could be applied to other watershed in southern Guam for predicting the soil erosion. We are presently exploring the adaptation of an existing model which would use ArcView as the pre-processor of the Spatial soil erosion data which would then be sent to a RUSLE based erosion model for predicting erosion in real time. To have a better understanding between the rainfall, stream flow, and sediment yield of the La Sa Fua watershed, requires at least one years data. The USGS Guam office is currently collecting this information and upon release of these data, we will use it to calibrate the erosion model and better define the relationship between sediment yield and rainfall data for of the La Sa Fua watershed.

Basic Information

Title:	Groundwater Infiltration and Recharge in the Northern Guam Lens Aquifer as a Function of Spatial and Temporal Distribution of Rainfall
Project Number:	B-10
Start Date:	3/1/2000
End Date:	2/28/2001
Research Category:	Climate and Hydrologic Processes
Focus Category:	Groundwater, Climatological Processes, Water Quantity
Descriptors:	Atmospheric Processes, Climate, Data Analysis, Rainfall, Well hydrographs, Groundwater Recharge, Sustainable Yield
Lead Institute:	University of Guam
Principle Investigators:	Mark Lander, John W. Jenson

Publication

1. Lander, Mark, A., John W. Jenson, Colette Beausoliel, 2001, Responses of well levels on northern Guam to short-term and long-term variations of rainfall and sea level, Water and Environmental Research Institute of the Western Pacific, University of Guam, Mangilao, Guam, 23pp.
2. Lander, Mark, A., John W. Jenson, Colette Beausoliel, 2001, Responses of well levels on northern Guam to short-term and long-term variations of rainfall and sea level, "in" The Integration of natural and Social Sciences in the New Pacific Millennium, 10th Pacific Science Inter-Congress, University of Guam Graduate School & Research and Pacific Science Congress, Mangilao, Guam, p 106.

PROJECT SYNOPSIS REPORT

Project Title:

Problem and Research Objectives

The island of Guam is blessed with an enormous amount of fresh water stored in the thick limestone mantle that covers almost all of the northern half of the island and the eastern fringe of the southern half of the island. The Northern Guam Lens Aquifer (NGLA) provides 80% of Guam's potable water production of more than 40 million gallons per day (mgd) for its 150,000 permanent residents and 1,000,000 tourists who visit the island annually. As limits to production are approached, understanding aquifer characteristics is imperative if the aquifer is to be managed properly to meet future demand and to preserve water quality.

The NGLA is composed primarily of two permeable limestone formations, the Pliocene-Pleistocene Mariana Limestone, and the Miocene-Pliocene Barrigada Limestone (Tracey, et al. 1964). The Mariana limestone was deposited as a shallow-water fringing and barrier reef, and is thickest along the rim of the uplifted northern plateau. The older Barrigada limestone is a deeper-water limestone of bank and off-reef detrital deposits. The Barrigada limestone dominates the interior of the plateau, and accounts for the greatest volume of the aquifer, especially in the island's interior. The basement beneath the limestone is a late Eocene-Oligocene submarine volcaniclasitc deposit with a permeability many orders of magnitude lower than the overlying limestone.

The sustainable yield of the aquifer—defined as the rate of pumpage that can be sustained over the long run without affecting the quality of the water -- has been estimated in previous studies to be from about 60 mgd (CDM, 1982) to upward of 80 mgd (Mink, 1991). Sustainable yield is a global concept, however. Although it provides a useful aggregate benchmark for water resource planning, it provides no guidance for the determining the appropriate pumping rate for a particular well in a particular location. To support such decisions, water resource managers need a sufficiently precise understanding of local hydrogeologic characteristics for each well field to enable reliable prediction on well response to pumping and changes in recharge. As the aquifer approaches the total sustainable yield, it will be more and more important for developers to base decisions regarding the installation or design of a given well on a case-by-case analysis of local properties of the well field and the potential effects that a new well might have on neighboring wells.

Certain hydrologic and geologic factors must be better understood in order for water resource managers to reliably estimate sustainable production rates for individual wells in selected well fields. These include a better knowledge of the rainfall distribution over the island – the complexities of which are only now being revealed by Guam's NEXARD weather radar, and new dense rain gage networks. Another phenomenon that requires more precise understanding is the nature of the pathways taken by rainfall through the limestone matrix. Mylroie and Vacher (1999) have proposed a dual-porosity aquifer in which dissolution-widened fractures are typically superimposed on a high-porosity matrix. The conductivity associated with each component is high, though variable, and can be orders of magnitude different from the other. Previous conductivity studies on Guam suggest regional conductivities from 1-6 km/day (e.g., from Ayers and

Clayshulte's 1984 study of tidal-signal attenuation in inland wells) and local conductivities of 1-100 m/day (from pumping tests). Contractor and Jenson (2000) compared numerical simulations to groundwater-level time series data from observation wells on northern Guam. They concluded that temporary storage of infiltrating water in the vadose zone is significant and that infiltration rates are strongly dependent on the seasonal water content of the vadose zone. Optimizing the vadose parameters in the model did not achieve appreciable error-reduction in simulated water levels, suggesting that temporal and spatial variations in vadose zone characteristics are insufficiently known and/or that other processes affecting the temporal and spatial distribution of recharge have yet to be discovered. They noted three plausible sources of error; 1) unknown spatial variability of the hydraulic conductivity in the aquifer, 2) unknown variations in evapotranspiration, and 3) large errors introduced, especially under wet conditions, by the dependency of infiltration and storage on precipitation rates on Guam. Continued modeling studies, along with statistical comparison with the historical record and field hydrographic studies were recommended. This paper is an ongoing attempt at the latter. The preliminary results of a study of the effects of variations in rain and sea level on the water-level time series in three observation wells are presented.

Methodology

Removing the tidal signal in the well time-series

The correlation of well water levels with the daily and monthly mean sea level is in general a function of distance from shore. All water level time series of the NGLA exhibit statistically significant cross-correlations with the time series of the daily average tide (expressed in feet above mean sea level). The tidal signal is transferred rapidly into the aquifer, and cross-correlations are highest at zero time lag for all periods investigated (daily to monthly). At some wells, the variations of sea level account for upwards of 50% of the variance of the time series of daily and monthly average water levels.

The linear cross correlation value is used to remove the tidal signal from the well water level time series. The cross correlation coefficients between the sea level and the water level of a given well can be used in a linear regression to predict the value of one variable given the value of the other. The best prediction that a linear regression can yield is given by

$$(A_i)^* = (r)\,(s_A/s_B)\,(B_i)' + \bar{A} \qquad (1)$$

where: ( )* indicates the predicted value;
( )′ indicates departure from the mean value;
subscript *i* indicates the i^{th} value of the time series;
s_A and s_B are the standard deviations of variables *A* and *B* respectively;
r is the cross-correlation coefficient between variables *A* and *B*; and,
the over-bar indicates the mean value of the indicated time series.

Using Equation (1), the water level may be predicted from the sea-level time series. An adjusted well-level time series that is not correlated with the sea level may be obtained by subtracting the i^{th} term on the right-hand side of equation (1) from the i^{th} raw value of the well-level time series. In this manner, the well-level time series is "de-tided". Note that the well water level time series may be similarly adjusted to "de-rain" the time series, or to remove the component of any variable that has a non-zero cross-correlation with the water level. In this report, the sea-level signal was always removed first in order to evaluate the relationship of the remaining "de-tided" time series to the rainfall. Maximum correlations of water level with rainfall tended to occur at a time lag, whereas maximum correlations of water levels with sea level were always simultaneous at the frequencies examined (daily and monthly).

Using rainfall and tide to predict water levels

The "de-tided" water level time series may be cross-correlated with any other time series (such as time series of rainfall) to form a multiple linear regression equation of the form:

$$(A_i)^* = (r_{A:B})\,(s_A/s_B)\,(B_i)' + (r_{A:C})\,(s_A/s_C)\,(C_i)' + \bar{A} \qquad (2)$$

where: ( )* indicates the predicted value;
( )′ indicates departure from the mean value;
subscript *i* indicates the i^{th} value of the time series;
s_A, s_B, and s_C, are the standard deviations of variables *A*, *B* and *C* respectively;
$r_{A:B}$ is the cross-correlation coefficient between variables *A* and *B*;
$r_{A:C}$ is the cross-correlation coefficient between variable *A* (signal of *B* removed) and variable *C*; and,
the overbar indicates the mean value of the time series.

Such an equation derived to predict the level in well BPM1 from the rain and tide

$$(BPM1_i)^* = 0.5281\,(TIDE_i)' + 0.02227\,(RAIN_i)' + 2.723 \qquad (3)$$

yields a predicted time series for BPM1 that explains 66% of the variance of the raw time series. An investigation of the analysis of the variance explained by the rain and the tide (and the inter-relationships among other variables, such as the wind and the tide) at several well sites occurs in a later section.

Integrated anomalies

All of the variables examined in this report (rainfall, the Southern Oscillation Index or SOI, sea level, and water levels) were subjected to an analysis wherein the long-term annual or monthly mean of the variable is removed and the anomalies of each variable are added in sequence to create a time series of the running total. These running totals, or "integrated anomalies," sharply highlight long-term deficits or surpluses. The running totals of all the variables show prominent long-term deficits and surpluses that are clearly inter-related.

Principal Findings and Significance

Variations in rainfall and sea level cause variations in well water levels. The combined variations in sea level and rainfall in real time or near-real time account for up to 66% of the variance of water levels in the wells, with sea level accounting for the larger share of this variance near the coast, and the rain accounting for the larger share of the variance at well locations further inland. There is evidence that multi-year variations of rainfall appear in the water levels at time lags up to nearly two years. Heavy 24-hour rainfalls of up to 3 inches may cause no immediate response of water levels if they occur at the end of prolonged dryness. Similar rain events cause immediate and large increases of water level if they occur during prolonged wet periods. Rapid increases in water levels in response to heavy short-term rain events decay to background levels within a period of about 10 days. The observed response of the wells to variations in the rainfall and sea level suggests a complicated mix of diffuse and open pathways through a heterogeneous limestone medium.

A close scrutiny of the well response to the forcing of TIDE and RAIN may help to better understand the volumes and rates at which rainwater is captured in storage by the NGLA, and how it travels through the limestone matrix. The mix of time lags at which the wells respond to the RAIN suggest that both the diffuse and open pathways are working to move water through the NGLA independently, with different pathways having different characteristic distributions and response times. Wells respond to widespread heavy rain events with a sharp spike within one day of an event, then return to pre-event levels after about 10 days. Multi-year surpluses or deficits of rainfall tend

to be reflected in the water levels at a nearly 2-year time lag. This 2-year memory of the rain forcing suggests that substantial long-term vadose storage is occurring.

The optimization of vadose parameters in Contractor and Jenson's model (Contractor and Jenson, 2000) achieved only about a 30% error-reduction in the model's prediction of water level, suggesting that temporal and spatial variations in vadose zone characteristics are insufficiently known and/or that other processes affecting the temporal and spatial distribution of recharge have yet to be discovered. They noted three plausible sources of error; 1) unknown spatial variability of the hydraulic conductivity in the aquifer, 2) unknown variations in evapotranspiration, and 3) large errors introduced, especially under wet conditions, by the dependency of infiltration and storage on precipitation rates on Guam. The integrated anomalies of the wells used in this report (A16, A20, and BPM1) (Fig 11), and in others not shown, indicate that *all* of these wells are responding similarly to the same long-term forcing. Moreover, A16 and BPM1, in which freshwater is hydraulically connected with the sea, track this forcing in concert. The major surpluses and deficits of integrated well-level anomalies on A16 and BPM1 appear to lag by nearly 2 years similar surpluses and deficits in the integrated rainfall anomaly (Fig. 12) (at A20, the time lag of the response is approximately 6 months). This would suggest that spatial variations in the hydraulic conductivity of the aquifer may not appreciably alter NGLA response to long term variations in forcing, but this hypothesis can be tested only by examining a representative sample of observation wells across the aquifer. As noted, the karst and associated aquifer properties of the area covered in this study differ in both kind and degree from those in the non-argillaceous units of the aquifer. A future study will examine other wells in the other limestone units of the NGLA to evaluate the similarities and differences in behavior from the observations reported in this study.

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Basic Information

Title:	Implementation of SWIG2D in MATLAB
Project Number:	B-11
Start Date:	3/1/2000
End Date:	2/28/2001
Research Category:	Ground-water Flow and Transport
Focus Category:	Models, Groundwater, Methods
Descriptors:	Coastal/island aquifer modeling
Lead Institute:	University of Guam
Principle Investigators:	John W. Jenson

Publication

PROJECT SYNOPSIS REPORT

Project Title: Implementation of SWIG2D in MATLAB

Problem and Research Objectives

SWIG2D (Saltwater Intrusion/Groundwater flow-2-Dimensional) is a two-dimensional sharp-interface finite element FORTRAN code that has been in use for nearly two-decades at WERI and at the University of Arizona. Over the years, it has been steadily updated to accommodate implementation on evolving platforms and to incorporate new techniques in numerical computation. In the last several years, MATLAB has become the code of choice for many applications, and is now widely taught to students in programming and numerical methods courses. Implementation of the SWIG2D code in MATLAB will enable users to take advantage of state-of-the-art techniques on computation and numerical methods. It will also make the code more transparent and versatile.

Methodology

The existing FORTRAN code has been used and tested for many years. With this project, we have translated the existing code into MATLAB and are revising the input-output out modules to take advantage of the new interface programs that allow for the creation of finite-element meshes and associated input date from GIS-based maps, and for the display of output in with state-of-the-art analysis tools.

Principal Findings and Significance

The consequence of this project is the preservation and refinement of a tool for modeling groundwater flow and salt-water intrusion that can serve for both research and instructional needs. One of the principal advantages of SWIG2D is its simplicity and versatility. The model will continue to be available to researchers working on coastal and island aquifers as well as instructors who are teaching the basic techniques of modeling to students. WERI intends to use the new model during the next year for both of these purposes. A users manual for the new code will be first published as a WERI technical report and later submitting to a journal that addresses computational methods in hydrology..

Information Transfer Program

Basic Information

Title:	Development of a Western Pacific Rooftop Rain Catchment System Web Site
Start Date:	3/1/2000
End Date:	2/28/2001
Descriptors:	rain water catchment sytems, computers, Information Dissemination, Rainfall,
Lead Institute:	University of Guam
Principle Investigators:	Leroy F. Heitz

Publication

1. Heitz, Leroy, 2001, Rainwater Catchment System Design in the Western Pacific, The Integration of Natural and Social Sciences in the New Pacific Millennium, 10th Pacific Science Inter-Congress, Guam, June 6-11.

PROJECT SYNOPSIS REPORT

Project Title: Development of a Western Pacific Rooftop Rain Catchment System Web Site

Problem and Research Objectives

The islands of the Western pacific, while usually blessed with high rainfall rates, continue to suffer from water supply deficiencies due to many factors. Most of the islands are very remote. In virtually all cases, each island is completely dependent on locally available resources. These islands are periodically struck by long periods of El-Niño induced drought. These droughts bring great hardships to those islanders living on the smaller atolls and rural areas of the high islands. They depend almost exclusively on rooftop rain water catchment systems (RWCS) as their primary source of water. Serious supply problems occur when the components of the RWCS are not sized appropriately.

Over the past 20 years WERI investigators have been very active in research in the area of rain water catchment systems. Projects have included developing rain catchment system modeling programs, rain catchment design criteria, and design publications. During this same time period users of this information have become more sophisticated in the use of computers and the world wide web has become available to a very large population of the Western Pacific islands.

Many individuals working in government offices dealing with water supply and rain water catchment systems have direct access to the world wide web in their offices. Also these days private individuals can access the web from all the major islands or island centers in the Western Pacific. Although these islands are very much geographically isolated, they are only a mouse click away from accessing information from the World Wide Web. What was needed is a means to make the publications and computer programs previously developed in WERI projects more easily accessible through the World Wide Web. The web site “Western Pacific Rooftop Rain Catchment System Web Site” added to the already successful WERI web site hosted by the University of Guam. This web site allows anyone to have immediate access to design information and computer programs for properly sizing the components of a new RWCS or upgrading existing systems. This web site also serves as a forum for the discussion of rooftop rain catchment system development and implementation issues.

Methodology

Activities required to accomplish the objective of this project included:

1. Designing the overall appearance and functionality of the Rain Catchments System Web site.
2. Putting all existing WERI publications dealing with rain water catchment system planning, design and construction into web accessible format.
3. Modifying existing rain catchment systems design programs so they can be used interactively on the web site.
4. Researching and adding links to other World Wide Web pages that might have information on rooftop rain water catchment systems.
5. Developing the required HTML language codes to implement the web site and making the site operational on the University of Guam host computer.

The principal investigator was in charge of designing the overall appearance and functionality of the web site. We hired two student assistants from our computer science and chemistry departments who had knowledge in web page authoring and computer programming. These individuals coordinated putting existing WERI rain catchment publication into web accessible format. The student assistants and principal investigator worked together to modify existing rain catchment system design programs for direct web application. The student assistants made an extensive search of the web to find appropriate links to other rain catchment oriented web sites.

Principal Findings and Significance

The primary results of this project is the Western Pacific Rooftop Rain Catchment System Web Site

Figure 1 below shows the home page for the Web Site. The address for this site is:

http://uog2.uog.edu/weri/rain/index.htm

Figure 2 shows some sample pages from Design Brochure portion of the site. This section of the web site contains complete listings from the two previously published Water Informational Bulletins on rooftop rainwater catchment system design for Chuuk and Yap States, FSM and Pohnpei State, FSM.

Figure 3 shows an example of the web based rooftop rainwater catchment system design program that was developed as a result of this project. This program allows users to actually design the components of a water catchments system on line.

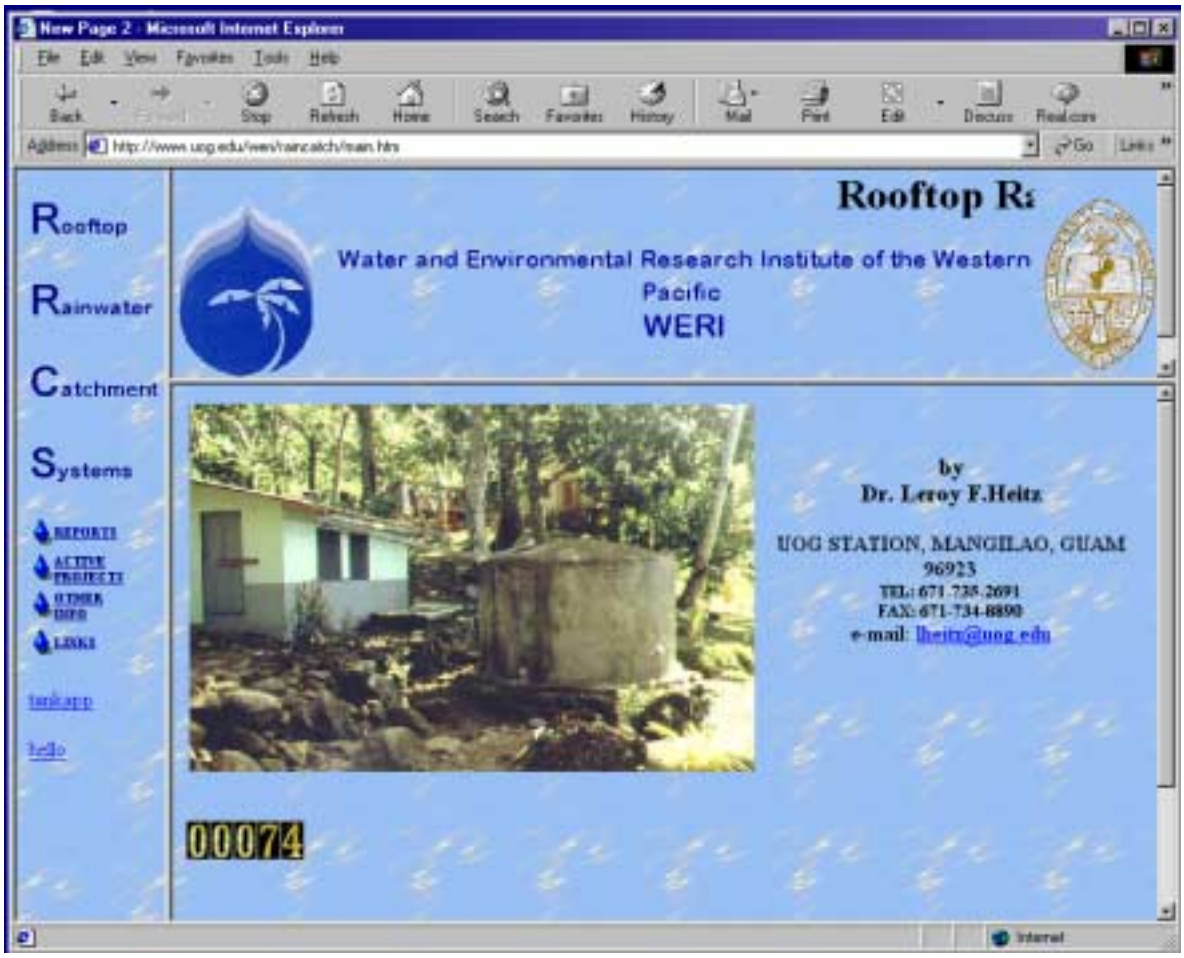

Figure 1 The Western Pacific Rooftop Rain Catchment System Web Site Home Page

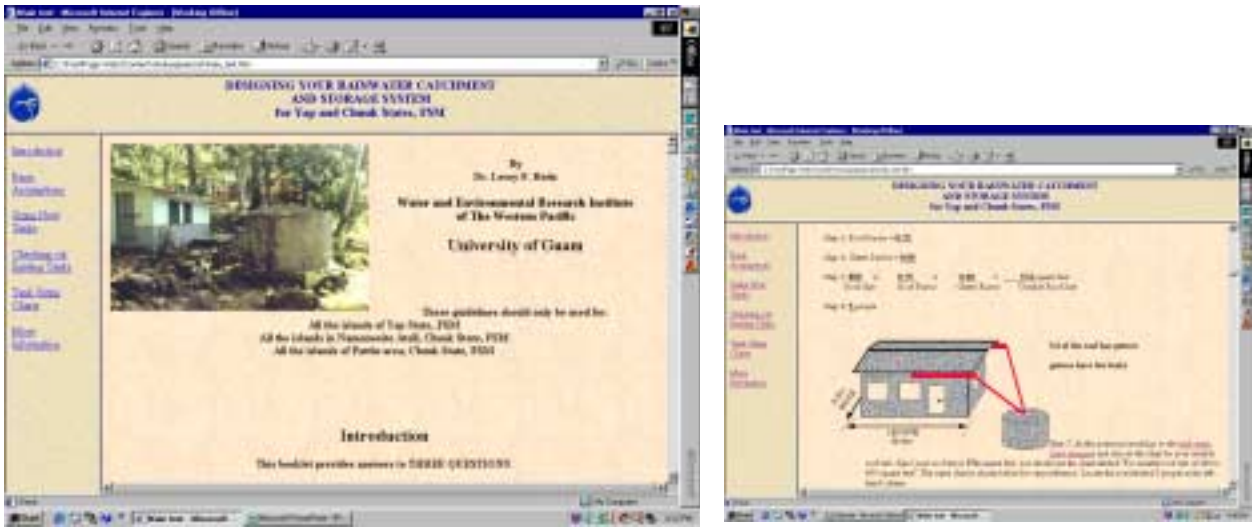

Figure 2 Samples from the Design Brochures Section of the Western Pacific Rooftop Rain Catchment System Web Site

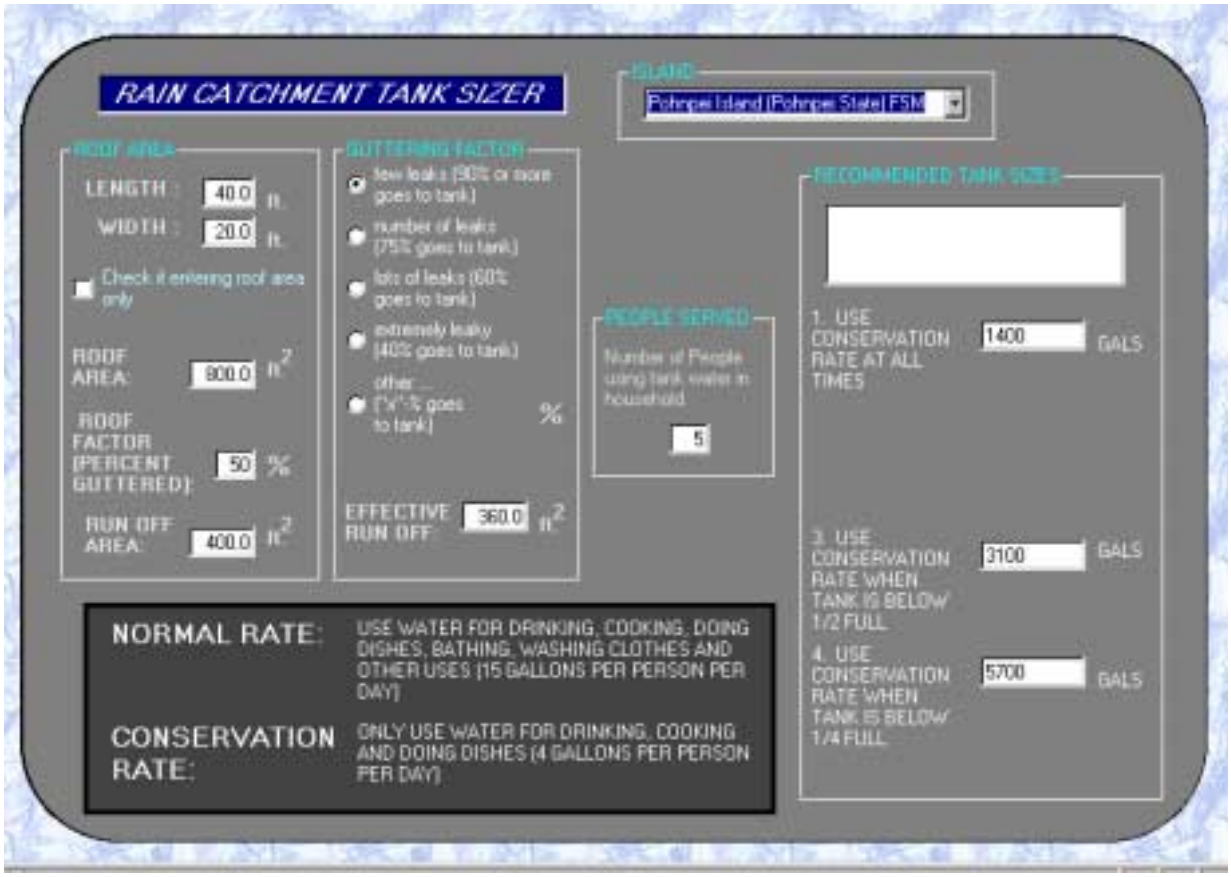

Figure 3 Interactive Web based Rooftop Rainwater Catchment System Design Program.

USGS Summer Intern Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	6	0	0	0	6
Masters	5	0	0	0	5
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	11	0	0	0	11

Notable Awards and Achievements

None

Publications from Prior Projects

1. Lander, Mark A., and John W. Jenson, Colette Beausoliel, 2000, Response of Well Water Levels on Northern Guam to Variations of Rainfall and Sea Level, Water and Environmental Research Institute of the Western Pacific, University of Guam, UOG Station, Mangilao, Guam, Report No. 94, 36pp.
2. Khosrowpanah, Shahram, and Leroy Heitz, Colette G. Beausoliel, 2001, The Application of Slow Sand Filtration Technology for Kosrae State, The Federated States of Micronesia: A Pilot Project, Water and Environmental Research Institute of the Western Pacific, University of Guam, UOG Station, Mangilao, Guam, Report No. 91, 36pp.
3. Contractor, Dinshaw N., and John W. Jenson, Colette 1999, Simulated Effects of Vadose Infiltration on Water Levels in the Northern Guam Lens Aquifer, Water and Environmental Research Institute of the Western Pacific, University of Guam, UOG Station, Mangilao, Guam, Report No. 91, 36pp.
4. Contractor, D.N., and J.W. Jenson, 2000: Simulated effect of vadose infiltration on water levels in the Northern Guam Lens Aquifer. Journal of Hydrology, 229, 232-254