Water and Environmental Research Institute of the Western Pacific
Annual Technical Report
FY 2010

Introduction

The Water & Environmental Research Institute of the Western Pacific or WERI is one of 54 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 36th year of operation.

WERI's mission is to seek solutions through research, teaching and outreach programs, to issues and problems associated with the location, production, distribution, and management of freshwater resources. The Institute provides its regional stakeholders with technical expertise in a diversity of water resources related fields including tropical climatology, surface water hydrology, rainfall catchment systems, groundwater modeling and management, water distribution systems, soil erosion and mitigation strategies and various aspects of water quality. Faculty members contribute significantly to both undergraduate and graduate teaching programs at the University of Guam (UOG) and conduct vigorous research aimed at improving economic conditions and the quality of life for citizens of Guam and the regional island nations. WERI also operates a state of the technology water analytical laboratory and geographical information systems analysis and training 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 funds (via the US Geological Survey) under Section 104-B of the Water Resources Research Act. WERI has responsibility for the administration of three 104-B base grants: one for Guam, one for the Commonwealth of the Northern Mariana Islands (CNMI), and one for the Federated States of Micronesia (FSM). This report summarizes the Institute's regional activities under the USGS 104-B base grant program for the period March 1, 2010 to February 28, 2011 (FY'10).

Currently WERI has a fulltime director who is also a UOG faculty member, five (5) regular and one (1) emeritus research faculty, a water analysis laboratory manager and technician, a GIS and network administrator, two office staff, as well as six (4) graduate research assistants who are completing their MS degree in the UOG Environmental Sciences program.

During FY10, WERI faculty were involved as principal investigators on twelve (12) research and training projects. Funding sources for these projects, in addition to the US Geological Survey, included the National Oceanic and Atmospheric Administration, the National Weather Service and the National Science Foundation, and local agencies such as the Guam Bureau of Statistics and Plans, the Guam Environmental Protection Agency, and direct appropriations from the Guam Legislature.

Over the same time frame, WERI faculty and staff taught ten (10) graduate courses and five (5) undergraduate courses in the Environmental Science MS program and the undergraduate Pre-Engineering curricula respectively. At the same time WERI faculty were first or second authors on seventeen (17) refereed journal articles and conference proceedings, four (4) technical reports, twelve (12) professional presentations, and three (3) workshops. WERI faculty members served on sixteen (16) thesis committees of students in the Environmental Science and Biology MS programs and chaired eight (8) of them.

Following is a list of non USGS Funded Projects carried out by the Institute during the 2010-2011 reporting period:

DIRECT LOCAL FUNDING: Guam Hydrologic Survey • Guam Geologic Map Update and Revision • Reconstructing the Climate History of Guam • Temporal and Spatial Variations in Guam's Groundwater Quality Water Resources Monitoring Program • In Cooperation with Hawaii District, USGS

GUAM BUREAU OF STATISTICS AND PLANS: • Watershed Management GIS Scholarship for Student in Environmental Science MS Program • To Develop the Erosion Potential GIS Based Tool for the Piti/Asan Watershed • To Provide GIS Technical Support for GIS Applications for Watershed Management Projects for Guam's Priority Watersheds

NATIONAL SCIENCE FOUNDATION: • Holocene Hydrologic Variability Across the Western Pacific Warm Pool

NATIONAL WEATHER SERVICE: • Pacific ENSO Applications Center with University of Hawaii: JIMAR Project, Climate Forecast & Information • Pacific ENSO Applications Center with University of Hawaii: JIMAR Project, Development of an Extended and Long-Range Precipitation System over the Pacific Islands

SAIPAN COMMONWEALTH UTILITIES COMMISSION (CUC), Guam WATERWORKS AUTHORITY (GWA) & GUAM ENVIRONMENTAL PROTECTION AGENCY (GEPA): • Training of GWA, GEPA and CUC Engineers and Private Consultants in use of the MWHSOFT Water Distribution System Modeling Program

OTHERS: • AECOM Environmental Consultants: Review of Water Utility Study to Support EIS MC Relocation from Okinawa, Japan to Guam • AECOM Analytical Laboratory Services: Water Utility Study to Support Marine Corp EIS Relocation, Guam • Setiadi Architects, LCC: Conservation/Restoration Area: Depression/Burrow Pit Study for Bordering Developable Land, Storm Drainage and Runoff

Research Program Introduction

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 Commonwealth of the Northern Mariana Islands (CNMI) and the Federated States of Micronesia (FSM) consist of representatives from various government departments that deal with water resources, representatives from the local colleges, private sector engineers, environmentalists, and planners, and University of Guam research faculty.

WERI held RAC meetings in Guam, the FSM and the CNMI in October 2010. Twenty three (23) people attended the Guam meeting, twenty four (24) attended the FSM meeting and twenty one (21) attended the CNMI meeting. Each meeting provided a scientific forum for information exchange on new and recently completed projects. Each RAC group examined the research education and training priorities identified in past years and added or amended where appropriate.

In early November, a Request for Proposals (RFP) letter was sent out by e-mail to over three hundred (300) regional representatives in Guam, the CNMI and FSM. Recipients included all past and present RAC members; faculty members at the University of Guam, the Northern Marianas College in Saipan and the College of Micronesia in Pohnpei, and water resource professionals from several government agencies. Accompanying the RFP message were: a) a blank proposal form for submittal on the USGS Web Site, b) detailed instructions on how to fill out the form, and c) the critical water resource research, education and training needs identified for Guam, the CNMI and FSM.

Eight (8) research proposals, three (3) for Guam, two (2) for the CNMI and three (3) for the FSM; two (2) environmental educational programs, one (1) for Guam and one (1) for the CNMI, and three (3) information transfer and training programs, one each for Guam, the CNMI and the FSM, were submitted for consideration in response to the RFP. Three regional review panels, each composed of highly regarded water resources professionals and RAC members, plus two previous WERI Directors (now retired), were tasked with evaluating each proposal's regional relevance in accordance with the long-standing criteria listed in the RFP. The appropriate proposals were e-mailed separately to each reviewer along with the critical needs list for the region and a scoring form. The reviewers were advised to work independently and given two weeks to submit their scores and comments to the WERI Director. The proposal scores were then tabulated and the projects ranked in descending order of average score. Projects approved for funding were selected based on their regional ranking and availability of funds.

Sustainable Well Yield Determinations Using Conductivity Probes on Active Wells

Basic Information

Title:	Sustainable Well Yield Determinations Using Conductivity Probes on Active Wells
Project Number:	2009GU159B
Start Date:	3/1/2009
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	N/A
Research Category:	Water Quality
Focus Category:	Water Quality, Groundwater, None
Descriptors:	Groundwater, Salinity, Saipan
Principal Investigators:	Derek Chambers, Mariano Iglecias

Publications

There are no publications.

PROJECT SYNOPSIS REPORT

Project Title: Sustainable Well Yield Determinations Using Conductivity Probes on Active wells

Problem and Research Objectives

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

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

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

Methodology

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

The three wells selected for the study were IF-205, IF-201 and IF-101 which are in the Isley Field well field, located between the Saipan International Airport and the village of Dan Dan. These three wells were selected because they are in the heart of the Isley Well

Field, have average chloride concentrations higher than the surrounding wells, and have well casings large enough to accommodate the sounding tubes.

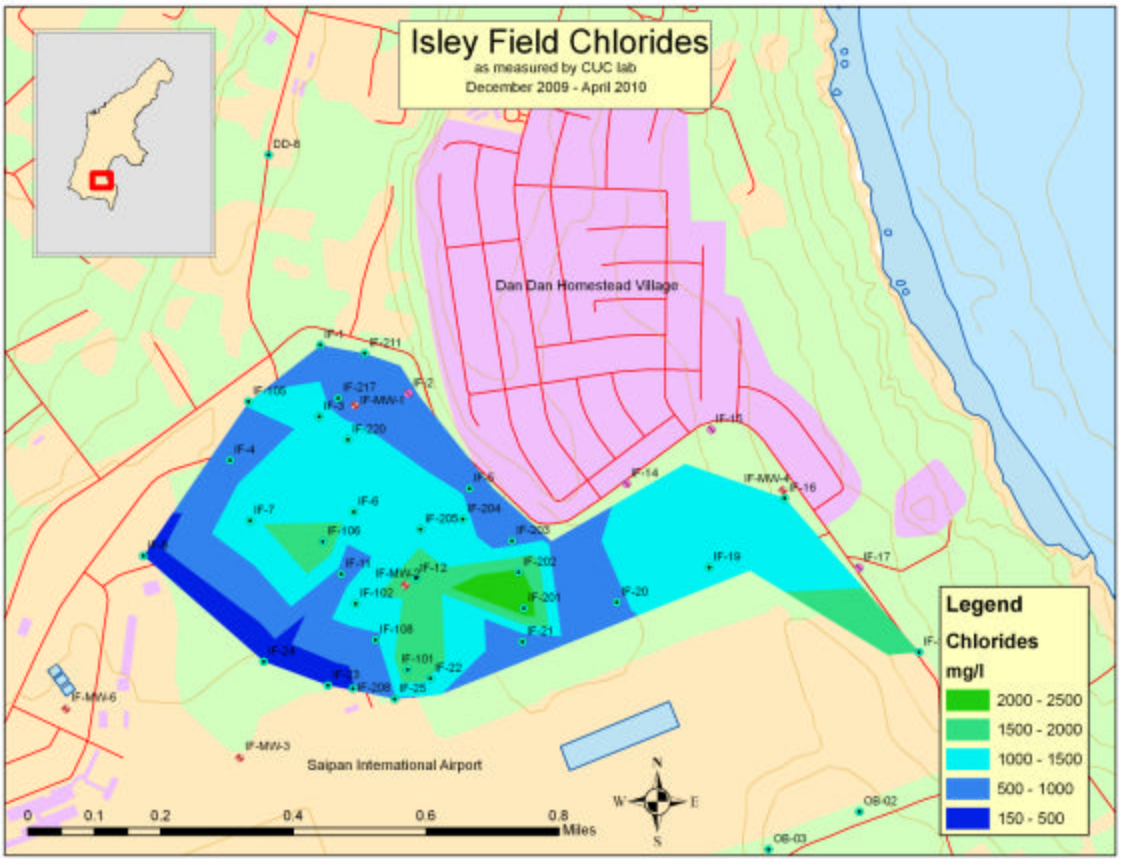


Figure 1: 2010 Average Chloride Concentration in Isley Field Wells

1-1/4 inch diameter PVC well casing and well screen to be used as sounding tubes for the conductivity probes were ordered from a vendor in Oregon and arrived on Saipan in February 2010. The conductivity probes were ordered from a vendor in Ontario, Canada and arrived on Saipan in March 2010. Sanitary well caps were fabricated on Saipan to accommodate the sounding tube, the drop pipe and electrical wiring. The sanitary well caps were completed in December 2010. The Commonwealth Utilities Corporation well pump maintenance crew installed the sounding tubes in the three wells in late January 2011.

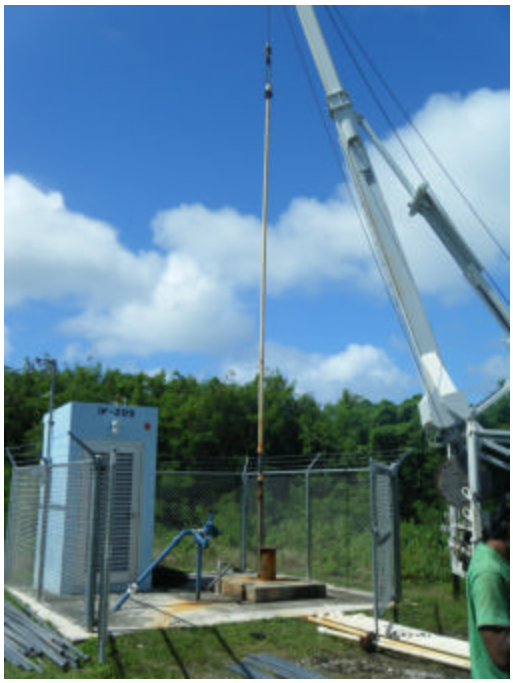
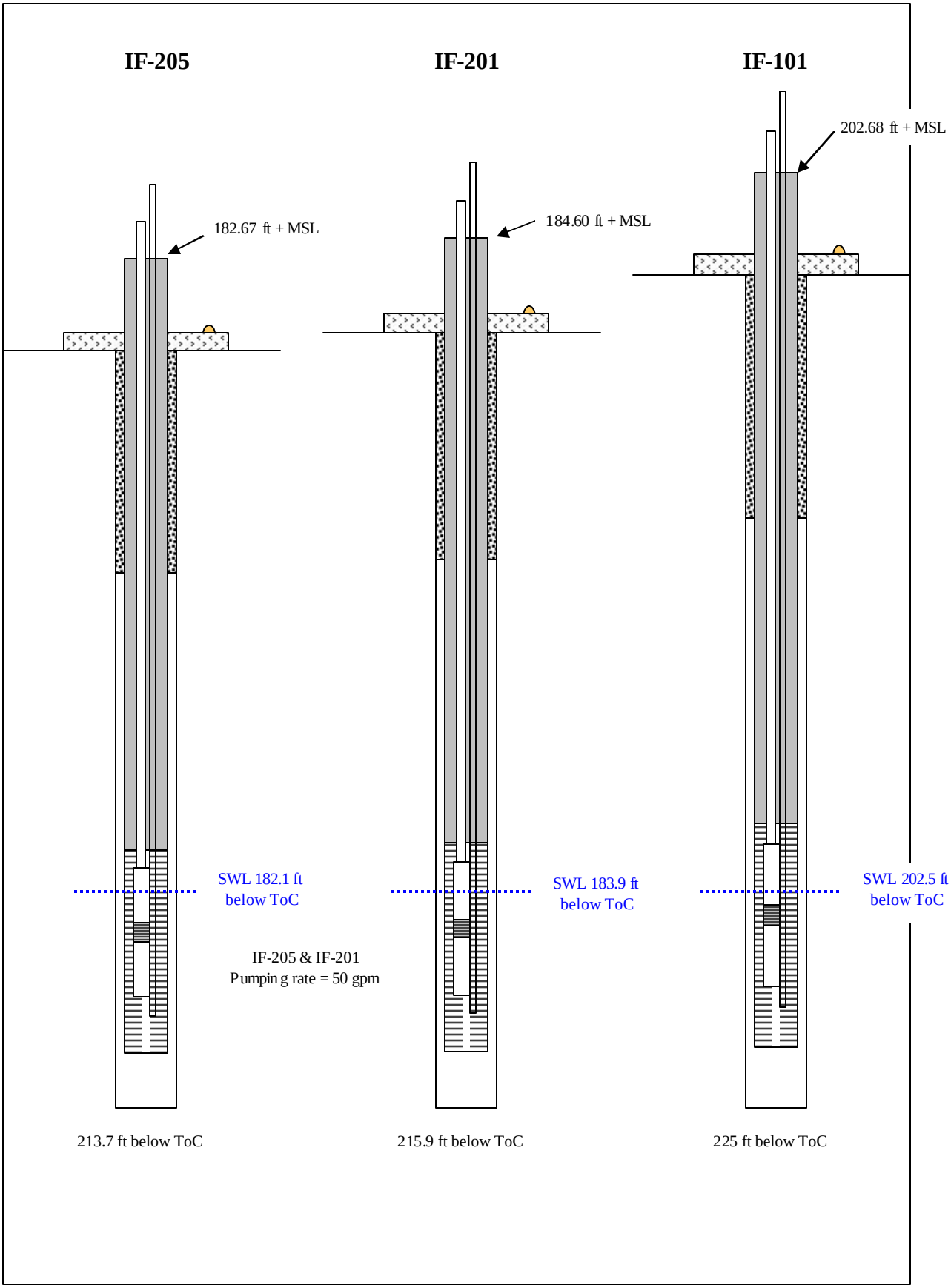


Figure 2: pulling drop pipe and pump

Figure 3: installing sounding tube

Figure 4: lowering drop pipe, sounding tube, well cap

Figure 5: new well cap and sounding tube


IF-205
IF-201
IF-101
182.67 ft + MSL
184.60 ft + MSL
202.68 ft + MSL
SWL 182.1 ft below ToC
SWL 183.9 ft below ToC
SWL 202.5 ft below ToC
IF-205 & IF-201
Pumpin g rate = 50 gpm
213.7 ft below ToC
215.9 ft below ToC
225 ft below ToC

In May 2011 the barometric probe was installed in the control room for IF-205, and CTD probes were installed in the sounding tubes for wells IF-205 and IF-201.

Figure 6: installing probe in IF-205

Figure 7: unwinding probe cable

The probes hang from communication cables which allow access to the probe without raising it out of the well. The probe information can be read in real time, or data can be logged and downloaded at a later date.

Principal Findings and Significance

As of May 18, 2011, the probes are collecting data on the tidal influence of the dynamic water level in the wells, and the change in conductivity at the level of the probes. The data has yet to be downloaded or analyzed.

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

Basic Information

Title:	The Influence of Sediment Load and Riparian Vegetation on the Diversity and Habitat use of Native Streamfish and Invertebrates of Guam.
Project Number:	2010GU166B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	N/A
Research Category:	Biological Sciences
Focus Category:	Ecology, Surface Water, Sediments
Descriptors:	Riparian Vegetation, Sedimentation, High Island, Streams, Surface Water, Streamfish, Macroinvertebrates, Canopy, Microhabitat, Freshwater, Savanna, Sediment Trap
Principal Investigators:	Frank Camacho

Publications

There are no publications.

PROJECT SYNOPSIS REPORT

Project Title: The influence of sediment load and riparian vegetation on the diversity and habitat use of native streamfish and invertebrates of Guam

Problem and Research Objectives

Insular streams and rivers are ecologically and culturally valuable resources on tropical high islands. As population growth on Micronesian high islands has increased over the past half century, watersheds have increasingly become threatened by anthropogenic disturbances. On Guam, deforestation in southern watersheds is largely the result of wildfires associated with illegal hunting activities; in these areas, riparian forests have been replaced by fire-adapted savanna vegetation. These savannas are associated with high levels of erosion and sedimentation and may be ineffective at preventing these particles from entering rivers. While considerable attention has been given to the effects of erosion and sedimentation on terrestrial systems and adjacent marine habitats (e.g., coral reefs and estuaries), how sediment load and the floristic composition of the riparian vegetation influence the ecosystem dynamics and biodiversity of the insular streams that transport these particles is poorly known. In order to address these gaps we have been examining the diversity, distribution, and abundance of streamfish and macroinvertebrate assemblages in stream reaches under different levels of (1) riparian canopy closure, (2) sediment load, and (3) vegetation type (i.e., savanna versus ravine forest). Furthermore, microhabitat usage, such as focal point substrate and current velocity, is being characterized.

Several key objectives are being addressed by this study: (1) This project will attempt to expand our current state of knowledge about how sediment load and canopy cover influence biodiversity and habitat use by native streamfish and macroinvertebrates; (2) a relational database will be created of streamfish densities and the various physical and chemical parameters of each habitat and will be provided to local resource agencies; (3) significant training in stream monitoring techniques will be available for an undergraduate student; (4) we will provide a public workshop on streamfish identification and monitoring methods based upon the results of our survey and analyses. This project will improve our understanding of the ecology of native streamfish and macroinvertebrates in relation to riparian vegetation and sediment load across several watersheds on Guam. Such fundamental information regarding how habitat use by these organisms is altered by high sediment loads and savanna vegetation is critically needed by resource managers in order to make sound decisions regarding restoration of these upland habitats

Methodology

Initially, stream reaches in four watersheds were established for study based upon (1) vegetation type (ravine forest versus savanna), (2) minimum-maximum elevation of the particular reach, (3) stream order, and (4) stream gradient. However, logistical difficulties resulted in focusing our efforts in the Asmafines River in the village Umatac. Areas of stream reach were classified as savanna if the riparian community possessed > 50% linear coverage by savanna species. Maximum elevation, stream order, and stream

gradient were based upon USGS 7.5-minute topographic survey maps and information from Best and Davidson (1981).

Field Surveys

Three sites within the middle reach of the Asmafines River were surveyed with five run and pool habitats sampled at each site using visual census techniques. This method involved observing streamfish and macroinvertebrates *in situ* and counting the number of each species within a defined area of the river channel (i.e., a quadrat). In addition to the density of fish and invertebrates, observations of each individual fish and prawn were recorded, including (1) the focal point substrate used by the organism and (2) the size class of the individual. A digital flowmeter was used to measure mean current velocity from several points in the quadrat. Within each quadrat, physicochemical variables (temp, and dissolved oxygen)were estimated with a YSI Pro optical dissolved oxygen/multimeter.

The dominant species of plants comprising the riparian vegetation at each site was characterized by analyzing the linear coverage of each species along a 50 m transect placed left edge water (LEW) of the stream. Importance values (Brower and Zar, 1999) were calculated based upon these estimates of linear cover. Canopy closure was estimated with a 25-point moosehorn densiometer with a viewing angle of 6° from zenith (Garrison, 1947). While this device allows an observer to calculate the percent canopy closure in a strict sense, it has been found to correlate closely with percent canopy cover at viewing angles of 6° from zenith or lower. Within a particular run or pool habitat, four readings were made from each corner of the quadrat and one reading will be taken from the center of the quadrat.

Sediment traps (n=4) were to be placed in each cascade, run, or pool that will be surveyed. These tubes were to be constructed from PVC following the methods of Hedrick et al. (2005). However, these traps were prone to washout and overfilling and were deemed unreliable. Therefore, as a measure of the degree of sedimentation in a particular habitat, visual estimates of percent substrate cover were made based upon the substrate classification scheme of Kaufmann et al. (1999).

Principal Findings and Significance

Differences in substrate use was apparent for the most common native streamfish, *Stiphodon* cf. *elegans*, which occupied boulders significantly more frequently than other substrate types (Figure 1). In contrast, freshwater prawns (*Macrobrachium lar*) were most frequently observed on sandy substrates (Figure 2).

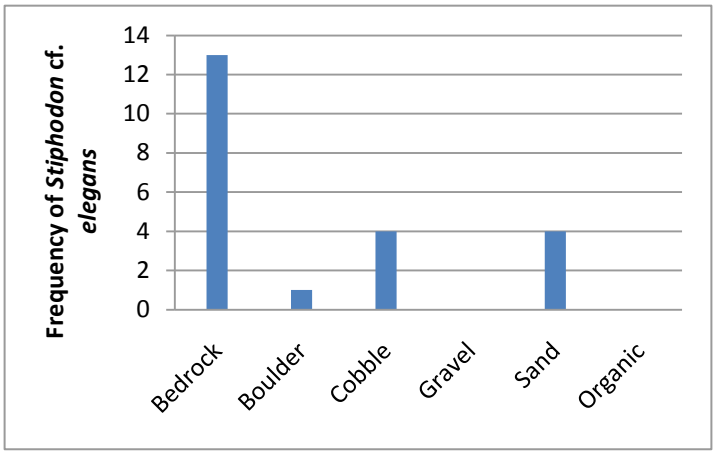


Figure 1. Frequency of *Stiphodon* cf. *elegans* on different substrate types in run and pool habitats of the Asmafines River on 5/4/2010. *Stiphodon* occupied boulders significantly more frequently than other substrates (Pearson chi-square=20.167; df=4; p<0.01)

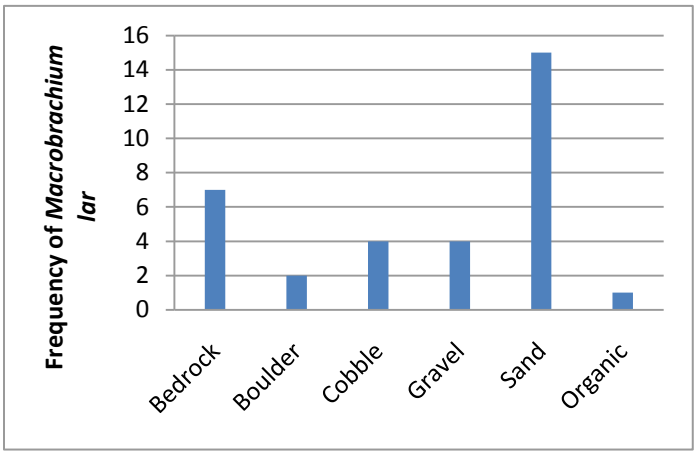


Figure 2. Frequency of *Macrbrachium lar* on different substrate types in run and pool habitats of the Asmafines River on 5/4/2010. *Macrobrachium* occupied boulders significantly more frequently than other substrates (Pearson chi-square=23.545; df=5; p<0.01).

Surveys of riparian vegetation revealed that *Miscanthus floridulus* was the dominant grass lining the channel of the Asmafines River in areas with low canopy cover. This is a fire-adapted grass that dominates the southern landscape. This species had the highest importance value (IV=1.434) at Site C. This area also had the lowest percent canopy closure (Figure 3). The other two sites (A and B) were mostly comprised of woody trees and shrubs (e.g., *Cocos nucifera* and *Pandanus tectorius*), with *Miscanthus* being a much less conspicuous component of the riparian community. However, no clear relationship between percent canopy cover and streamfish densities was observed for the most common gobiid species (*Stiphodon* cf. *elegans*) encountered in the Asmafines River.

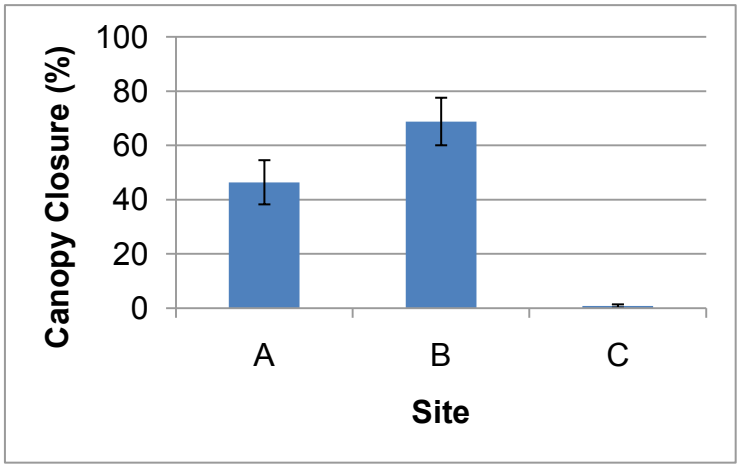


Figure 3. Mean percent canopy closure (± 1 S.E.) at three sites in the middle reach of the Asmafines River. Sites A and B were comprised woody trees and shrubs while site C was dominated by the savanna grass *Miscanthus floridulus*.

These results provide insight into the habitat requirements of native streamfish and prawns in Guam streams and will serve as a useful tool for resource managers in determining alterations in substrate and sediment input. In particular, streamfish such as *Stiphodon* may be negatively affected by increased sediment loads that obscure the surfaces of bedrock in runs and pools. This project is ongoing and it is expected to expand to include the Geus River in Merizo and portions of the Cetti River.

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Reconstructing the Pre-Historic Rainfall-Drought History of Guam

Basic Information

Title:	Reconstructing the Pre-Historic Rainfall-Drought History of Guam
Project Number:	2010GU169B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	N/A
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Drought, Geochemical Processes
Descriptors:	West Pacific Climate Record, Speleothem, Dripwater Chemistry
Principal Investigators:	John Jenson

Publications

1. Miklavič, Blaz., 2011, Formation of Geomorphic Features as a Response to Sea-Level Change at Ritidian Point, Guam, Mariana Islands “MS Dissertation”: Department of Geosciences, College of Arts & Sciences, Mississippi State University, Starkville, Mississippi, 86 p.
2. Miklavič, Blaz, John Mylroie, John Jenson, and Danko Taboro¨i, 2010, Abstract: Using Sea-Level Notches And Flank Margin Caves As Relative Sea-Level Change Indicators On Guam, A Volcanic Arc Island, The First Joint International Conference of the International Geological Correlation Programme, Volume Preparing For Coastal Change: A Detailed Process-Response Framework For Coastal Change At Different Timescales, Abstract: Hong Kong, 30 Nov-4 Dec 2010, INQUA Coastal And Marine Processes Commission.
3. Miklavič, Blaz, John Mylroie, John Jenson, Richard Randall, Jay Banner, and Judson Partin, 2010, in review, Interglacial limestone and its geomorphic features on Guam: implications for relative sea level changend flank margin cave formation, in Gamble, D.W., ed., 15th Symposium of the Geolgy of the Bahamas and other Carbonate Regions: Gerace Research Center, San Salvador Island, Bahamas, 17-21 June 2010.
4. Miklavič, Blaz, John Jenson, and John Mylroie, 2010, Program and Abstracts: Interglacial Limestone And Its Geomorphic Features On Guam: Implications For The Relative Sea Level Change And Flank Margin Cave Formation, 15th Symposium on the Geology of the Bahamas and Other Carbonate Regions: Gerace Research Center, San Salvador Island, Bahamas,, 17-21 June 2010, p. 26-72.
5. Miklavič, Blaz, John Jenson, and John Mylroie, 2010, Program and Abstracts: Syngenetic Cave Development on Guam, Mariana Islands, National Speleological Society Annual Meeting, 2-6 August, 2010, Essex Junction, Vermont, p. 50.

PROJECT SYNOPSIS REPORT

Project Title: Reconstructing the Pre-Historic Rainfall-Drought History of Guam

Problem and Research Objectives

This project was the latest in a decade of collaborative exploratory research of the karst and caves of the Mariana Islands by Dr. John Jenson of WERI and Dr. John Mylroie of Mississippi State University, in which they and their students have systematically explored and mapped the karst features and caves of the uplifted carbonate islands in the Western Pacific (Jenson et al., 2006; Keel et al., 2004; Mylroie et al., 2001; Mylroie et al., 2006; Stafford et al., 2004; Stafford et al., 2003; Stafford et al., 2005; Taboroši, 2000; Taboroši et al., 2005; Taboroši et al., 2004; Wexel, 2007). The central work of the study was a field investigation of the Pleistocene and Holocene deposits of northern Guam, which have already been surveyed sufficiently to map their general morphology and dimensions. Objectives included systematically mapping and studying these units in detail, to include identifying specific features and groups of features within the caves that may be associated with important geological or climatic events, and then determining the nature and relative timing of the events. Absolute ages calculated using the U-Th decay series (Edwards et al., 1987) established from previously collected specimens, as well as new ones collected during the proposed study, are being incorporated into ongoing laboratory analyses sponsored by separate funding (e.g., Partin et al., 2011, sumitted; Sinclair et al., 2011, submitted; Sinclair et al., 2008). Products include a graduate thesis (Miklavič, 2011) containing a set of detailed maps, with accompanying chronologies and descriptions of the inferred history of the caves as represented from the maps. Anticipated additional products include a WERI technical report and a professional paper.

Methodology

Field study included exploration of known caves and systematic searches of the terrain for undiscovered caves. Cave surveys employed the classic techniques of compass, tape, and inclinometer survey to map the dimensions and spatial relationships of cave features with accuracy and precision. The field team also surveyed and mapped the surrounding terrain and documented internal features and locations of samples from the caves. The stratigraphies and relative chronologies of the caves were studied and deduced by classic geologic field techniques. Samples were collected for thin-section analysis and radiometric dating.

Principal Findings and Significance

<u>Findings</u>: The Late Pleistocene Tarague Limestone deposits on the northern coast of Guam typically form a terrace up to 20 meters in elevation along the coast. Coral reef facies, and to a lesser extent, detrital facies, dominate the outcrops. In the study area (Miklavič et al., 2010, in review), the Tarague Limestone contains caves and coastal notches. The caves are dissolutional in origin and exhibit the attributes of flank margin caves, while the notches appear to be primarily bioeroded. The notches and a single cave in the Tarague Limestone are found ~4 meters above present sea level, matching the elevation of the Mid-Holocene Merizo Limestone surface in this area. Both the cave and

the notches are sea-level still-stand indicators, with restricted possible times of origin. This relationship suggests that they could have formed during the Pacific Mid-Holocene sea-level highstand (4.75 – 2.75 ka BP), and then undergone some subsequent tectonic uplift. Other Tarague caves, however, show higher elevations at 7 meters. U/Th age of 36 ka for speleothems from one of these 7-meter high caves suggests the cave formed during an earlier and lower sea-level still-stand; thus, the caves would have to have been subsequently uplifted to their present elevation. The MIS 5a and 5c interstadials are thus the most likely sea-level events to have formed these caves.

Significance: This study thus provides new constraints on the rates of tectonically-induced sea-level change on Guam, and the rates of cave development during the major climatic events/sea-level stands of the past 125,000 years. Data and insights gained by this work will further support the selection of additional promising speleothem specimens from which to derive higher-resolution climate records of the recent past, perhaps decadal or even annual records of the past few centuries or decades (cf., Fleitmann et al., 2004; Frappier et al., 2002; Zhang et al., 2008). They will also support judicious, targeted selection of a minimum number of specimens from which to construct an overlapping record of the entire history of the caves, which could span hundreds of thousands of years (e.g., Wang et al., 2008).

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Continuing Calibration and Application of LUOM in Southern Guam Watersheds

Basic Information

Title:	Continuing Calibration and Application of LUOM in Southern Guam Watersheds
Project Number:	2010GU170B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	N/A
Research Category:	Climate and Hydrologic Processes
Focus Category:	Models, Water Quantity, Water Supply
Descriptors:	Numerical Model, LUOM, Distributed Watershed Modeling.
Principal Investigators:	Charles Luo, Shahram Khosrowpanah

Publication

1. Luo, Q.C. and S. Khosrowpanah, 2011, Continuing Calibration and Application Of LUOM in the Southern Guam Watersheds, Technical Report No.131, Water and Environmental Research Institute of the Western Pacific, University of Guam, Mangilao, Guam, 97 pp.

PROJECT SYNOPSIS REPORT

Project Title: Continuing Calibration and Application of LUOM in Southern Guam Watersheds

Problem and Research Objectives:
In a preceding study, DEM, vegetation, soil, rainfall, and streamflow data were collected, and hydrologic watershed boundaries and stream networks delineated for several southern Guam watersheds (Luo and Khosrowpanah, 2010). The *Large-scale, Unified, and Optimization Model (LUOM)* (Luo, 2007), was calibrated against available rainfall and flow data from the Ugum watershed and four other watersheds, and provided missing streamflow data for these watersheds and seven other watersheds for which flow data was not available. Combining all available climate stations in southern Guam provided 54 years of rainfall data from which a time series of streamflow data were generated by the calibrated model for all 12 watersheds.

The objective of the project described herein, was to continue the calibration and application of LUOM for the southern Guam watersheds not covered earlier. Using the data collected in the preceding project, LUOM was calibrated against available data from three major (Talofofo, Ylig, Pago) and two minor (Atantano and Finile) watersheds. The calibrated model was then used to fill in the missing streamflow data for these watersheds and for several other southern Guam watersheds for which no prior streamflow records exist.

Methodology:
LUOM is a fully physically based, 2-dimensional distributed watershed model and was the main facility or tool used in this project. The diffusive wave approximations of the two-dimensional free surface flow equations were employed as the governing equations for the surface flows and included both overland and channel flows. The diffusive wave model is able to simulate backwater phenomena, in which the water may flow from the downstream reaches or the estuary to the upstream reaches of a river. The model is also able to simulate flows on the overland area with a zero slope. In this model, both overland and channel flows were placed in the same physical domain, in which a channel grid cell exchanges mass and momentum with the eight adjacent grid cells of overland, channels and water bodies. The finite difference method is utilized to discretize the governing equations and the optimization numerical scheme, SIMPLE, is employed to solve the finite difference equations using a tri-diagonal matrix. This method is based on the staggered grid scheme, in which the vectors of velocity were defined at the borders of the grid cell and the water depth was defined at center of the grid cell.

The surface flow model was coupled with models for evapotranspiration, infiltration and groundwater recharge, water exchange between aquifers and channels, and groundwater. In the evapotranspiration model (Luo, 2000), the combined method of energy balance and aerodynamics were used to calculate the potential evapotranspiration or reference crop evapotranspiration. The actual evapotranspiration was obtained by multiplying the reference crop evapotranspiration by a crop coefficient and a soil coefficient if the soil

moisture supply was sufficient; otherwise it is controlled by the maximum soil water or moisture that could be evaporated. In the infiltration and recharge to groundwater model, the two-layer Green-Ampt infiltration model was employed to calculate the infiltration. The water exchange between aquifers and channels was computed by Darcy's law, and the groundwater model provided the numerical solution of the Boussinesq equation using the finite difference method.

Principal Findings and Significance:
This study continued to calibrate and validate LUOM (Luo, 2007) in southern Guam watersheds not covered in the earlier study (Luo and Khosrowpanah, 2010). Once calibrated, the model was used to generate a long-term, time series of streamflow data for watersheds having no prior no streamflow records. In the current work, the model was calibrated in five watersheds gauged by USGS, namely the Talofofo, Ylig, Pago, Atantano and Finile watersheds. There are eight USGS streamflow gages in the Talofofo watershed, and the times over which data were collected from four of them coincided with rainfall data collections at the six USGS/NCDC rain gage sites located either within the watershed or close by. The LUOM was subsequently calibrated and validated with data from these four flow gages to provide streamflow estimates for 10 additional watersheds in this part of the island.

This modeling work is of considerable importance to Guam and other island in Western Pacific and will greatly assist with the successful implementation of sustainable management practices within watersheds throughout the region. By generating previously unknown flow estimates for ungaged river systems, the model allows researchers to develop correlations between streamflow, rainfall, and turbidity at various sections of a watershed. Such numerical relationships are vital for evaluating the appropriateness of specific watershed management practices. In Pohnpei, for example, all surface water quality monitoring was carried out by the US Geological Survey until shortly after the political status of the Federated States of Micronesia with the United States changed from Trusteeship into Free Association in 1986. Conservationists and resource managers for this part of the world urgently need updated streamflow and suspended sediment data in order to determine the true impact of fluvial discharges on coral reef communities in the area. This information could be made available with the hydrological model developed here. Finally, the methodology for producing streamflow estimates should also be of considerable interest to local water authorities tasked with exploring new surface water sources of drinking purposes. On Guam, for example, the availability of streamflow data will certainly help engineers identify potential sites for small dam construction in the island's southern watersheds.

Applications of LiDAR Data for Inarajan Watershed Management

Basic Information

Title:	Applications of LiDAR Data for Inarajan Watershed Management
Project Number:	2010GU171B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	N/A
Research Category:	Climate and Hydrologic Processes
Focus Category:	Methods, Models, Management and Planning
Descriptors:	LiDAR, Hydrological Model, Watershed
Principal Investigators:	Yuming Wen, Shahram Khosrowpanah

Publications

There are no publications.

PROJECT SYNOPSIS REPORT

Project Title: Applications of LiDAR Data for Inarajan Watershed Management

Problem and Research Objectives

Guam, an unincorporated U.S. territory in the western Pacific, is the largest (about 541.3 km^2) and southernmost island in the Mariana Islands. The population of Guam has gradually increased since WWII and currently stands at around 180,000. This is likely to increase dramatically in the near future as military personnel and their dependants are relocated to the island from Japan starting 2014. One estimate has it that the island's population will approach 250,000 by 2020 as a result of the military build-up. Clearly this will add significantly to Guam's current problems associated with water production and supply, and solid and hazardous waste disposal.

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

As part of the Consent Decree, Guam is required to site and must design, construct, and operate a landfill that is fully compliant with Guam's solid waste disposal rules and regulations. As part of the agreement, the landfill required to be in operation by September 23, 2007, or earlier. Within the constraints of the Consent Decree and in accordance with the 2000 Integrated Solid Waste Management Plan (ISWMP), the Government engaged in a site screening and site selection process. Based on the selection process, an area in Layon, Dandan, Inarajan, was selected for the future landfill site.

This research proposal focuses on applications of LiDAR data collected in early 2007 for Inarajan Watershed management purposes. In this project, GIS and related technologies such as remote sensing were used to collect, organize, model and analyze data on watershed characteristics. Remote sensing could be applied to collect data for hard-to-reach areas and to update the GIS database, while GIS, enhanced by remote sensing and spatial analysis capabilities, was the core tool for this project. The overall objective of the project was to identify critical watershed characteristics from LiDAR data for the Inarajan Watershed. The main objectives of this project are listed as follows:

1. Process the LiDAR data collected in early 2007 for delineation of the Inarajan Watershed
2. Use hydrological model to delineate the Inarajan Watershed
3. Obtain watershed characteristics for the Inarajan Watershed.

Methodology

GIS, remote sensing and geospatial statistics were used to complete the project. LiDAR data collected from February to May 2007. Land cover data, satellite imagery and existing GIS data for Inarajan Watershed, and new landfill site selection information were available. The GIS Lab at the Water and Environmental Research Institute (WERI) is equipped the state of the art computers and ArcGIS software with extensions such as Spatial Analyst, 3D Analyst, and Geostatistical Analyst. Other geospatial technologies related software such as Erdas Imagine, and open source GIS software including GRASS and Quantum GIS are also available at the GIS Lab. ArcGIS and remote sensing software at the GIS Lab were applied to process and analyze the LiDAR data to get watershed characteristics information. The primary model used was the hydrological model in ArcGIS Spatial Analyst.

Principal Findings and Significance

It takes a lot of space to store raw LiDAR data for Guam, and it's time consuming to process the data. There are 656 coverages or blockes of LiDAR digital elevation data available for Guam (Figure 1). However, the project only focused on the Inarajan Watershed, and only 1 meter digital elevation data focusing on Inarajan Watershed was applied. 44 coverages of LiDAR data were employed for this project. All of the 44 coverages of data were merged into a single raster data for further processing. In order to accurately delineate the boundary of the Inarajan Watershed, a buffer distance of 250 meters was utilized to buffer the watershed boundary mapped from DEM data of 10 meters spatial resolution. Such a buffer distance should be large enough for accurate delineation of the Inaranjan Watershed from the LiDAR data. However, this was a challenge to use the LiDAR data since there are a lot of gaps. The gaps must be filled before use. There are two feasible ways to fill the gaps, one is to use DEM data from USGS to fill the LiDAR data gaps, and the other to apply spatial interpolation methods to estimate the values for the gaps. DEM data was employed to fill the gaps for this project. Sinks needed to be found, and filled for a hydrological modeling purpose. Then the hydrological model in ArcGIS was utilized to map the boundary of the Inarajan Watershed. A hydrological edge was defined so that all areas trained to the general Inarajan Bay as a unified watershed (Figure 2). Some of the watershed characteristics such as slope and aspect could be derived from the processed LiDAR data. The processed LiDAR data also can be used to calculate parameters for the universal soil loss model (USLE) slope length, and other applications such as visibility, suitability, and robust farming planning. The updated LiDAR data will be beneficial to the new dump site design and management located within Inarajan Watershed and environmental modeling and assessment potentially affected by the new dump site (Figure 3).

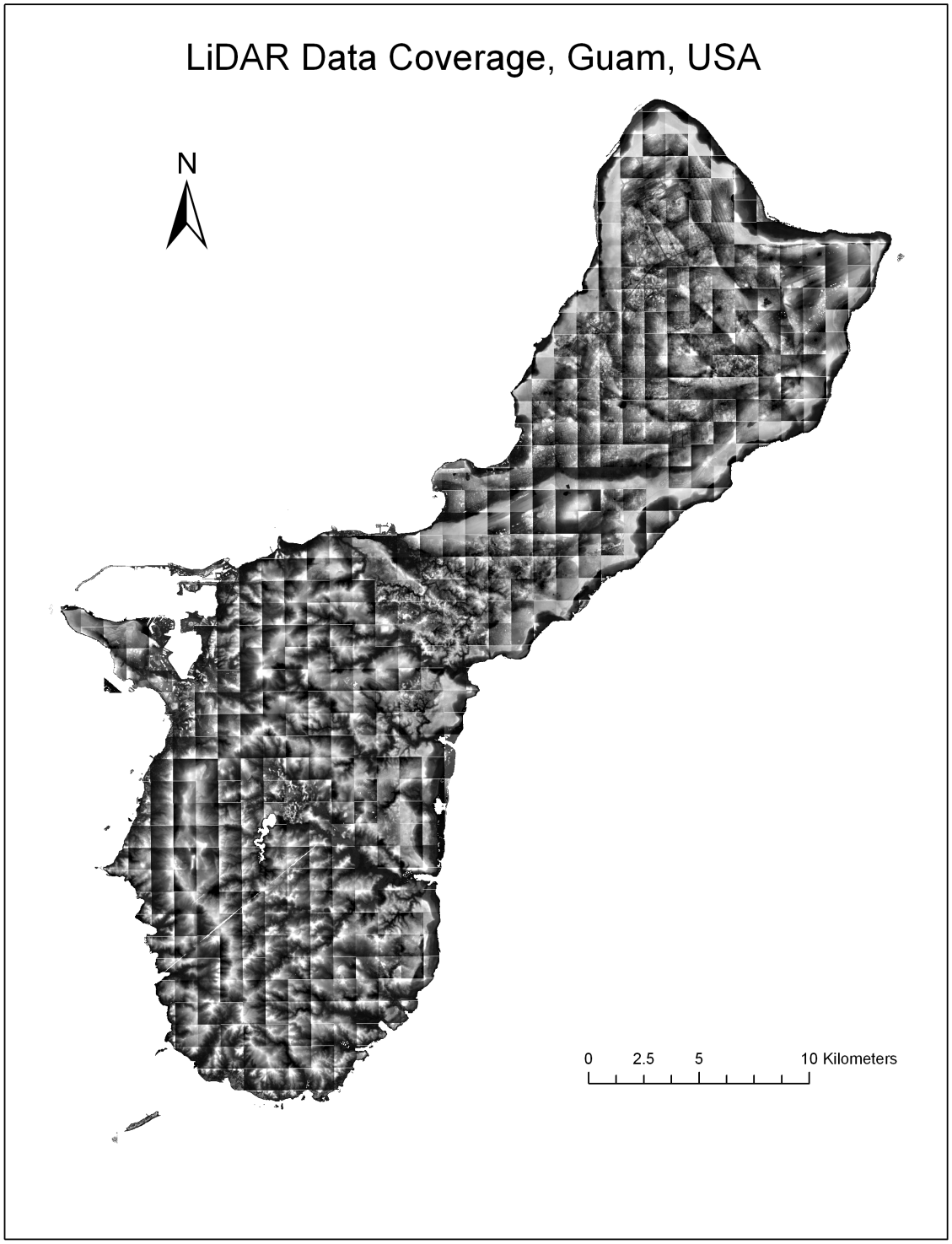

Figure 1. LiDAR Data Coverage on Guam

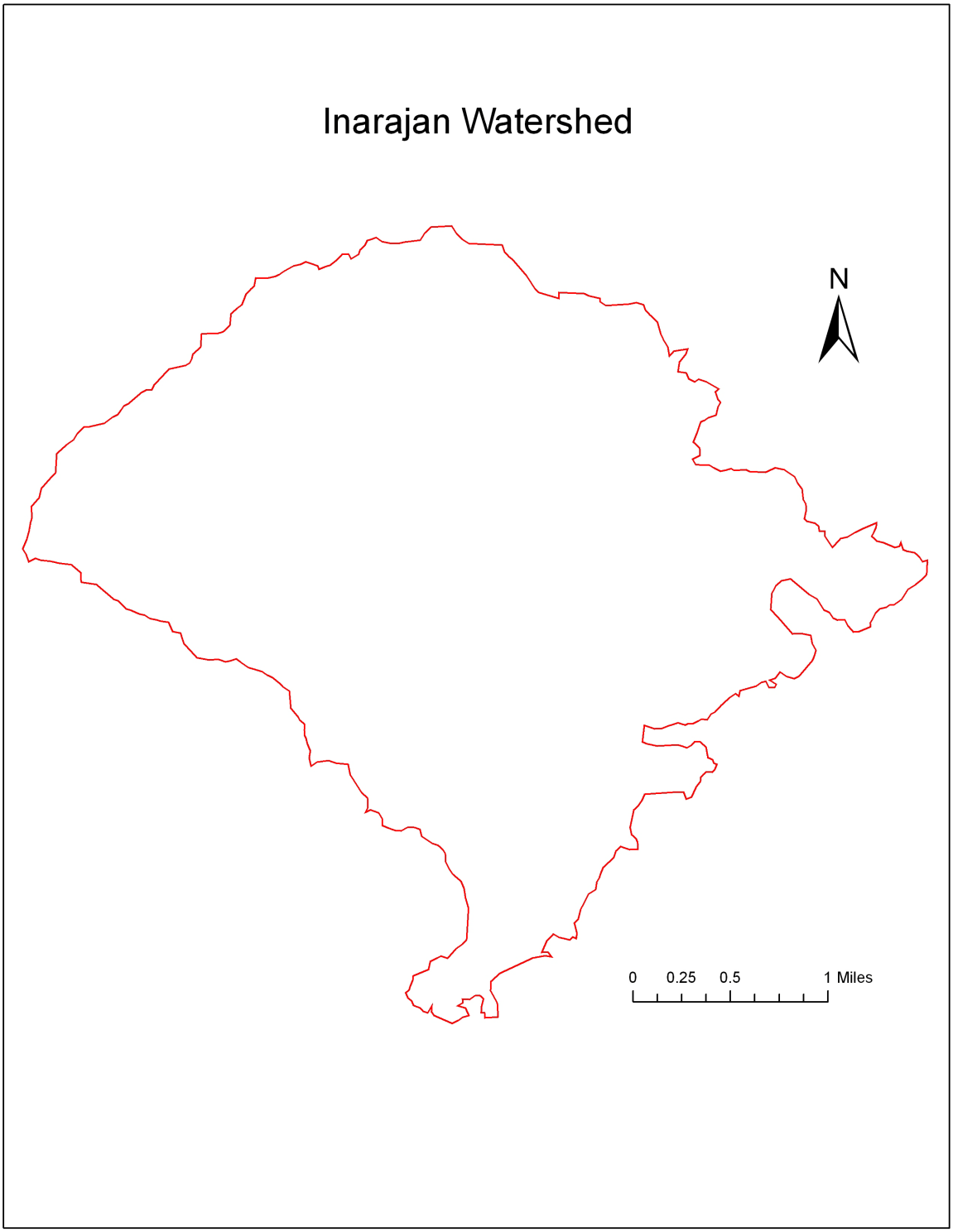

Figure 2. Boundary of the Inarajan Watershed

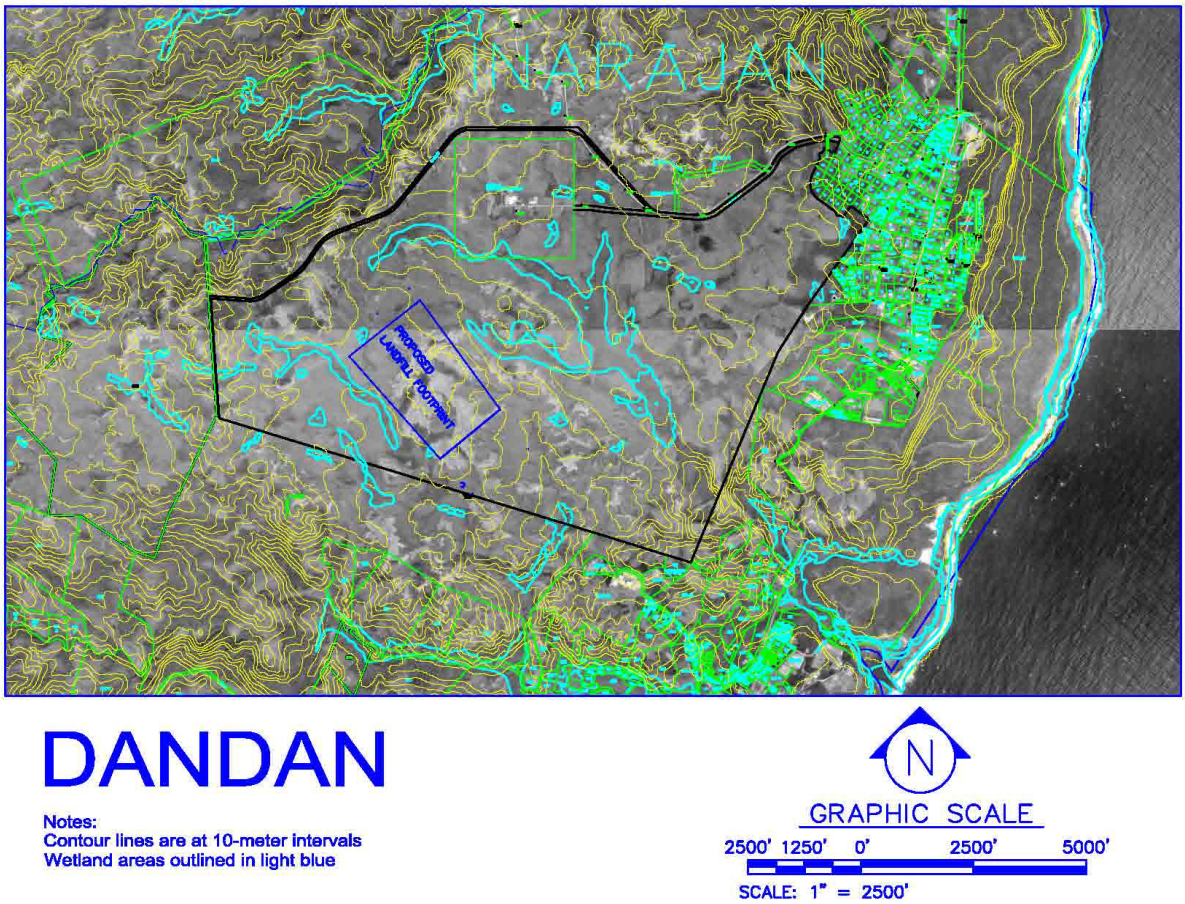

Figure 3. New Landfill Site in Layon, Dandan, Inarajan, Guam

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

Basic Information

Title:	Impact of Urban Runoff, Wastewater Discharges and Past Solid Waste Disposal Practices on Contaminant Profiles in Fish from Saipan Lagoon
Project Number:	2010GU174B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	N/A
Research Category:	Water Quality
Focus Category:	Toxic Substances, Non Point Pollution, Water Quality
Descriptors:	Monitoring, Fish, PCBs, Mercury, Lead, Saipan,
Principal Investigators:	Gary Denton, Michael Trianni

Publications

There are no publications.

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

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

A pollution monitoring and assessment program for Tanapag Lagoon was initiated by WERI in 1997. We now have a reasonable understanding of the distribution and abundance of contaminants of primary concern (heavy meatals and PCBs) in biotic and abiotic components within this water body (Denton *et al.* 2001, 2006, 2008, 2009). In 2004, relatively high levels of mercury were discovered in fish captured off Hafa Adai Beach at the northern end of Garapan Lagoon (Denton *et al.* 2010). The source of the mercury contamination was later traced back to an old incinerator site at the local hospital about 1 km inland (Denton *et al.* 2011). The incinerator was operational for about 20 years before it was closed down by USEPA in 2006 for multiple violations of the Clean Air Act (USEPA 2005). These findings prompted a more intensive study of contaminant abundance in the southern half of Saipan Lagoon starting with an evaluation of storm drain sediments and nearshore biota in 2008 and offshore sediments in 2009. A notable outcome of these investigations was the identification of substantial lead and copper contamination in sediments and bivalve mollusks at the southern end of Chalan Kanoa Lagoon (Denton and Starmer 2010). The source of this contamination remains to be identified but is believed to be associated with a nearby dumpsite. The study described herein examined mercury, lead and PCBs in fish from selected sites in Garapan Lagoon and was considered a logical extension of the monitoring work already competed. Specimens were also taken from Tanapag Lagoon for comparative purposes.

Methodology:
Two common fish types were selected for analysis, the squirrel fish, *Myripristis* spp, and the emperor, *Lethrinus* spp. Both fish types are widespread throughout the region, have limited foraging ranges and are highly favored table fish by local fishermen. Specimens were collected

from fringing reef/reef shoals (*Myripristis* spp.) and seagrass beds (*Lethrinus* spp.), from seven sites along the entire length of Garapan Lagoon (Figure 1) using spear gun and hook and line. Neither fish types were found at all sites. Representatives were also taken from various sites in Tanapag Lagoon for comparative purposes. Captured specimens were immediately placed on ice and transported to the laboratory for dissection after body weight and length determinations were taken. Axial muscle was removed from both sides of each fish for contaminant analysis followed by homogenization and freeze drying. The analytical procedures and protocols adopted were essentially the same as those described earlier (Denton *et al.* 1999).

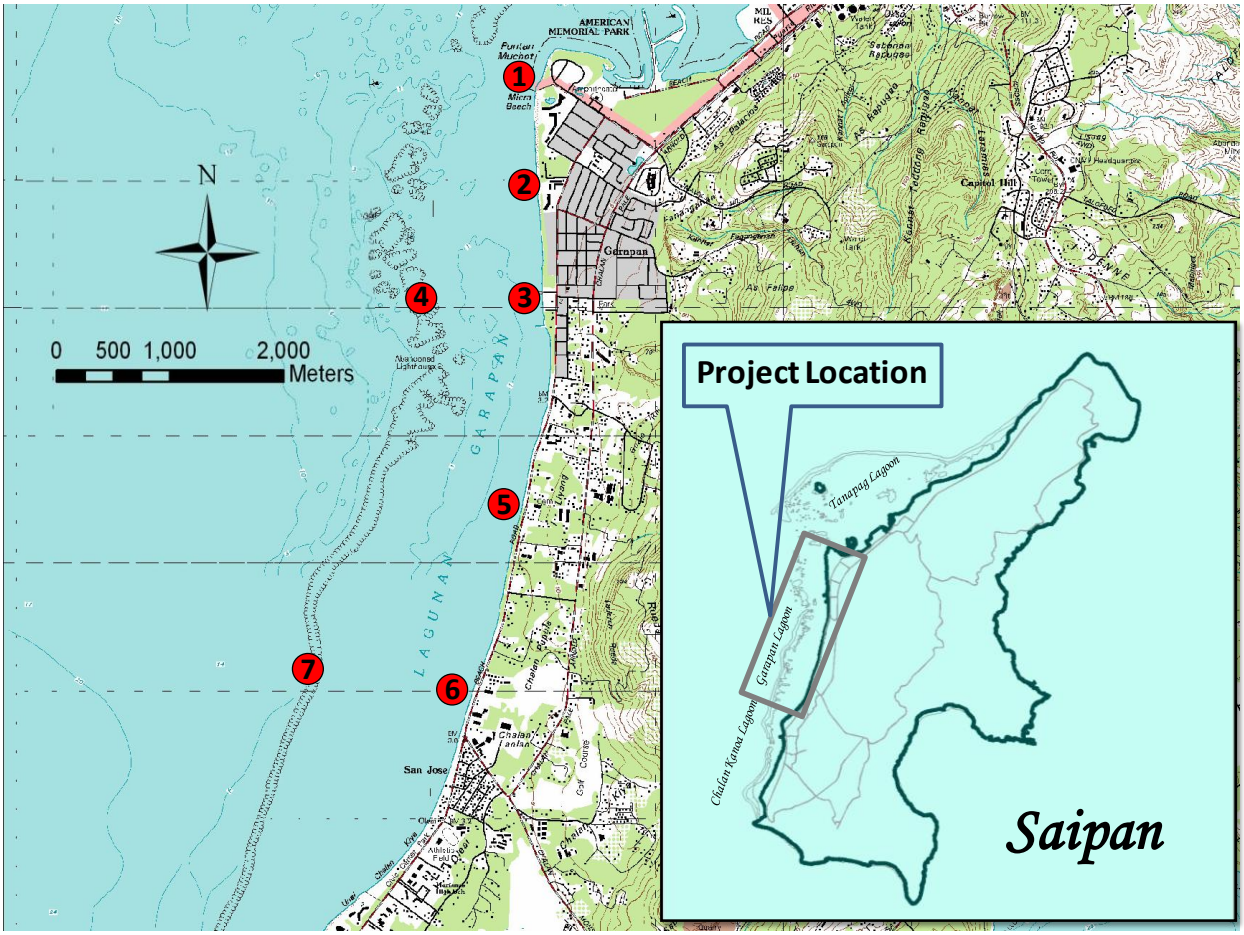

Figure 1: Map of Saipan (15°12'N, 145°43'E) showing project location (inset) and fish sampling sites within Garapan Lagoon.

Principal Findings and Significance

All the data reported herein, including all referenced values, are expressed on a wet weight basis unless otherwise stated.

Mercury

Fish naturally supply a greater proportion of dietary mercury to man than any other food and levels found in specimens from non-polluted waters generally range between 0.001-0.100 µg/g in muscle tissue (Holden 1973) The great majority of fish examined during the present study were within this range (Figs. 2-3).

Almost all of the mercury in fish (80-100%) exists in the highly toxic methylmercury form (Bloom 1992). The U.S. Food and Drug Administration 'action level' for methylmercury currently stands at of 1.0 µg/g (USFDA 2000). This standard is generally considered inadequate for the protection of human health because it fails to take into account fish consumption frequencies. The USEPA fish consumption guidelines for methylmercury recommend that only fish with mercury levels of less than 0.03 µg/g in their edible tissues can be consumed on an unrestricted basis (USEPA 2000). Some US states consider this to be overly protective and adopt a less stringent standard. Iowa, for example, decrees that all fish containing <0.3 µg/g methylmercury are safe to consume with no meal restrictions (IDNR/IDPH 2006).

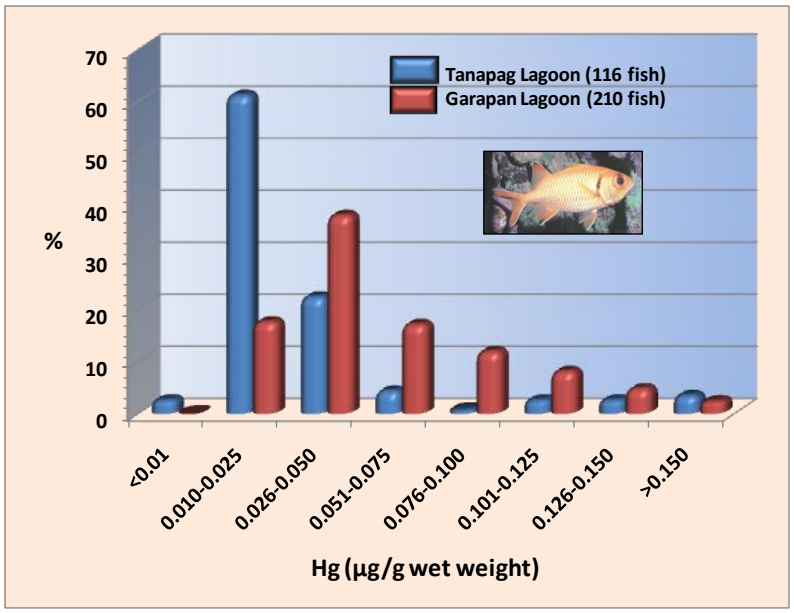

Figure 2: Total mercury in axial muscle of squirrel fish, *Myripristis* spp., from Tanapag and Garapan Lagoons.

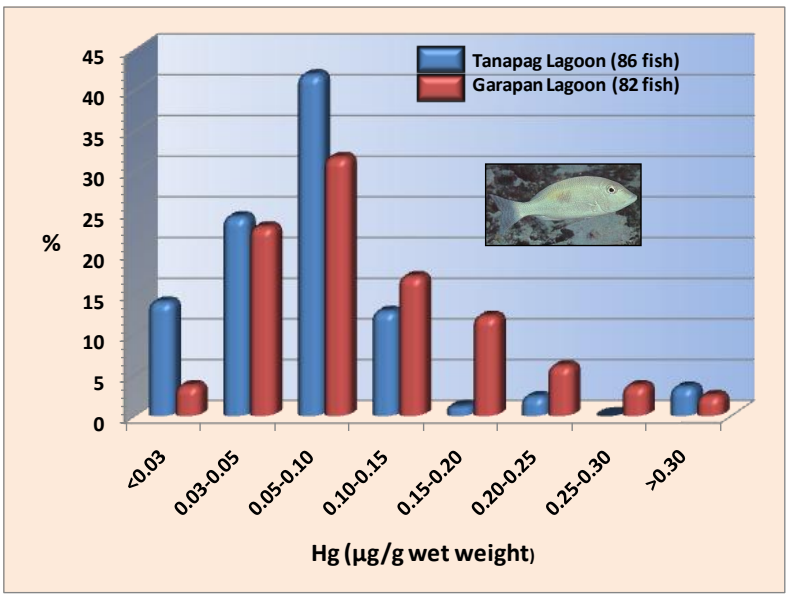

Figure 3: Total mercury in axial muscle of emperor, *Lethrinuss* spp., from Tanapag and Garapan Lagoons.

Fig. 2 suggests that ambient mercury levels available to *Myripristis* spp. in Garapan Lagoon are higher than those Tanapag Lagoon. This was concluded to be largely an artifact of size variations between populations of fish taken from each lagoon (Fig. 4). The data obtained from approximately equal size ranges and numbers of *Lethrinus* spp. captured from both lagoons support this contention (Fig. 5).

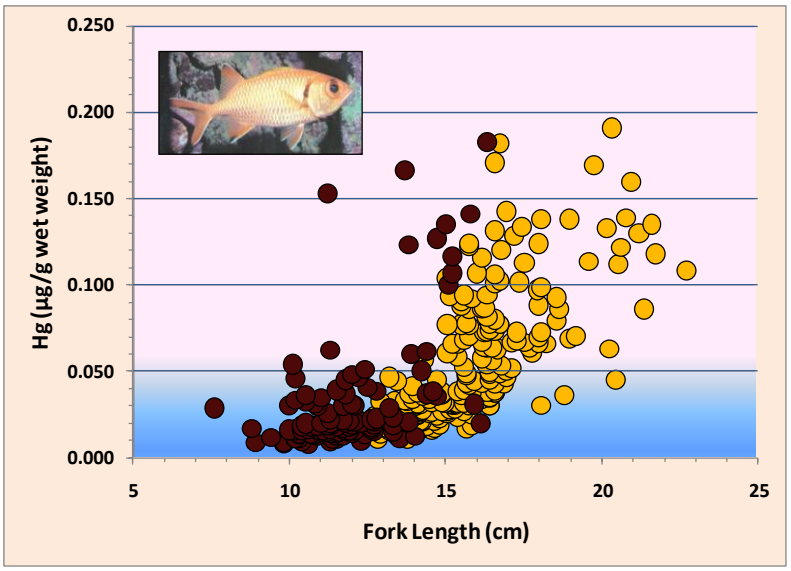

Figure 4: Scatter-plots of total mercury in axial muscle of squirrel fish, *Myripristis* spp., from Tanapag (red plots) and Garapan (dark plots) Lagoons.

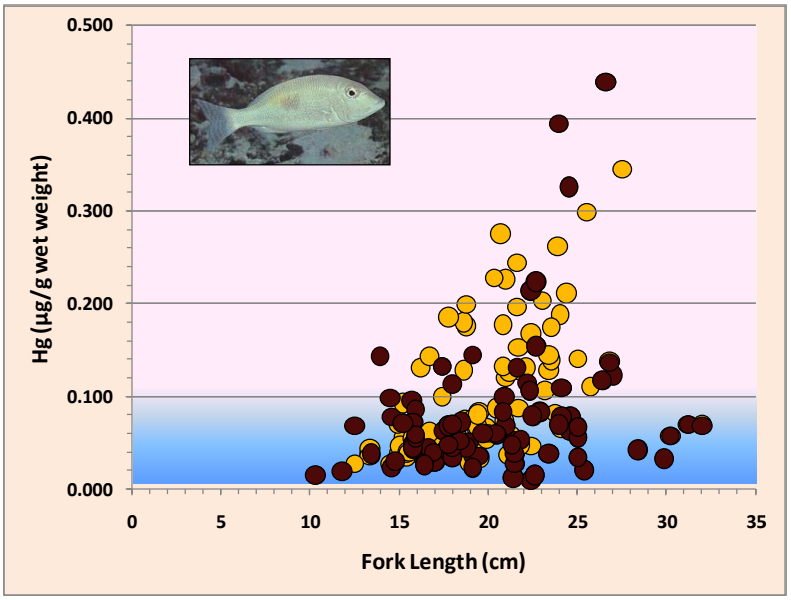

Figure 5: Scatter-plots of total mercury in axial muscle of emperor, *Lethrinus* spp., from Tanapag (red plots) and Garapan (dark plots) Lagoons.

Over all, the data suggests that both Tanapag and Garapan Lagoons are currently only lightly contaminated with mercury. Of special significance, here, is the fact that mercury levels in fish

from the Hafa Adai Beach (site 2) area in Garapan Lagoon appear to have attenuated markedly since the hospital incinerator ceased operation in 2006 (Fig. 6).

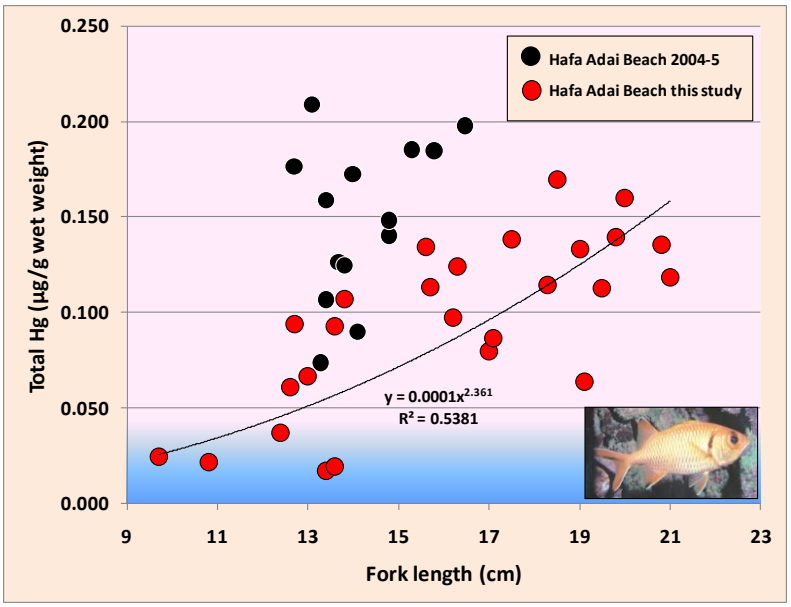

Figure 6: Mercury in axial muscle of *Myripristis* spp. before (black plots) and after (red plots) the medical waste incinerator at Saipan's public hospital was closed down by USEPA in 2006. Regression line fitted to most recent data.

Lead

Lead was not detected in the axial muscle of any fish analyzed during the present investigation. The limit of analytical detection was 0.1 µg/g or better in the great majority of samples analyzed.

It is generally acknowledged that human activities influence the lead content of marine teleosts although levels rarely exceed 3.0 µg/g even in the most polluted waters (Halcrow *et al.* 1973, Plaskett and Potter 1979). Portmann (1972) published mean lead levels ranging from <0.5-0.99 µg/g in various commercial fish species from UK coastal waters while Eisler (1981) concluded that lead levels in the majority of fish analyzed from U.S. coastal waters were 0.3-0.7 µg/g. Likewise, Bebbington *et al.* (1977) reported levels of 0.4-0.71 µg/g for commercial fish species from Australian waters. Based on these comparisons, lead does not appear to be a problem contaminant in fish from Garapan Lagoon or Tanapag Lagoon. Future studies will determine whether or not this pattern is repeated in fisheries resources from the more southerly Chalan Kanoa Lagoon. The high levels of lead known to exist in this part of Saipan Lagoon are of special interest in this regard.

PCBs

Saipan is not without its PCB problems and there have been extensive clean up and remediation activities associated with land-based sources of these contaminants in Tanapag village in the northern half of Saipan Lagoon (USEPA 2001, ATSDR 2001). Consideration of these contaminants in fisheries resources within the lagoon is therefore of critical importance.

From the literature, it is apparent that fish from relatively clean environments contain total PCBs in the low ng/g range whereas levels in specimens from contaminated waters may be two

to three orders of magnitude higher. The sum of the 20 PCB congers (Σ_{20}PCBs) measured in all fish during the current study ranged from 0.01-33.4 ng/g with a geometric mean value of 1.33 ng/g. No significant difference in PCB levels was found between the two fish types or between representatives from either lagoon. A frequency distribution histogram summarizing the pooled data from all fish for each lagoon is shown below (Fig. 7).

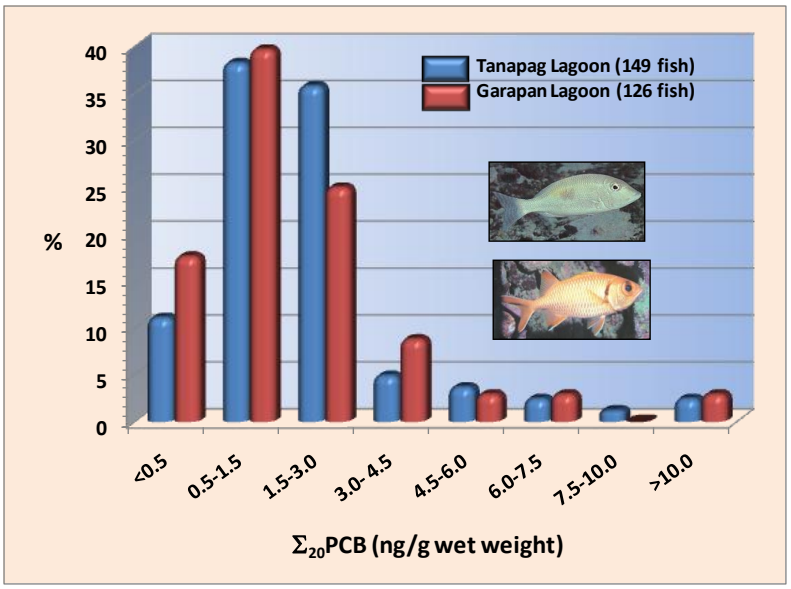

Figure 7: Σ_{20}PCBlevels in axial muscle of squirrel fish, *Myripristis* spp., and emperor, *Lethrinuss* spp., from Tanapag and Garapan Lagoons.

Tissue guidance levels for total PCBs in fish have been developed by the USEPA (2000) from non-cancer health endpoints. These advisories recommend that total PCBs in fish consumed on a daily basis (8-oz meal size) should not exceed 6 ng/g. Total PCBs in fish can be approximated from Σ_{20}PCB data using a multiplier of 2 (NOAA 1989). By this means it is apparent that almost 90% of all fish examined yielded total PCB concentrations within USEPA's unrestricted consumption guideline of 6 ng/g.

Based on the evidence presented, it would appear, then, that PCB levels in fish from the two lagoonal entities considered here do not currently pose a significant health risk to regular consumers.

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

Basic Information

Title:	Development of a GIS Data Base for Saipan's Drinking Water Delivery System
Project Number:	2010GU175B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	N/A
Research Category:	Engineering
Focus Category:	Models, Water Supply, Management and Planning
Descriptors:	Water Use Data, Water Demands, Distribution Systems, Model Studies, GIS Water System Management
Principal Investigators:	Shahram Khosrowpanah, Mariano Iglecias, Yuming Wen

Publications

There are no publications.

PROJECT SYNOPSIS REPORT

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

Problem and Research Objectives:
Saipan's water distribution system, which is operated by the Commonwealth Utility Corporation (CUC), is divided into 15 sub-regions as shown in Figure 1. Each sub-region (I.D. numbers shown in red on Figure 1) can be operated as a separate entity or connected with adjacent regions. Each sub-system consists of well or spring sources, transmission piping, tanks for storage of water, and distribution system piping to deliver water to the CUC customers.

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

A healthy water system that can perform its essential functions requires a good record of system inventory, location, connectivity, and maintenance practices. This information should be easily available to the water managers and field operators. Prior to this study, the water and wastewater inventory and maintenance data were being entered manually and stored in file folders. This created excess paperwork and it made it very difficult to track the frequency of maintenance, hard to provide information to the field operator groups, and created a lack of close communication between system managers and field operators. Additionally, there was no link between the physical hydraulic model of the water system that was previously created by WERI and the maintenance and system inventories. The objectives of this study were to: 1) Install GIS software on a newly purchased computer and provide three days training on the use of GIS and data entry to one or two personnel from CUC, 2) Export the information from Saipan's Haestad water system model into GIS layers, 3) Identify and create new data layers for features not included in the Haestad model but important for management of the CUC system, 4) Integrate the maintenance schedule and system inventories into GIS layers, 5) Make the data base available to the system managers and system operators.

This project concentrated on the drinking water side of the CUC operation. It is anticipated that in the future the data base will be extended to include the wastewater system and the data from water meters that are being installed. The benefit of this project will be to provide an improved and more efficient management and operation of the Saipan water system.

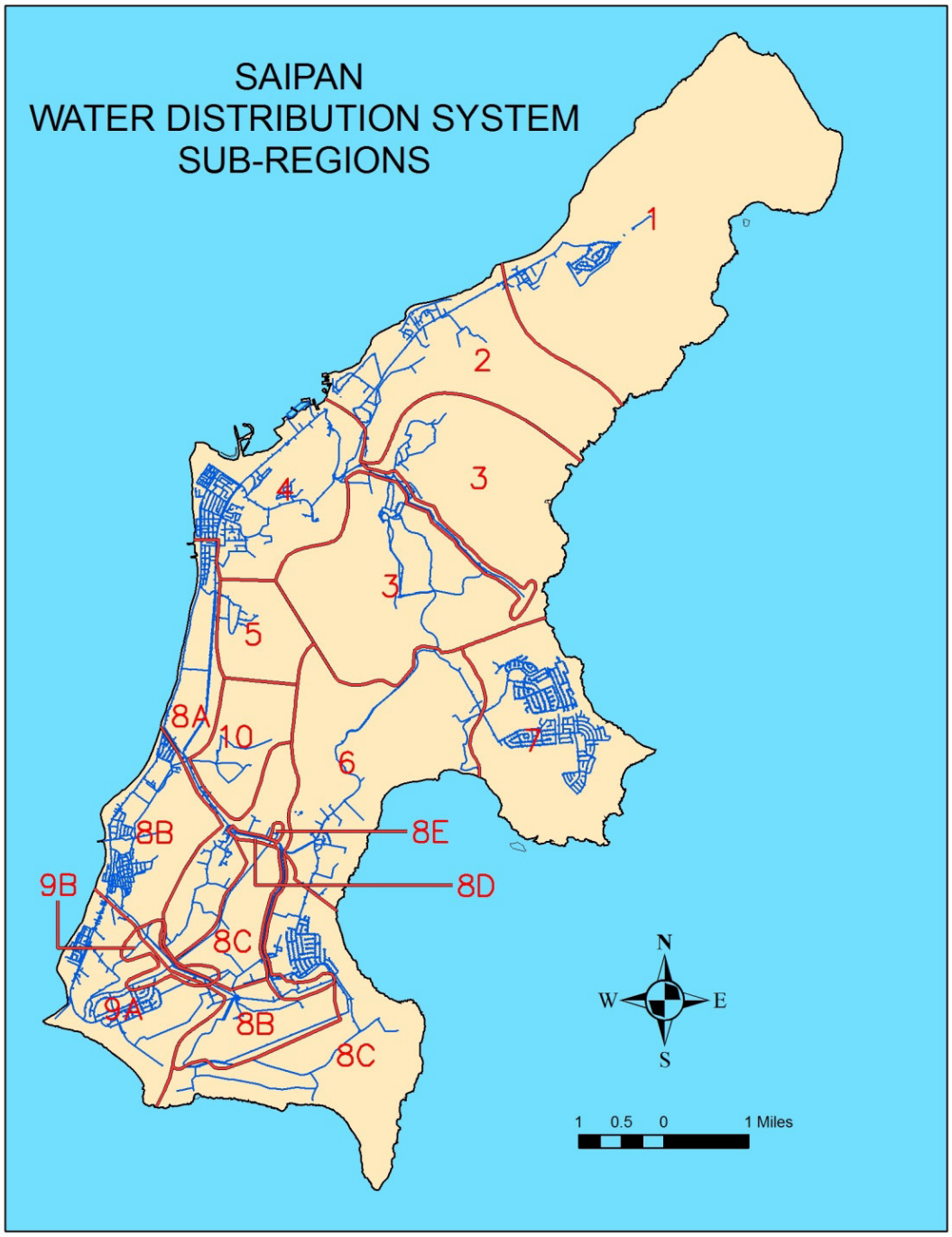

Figure 1. Saipan's Water Distribution System.

Methodology:
The overall objective of this study was to create a GIS data base that has all the system description and system maintenance information and make that information available to system managers and field operators. To accomplish the project's objectives, five steps were taken as described below:

I. **Instillation of compatible GIS software**
A copy of the Latest version of ArcMap software and a compatible computer that works with this GIS and CUC's Haestad Computer model was purchased for CUC. CUC now has a designated workstation that is compatible with CUC's GIS, data base, and water system model and that will be available to the water division staff.

II. **Exporting model data into GIS layers**
In close consultation with CUC water division staff it was decided that the new GIS that was to be developed should not be segregated by region as was shown in Figure 1. To accomplish this de-segregation, we applied various function of Haestad model to the each sub-region model that was developed from our previous studies. The next step was to determine what data layers were to be included in the GIS data layers and what attributes were to be included for each different layer. This again was accomplished with consultation with the CUC water division staff. Table 1 on the following page provides a list of the layers that are included in the data base along with a list of the management attributes that are included in the data base. The Haestad Software export tool was used to export the required feature data that was available in the model. This tool allows for any or all of the data available in the data table for a particular feature to be exported into ESRI shape file format. Figure 2 shows the completed GIS as viewed in the ArcMap program. Figure 3 shows sample attribute files for CUC Tanks, Pumps, and Pipes that are available in the GIS data Base.

III. **Designating new layers and their attributes**
Additional layers other than those available from the Haestad water system model data were determined by a series of meeting with CUC Water Division staff and other in CUC who have an interest in the GIS system. Table 2 shows the GIS management layers and their accompanying attributes that were added.

TABLE 1. GIS layers and management attributes from available Haestadt water system models

LAYER NAME	LAYER TYPE	ATTRIBUTE 1	ATTRIBUTE 2	ATTRIBUTE 3	ATTRIBUTE 4	ATTRIBUTE 5	ATTRIBUTE 6	ATTRIBUTE 7	ATTRIBUTE 8
Gate Valves	Point	Serial Number	Diameter	Elevation	Maker	Working			
Pressure Reducing Valve	Point	CUC Number	CUC Name	Diameter	Elevation	Set Pressure	Model	Status	
Pipes	Line	Label (Model Pipe ID)	Diameter	Length	Material	CH Value	Start Node	End Node	Installed Date
Tanks	Point	Label (CUC-Name and Model Tank ID)	Base Elevation	Maximum Elevation	Minimum Elevation	Total Active Storage	Tank Diameter	Picture *	
Well	Point	Label (CUC-Name and Model Well ID)	Elev (Ground Water Elevation)						
Pump	Point	Label (CUC-Name and Model Pump ID)	Pump Curve ***	Pump Maintenance Data **	Direct Feed To Customers (yes or no)				
Junctions	Point	Label (CUC-Name and Model Junction ID)	Elevation	People Served	Type of Fitting				

TABLE 2. GIS layers that were not available in the Haestad water system models

LAYER NAME	LAYER TYPE	ATTRIBUTE 1	ATTRIBUTE 2	ATTRIBUTE 3	ATTRIBUTE 4	ATTRIBUTE 5
Backflow Preventer	Point	CUC Number	Serial Number	Manufacturer	Customer Number	
Air Relief Valve	Point	CUC Number	Diameter	Manufacturer	Model	Status
Chlorination Point	Point	Treatment ID Number	Common Name	Region	Status	
Hydrants	Point	CUC Number	Serial Number	Manufacturer	Flush Date	

*Hyperlink to Picture of Tank **Hyperlink to CUC Excel Maintenance Data Base *** Hyperlink to Pump Curve
Underlined data layers were not available in the Haestad Model therefore next layers were constructed for these features

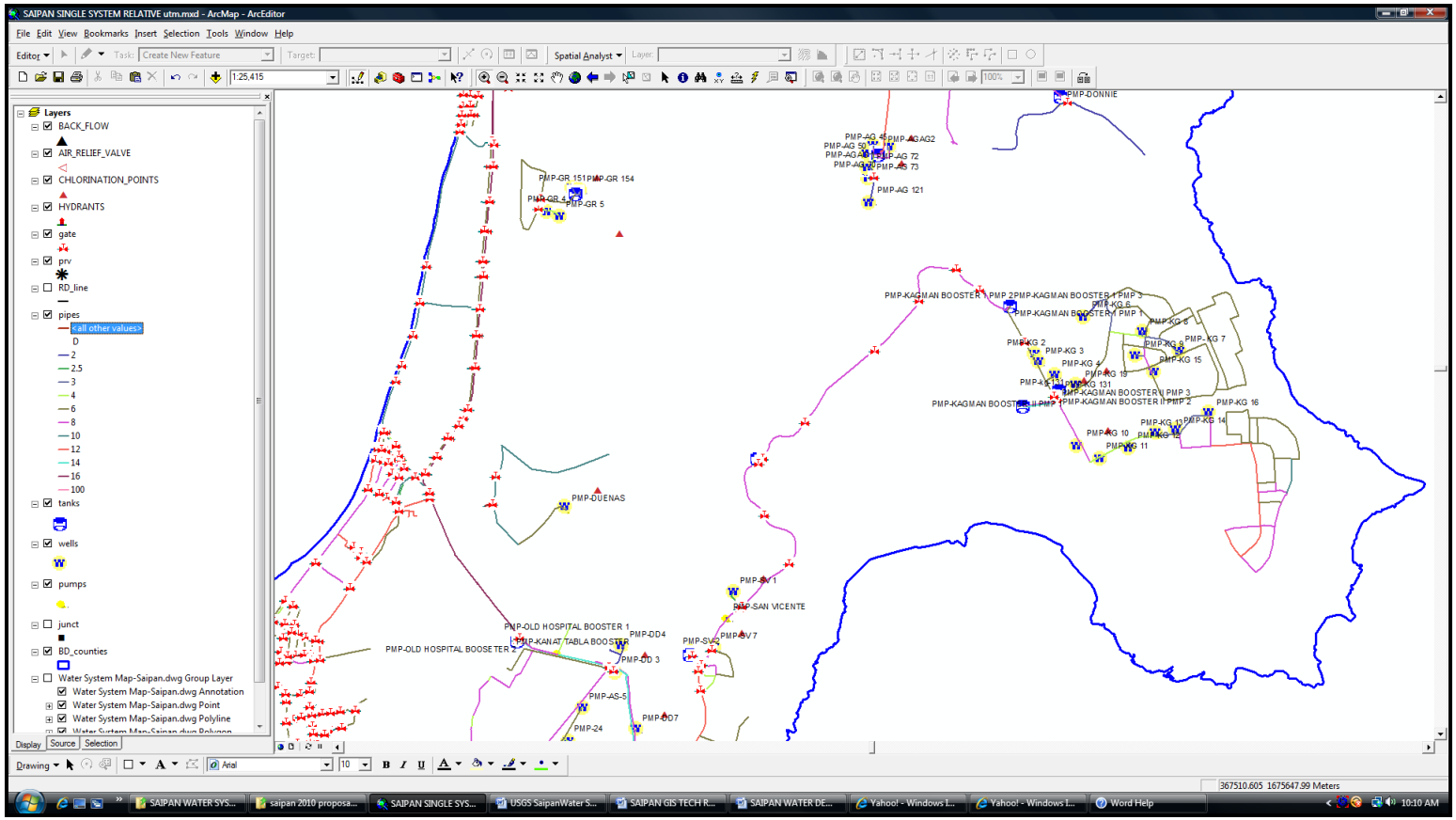

Figure 2. CUC Water System GIS Data Base as viewed in the ArcMap Program.

TANK ATTRIBUTE FILE

OBJECTID *	Shape *	LABEL	LABEL_1	DESC_	TOT_ACT	BASE_ELEV	H_MIN	INIT_HGL	MAX_ELEV	H_MAX	MIN_ELEV	H_MIN_1	VI	TANK_D	X	Y	
1	Point	T-ACHUGAO SUMP		ACHUGAO SUMP TANK	23937.66	233	0	237	241	8	233	0	0	0	183722.72	190116.68	
2	Point	T-MAUI		MAUI TANK	999369.17	255	0	256	276	21	255	0	0	90	174982	181420	<Null>
3	Point	T-TASA SUMP		TASA SUMP TANK	14362.6	34	1	42.9	43	9	35	0	0	0	177626.12	186800.31	<Null>
4	Point	T-AGAG TANK		AGAG TANK	103403.28	609	6	620	626	17	615	0	0	40	178847	173820.64	<Null>
5	Point	T-CAPITOL HILL			1000558.89	870	10	885	890	20	880	0	0	130.5	177905	178543	PICTEST1.JPG
6	Point	T-ISLEY TANKa			1000558.89	184	2	190	196	12	186	0	0	130.5	168867.36	148898.48	<Null>
7	Point	T-HOSPITAL			1007594.43	142	5	152	182	40	147	0	0	70	168319.35	159412.02	<Null>
8	Point	T-GUALO RAI		GUALO-RAI TANK	200012.27	303	7	315	327	24	310	0	0	44.75	169951.58	172601.73	<Null>
9	Point	T-ACHUGAO		ACHUGAO TANK	200111.78	221	4	229	233	12	225	0	0	65.25	183301.63	190235.53	<Null>
10	Point	KOBBLER NSUMP 0120			14961.04	125	0	127.5	130	5	125	0	0	0	166236.79	150315.55	<Null>
11	Point	T-SAN VICENTE		SAN VICENTE TANK	500132.32	320	5	330	352	32	325	0	0	56.15	173382.25	159029.02	<Null>
12	Point	T-2			1081322.14	370	0	390	411	41	370	0	0	67	183134.51	166418.85	<Null>

Record: 1 Show: All Selected Records (1 out of 27 Selected) Options

PUMP ATTRIBUTE FILE

LABEL	LABEL_1	PUMP_DEFIN	DESC_	ELEV	X	Y	PUMP_CURVE	PUMP_DATA	PUMP_MAIN_DATA	DIRECT_FEED
PMP-AS-5		AEROMOTOR 50-500 (PMP-24) (PMP-AS-5) (PMP-AS-2)		0	170231.39	157434.51	<Null>	<Null>	<Null>	<Null>
PMP-KUMOY 3		AERMOTOR 6A80-10 (PMP-KUMOY 3)		-14	164613.33	153139.81	<Null>	<Null>	Pump Data-Region 8A.xls	<Null>
PMP-AS-2		AEROMOTOR 50-500 (PMP-24) (PMP-AS-5) (PMP-AS-2)		-5	169112.56	155904.09	<Null>	<Null>	<Null>	<Null>
PMP-KAGMAN B		PEERLESS 3PV11 50 HP (PMP-KAGMAN BOOSTER 1 PMP 1) (PMP-KAGMAN BOOSTER 1 PM		364	182684.57	169310.08	<Null>	<Null>	<Null>	<Null>
PMP-KV 25		AERMOTOR 75-500 (PMP-KV 22) (PMP-KV 25) (PMP-KV 11) (PMP-KV 12) (PMP-KV 17) (PMP-M		-5	161297.16	148113.62	<Null>	<Null>	Pump Data-Region 9A.xls	<Null>
PMP-SQ 11		Aermotor 75-750 (PMP-SQ 6) (PMP-CL 5) (PMP-SQ 12) (PMP-SQ 149) (PMP-PR 164) (PMP-SQ 7)		-2	177228.98	180290.41	TEST PUMP CURVE.pdf	<Null>	Pump Data-Region 4.xls	<Null>
PMP-KG 13		AERMOTOR 35-300 (PMP- KG 7) (PMP-KG 9) (PMP-KG 13) (PMP-KG 14) (PMP-KG 11) (PMP-KG		-4.25	187044.46	165593.94	<Null>	<Null>	Pump Data-Region 7.xls	<Null>
PMP-SQ 150		AERMOTOR 230S250-9BB (PMP-SQ 150)		-2.5	177007.1	183672.21	<Null>	<Null>	Pump Data-Region 4.xls	<Null>
PMP-KAGMAN B		PEERLESS 4PV8A (PMP-KAGMAN BOOSTER II PMP 2) (PMP-KAGMAN BOOSTER II PMP 3) (P		0	184114.4	166842.4	<Null>	<Null>	<Null>	<Null>
PMP-MQ 9		GRUNDFOS 40S75-21		-8	190882.01	195806.22	<Null>	<Null>	Pump Data-Region 1.xls	<Null>
PMP-KV BOOSTE		GRUNDFOS 200-800 9PM (PMP-KV BOOSTER PMP 1) (PMP-KV BOOSTER 1 PMP 2)		131	166229.57	150254.48	<Null>	<Null>	<Null>	<Null>
PMP-JF 206		AERMOTOR 75-500 (PMP-JF 23) (PMP-JF 208) (PMP-JF 206) (PMP-JF 109) (PMP-JF 202) (PMP-JF		-2	171590.87	150089.74	<Null>	<Null>	Pump Data-Region 8A.xls	<Null>

Record: 1 Show: All Selected Records (0 out of 151 Selected) Options

PIPE ATTRIBUTE FILE

OBJECTID *	Shape *	LABEL	LABEL_1	DESC_	L	MATERIAL	MAT_DESC	C	KM	START_NODE	STOP_NODE	D	Shape_Length	INSTALLED_DATE
1	Polyline	P-47a			15	PVC	PVC	150	0	PBV-3	J-31a	16	15.000001	<Null>
2	Polyline	P-172b			261	Asbestos Cement	Asbestos Cement	140	0	J-70b	J-71b	6	260.553234	<Null>
3	Polyline	P-137b			785	PVC	PVC	150	0	J-54c	J-57c	6	785.084823	<Null>
4	Polyline	P-406			349	Asbestos Cement	Asbestos Cement	140	0	J-194a	J-205a	8	349.155325	<Null>
5	Polyline	P-43f			1209	PVC	PVC	150	0	TCV-12e	J-19g	10	1209.376496	<Null>
6	Polyline	P-441			389	Asbestos Cement	Asbestos Cement	140	0	J-225b	J-227c	8	388.70772	<Null>
7	Polyline	P-290d			1324	PVC	PVC	150	0	J-152b	J-136c	8	1323.700223	<Null>
8	Polyline	P-499a			14	PVC	PVC	150	0	FCV-185a	J-58e	8	13.967846	<Null>
9	Polyline	P-13a			173	PVC	PVC	150	0	J-9b	FCV-4a	12	172.999798	<Null>
10	Polyline	P-715			374	PVC	PVC	150	0	J-344	J-345	4	373.855044	<Null>
11	Polyline	P-252a			11	PVC	PVC	150	0	J-115b	FCV-122	10	10.56104	<Null>
12	Polyline	P-217a			26	PVC	PVC	150	0	T-TASA SUMP	PMP-TASA SUMP	12	26.100281	<Null>
13	Polyline	P-446b			2797	PVC	PVC	150	0	J-233c	J-94d	6	2796.872055	<Null>
14	Polyline	P-561a			22	PVC	PVC	150	0	J-281	FCV-216	6	21.837231	<Null>
15	Polyline	P-579			54	PVC	PVC	150	0	J-287	FCV-226	6	53.560594	<Null>

Record: 1 Show: All Selected Records (0 out of *2000 Selected) Options

Figure 3. Sample Attribute files for CUC Tanks Pumps and Pipes that are available in the GIS data Base.

IV. Integrate the maintenance schedule and system inventories into GIS layers

CUC Water Division provided the pump maintenance spreadsheet workbooks that were incorporated into the GIS layers. This was the only data available that was in a format that could be readily used by the GIS. Hyperlinks are provided in the GIS for each well and pump site to access this data base. A data attribute called "Pump Curve" was also added to the pump data. CUC engineers will be able to input the names of scanned pump images in the data base and they will be easily accessible from the GIS. Special hyperlink fields were added so that pictures of the tank features could also be viewed directly from the GIS program. Any new maintenance files or scanned images must reside in the same folder as the "GSI.mxb" file for the CUC GIS.

Figure 4 shows how by using the GIS "Identify" command a particular pump is chosen. Then by selecting the hyperlink for the maintenance data base the maintenance data for that particular pump is made available. Figure 5 shows Pump Curve Data accessed directly from the ArcMap Program.

V. Make the data base available to the system managers and system operators

The final phase of the study was to make the GIS database available to CUC water division. A new computer was purchased for the CUC water division and the computer was loaded with ArcMap and the Haestad Water system model during the first Phase of this project. All of the GIS management data was combined into one common ESRI geodatabase. This allows for easy maintenance and exchange of all the required GIS files. These files along with the GIS Management System "MXB" file and other auxiliary files were loaded onto a CD for transport and loading onto the CUC water system computer. The files were transferred and the entire system was checked to be sure that it was operating properly on the CUC computer.

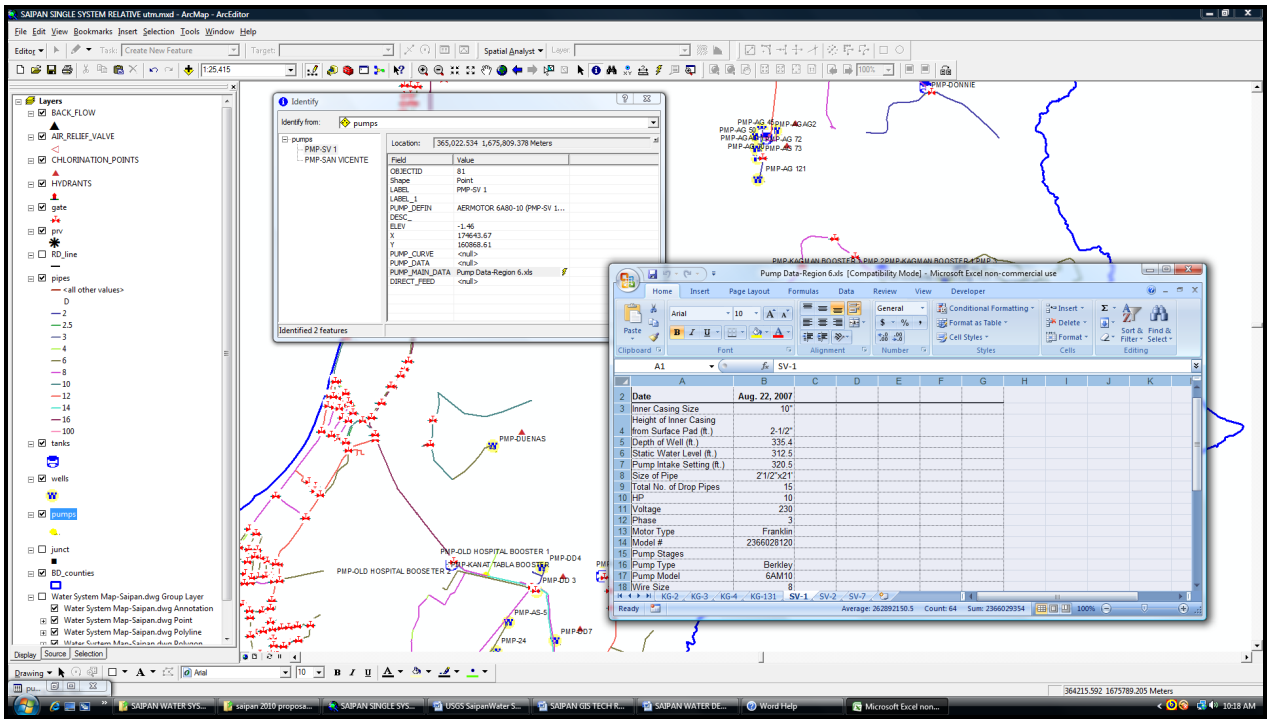

Figure 4. Pump Maintenance Data for Well Pump SV-1 accessed directly from the ArcMap program.

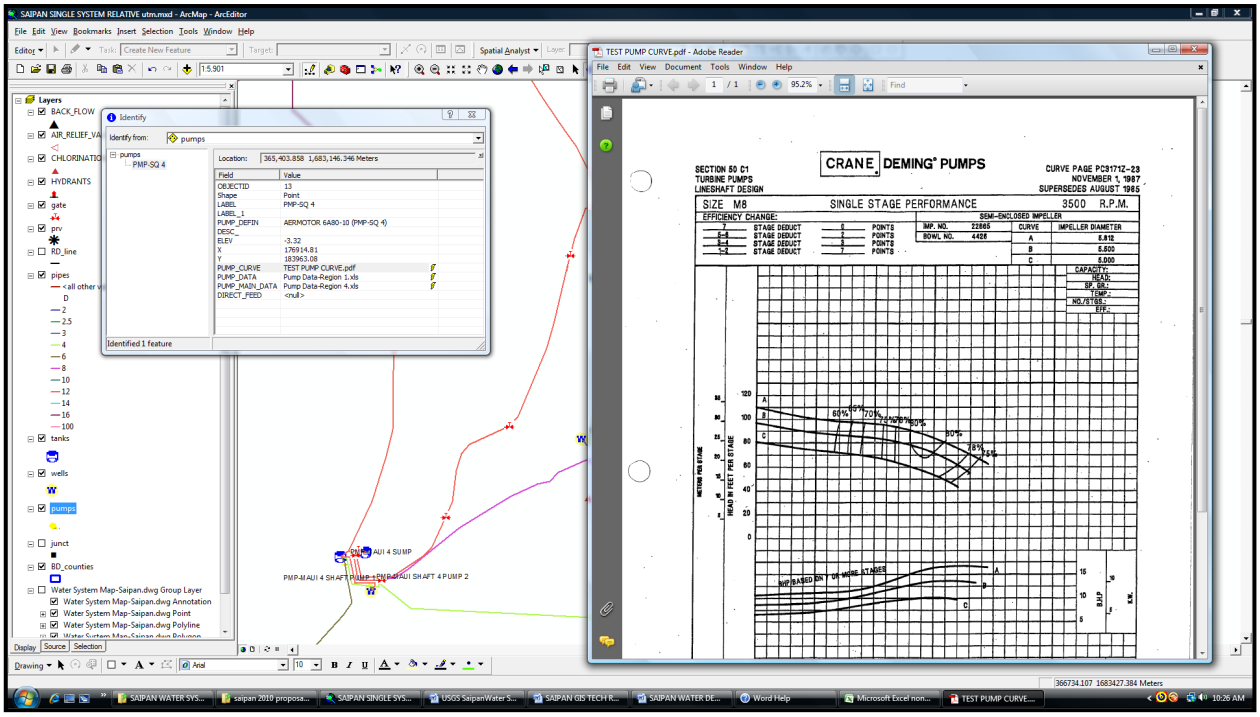

Figure 5. Pump Curve Data accessed directly from the ArcMap Program.

Principal Findings and Significance:
What this study accomplished was to initiate the creation of a GIS data base that contains the system description and system maintenance schedules. Now this information will be readily available to CUC water system managers and field operators. This is an important first step in meeting the US EPA Stipulated order requirement of developing a water system master plan and a comprehensive GIS management tool. Beyond satisfying the stipulated order this project will help CUC to provide an improved and more efficient management and operation of the Saipan water system and improved service to their customers.

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[i] Stipulated Order, Civil Case No. CV08-0051, United States District Court, Commonwealth of the Northern Mariana Islands. March 1, 2009.

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

Basic Information

Title:	Comprehensive Survey of the Current State, Infrastructure, and Usage of Freshwater Resources in the Mortlock Islands, Chuuk State, Federated States of Micronesia
Project Number:	2010GU178B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	N/A
Research Category:	Climate and Hydrologic Processes
Focus Category:	Water Use, Management and Planning, Groundwater
Descriptors:	Micronesia, Low Islands, Atolls, Reefs, Coral Islands, Groundwater, Wells, Rainwater Catchment, Water Storage Tanks, Water Quality, Water Supply, Water Use, Typhoons, Floods, Saltwater Intrusion, Hydrology, Hydrogeology, Waste Disposal, Burial Practices, Septic Tanks, Pit Toilets, Piggeries, Traditional Agriculture, Traditional Resource Management, Taro Patches
Principal Investigators:	Danko Taborosi

Publications

There are no publications.

PROJECT SYNOPSIS REPORT

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

Problem and Research Objectives
Low islands (mostly coral atolls) in the Federated States of Micronesia comprise less than 5% of the total land area of the country but are home to nearly 20% of the population. The disproportion between the number of people and the land area and resources available to them is the greatest in the Mortlock region (Fig. 1) of Chuuk State. In that extremely densely inhabited part of the most populous Micronesian state, six atolls with minuscule land area support over 7,000 people (13% of the state's total population). Their freshwater resources, already inadequate at extreme population density, are further threatened by rapid social and lifestyle changes, damage by pollution and unsustainable practices, and violent weather and possible effects of global climate change. Despite the fact that several individual islands have experienced serious water shortages and environmental and health emergencies in recent years, there are no sustainable development and contingency action plans for the future. Designing effective environmental planning, resource management, and emergency preparedness programs must take into consideration that fact that individual islands are highly distinct in resource availability, population sizes, infrastructure level, and environmental quality. Consequently, the extent of specific problems and potential threats on a particular island can only be evaluated and alleviated if sufficient and accurate information is available from each island.

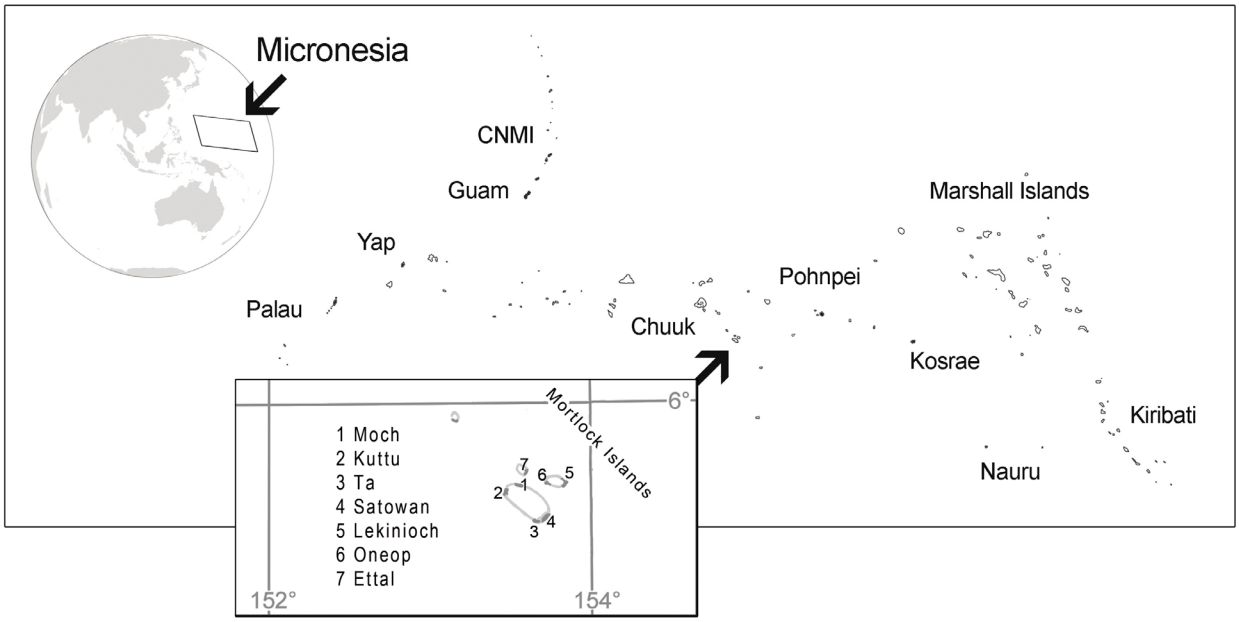

Fig. 1: Map of Micronesia with indicated location of the Lower Mortlock region, a cluster of atolls where the studied islands (Moch, Kuttu, Ta, Satowan, Lekinioch, Oneop, and Ettal) are situated.

Over the past year, we have carried out several research trips aiming to characterize freshwater resources, infrastructure, and practices in the target area of all populated islands in the middle and lower Mortlocks region, specifically the islands/municipalities of Moch, Kuttu, Ta, Satowan, Lekinioch, Oneop, and Ettal (Fig. 2a). We have focused on evaluating the extent and condition of water resources, inventorying all water-related infrastructure, and documenting the local people's concerns and relationship with water resources. Such information is vital in order to understand water availability and allow informed response to (or avoidance of) potable water emergencies, agricultural difficulties, food shortages, health problems, and other environmental crises that may arise due to lack of knowledge, awareness, or preparation.

The central objective of the project has been to acquire the currently lacking baseline information to support resource management, sustainable development, emergency prevention, and other environmental, scientific, humanitarian, or engineering activities in select islands. Specifically, our main goals were to:

a) examine the current condition of the islands' freshwater resources;
b) describe the local people's usage patterns of those resources, experiences, concerns;
c) inventory, assess, and map hydrologically significant infrastructure of each island.

In addition, we aimed to:

d) compile a comprehensive reference source and GIS data sets for the Mortlock Islands;
e) note relevant lifestyle practices (e.g., waste disposal, burials, animal husbandry, etc.);
f) Record each island residents' attitudes and other relevant cultural norms, perceptions, behavior and opinions related to freshwater resources;
g) identify and report any unusual situations or problems related to freshwater resources.

The information gathered is currently being processed for dissemination and publication, with hopes that it will be used by government planners, resource managers, engineers, educators, environmental scientists, and others dedicated to sustainable use of freshwater resources and improving the livelihood of outlying rural communities in Micronesia.

Methodology

Considering that the main goal of this project was collection of baseline data, the central part of the project was field surveying. We used a combined approach involving geologic, engineering, and sociologic fieldwork in order to best document hydrologically relevant natural aspects and infrastructure, as well as understand the local people's usage patterns and perceptions of their freshwater resources.

Essentially, the fieldwork comprised of several research trips (one or two per island), each of which included a 1) hydrogeologic component comprising of field observations and mapping, 2) engineering component comprising of infrastructure examinations and measurements, and 3) "people-oriented" component comprising of standardized questionnaires for local residents and freeform interviews with local leaders.

Mapping and observations in the field were carried out by systematic walks around the island during which locations of households, buildings, and other landmarks were recorded by GPS. A mobile mapping unit capable of creating GIS shapefiles in the field was used to delineate paths, taro patch boundaries, sea walls, and other linear or polygon features. Special attention was paid to any unusual coastal features, such as prominent vegetation decay, collapsing trees, apparent erosion, etc. Spatial data collected in the field was later processes using ArcGIS 9 software and cross-referenced with available satellite imagery to produce original maps of the islands surveyed. Several control points (features visible in vertical imagery, e.g. airstrips, school courts, etc.) were collected in the field and used to estimate GPS error and make adjustments to the GIS coverages.

Following the completion of mapping activities on each island, we proceeded with a comprehensive and methodical survey of water-related infrastructure. Each and every household, public site, and vacant/abandoned residence was visited; the number of resident adults and children was recorded. In each household, we have measured the volumes of all water storage tanks (used and unused), evaluated their condition, and noted the type and state of their catchments. We have also examined all wells that a particular household owns or has access to and checked their condition, depth, lining, groundwater appearance, etc. At the same time, we have taken many photographs of infrastructure and daily life using a camera coupled with an automated GPS logger which recorded current position every 5 seconds. This allowed accurate georeferencing of the acquired images, which were later used to accurately map the locations of water catchment and storage systems, water wells, and other features.

Series of interviews with local residents started during the infrastructure surveys, when residents of each household were asked basic questions related to the sources of the water they use for drinking, cooking, washing, and bathing, and the quality of water in their tanks and wells. At every tenth household, we asked a pre-determined set of additional questions which helped us better understand the daily patterns of water use in normal times and coping strategies at times of water shortage. Finally, on each island, we interviewed the local mayor and several other prominent community members in group and individual sessions, and elicited responses to an extended set of questions regarding the water situation on their island, any current or past problems, history of emergencies and relief operations, and other relevant topics. Overall, the questions were designed to (1) record objective information (e.g., regarding specifics of catchment systems and wells), (2) determine customary behavior (e.g., regarding common and uncommon use of well water), (3) note people's impressions and perceptions (e.g., opinion of water quality and overall fresh water situation on the island), and (4) document past incidents (e.g., cases of water shortages or food shortages, epidemics, and weather-related crises in the island's past). All interviews were saved using a digital audio recorder and transcribed.

Upon completion of the fieldwork portion of the project, we proceeded to process gathered data and prepare final reports and products. Results of work on each island will be presented in an individual report, which will be the all-inclusive information base for the water resources of that island and will contain all data and metadata acquired and observations made there, including technical information, detailed household-by-household tables, inventories of infrastructure, geographic coordinates, photodocumentation, researchers' assessments, informers' names, interview dates, and key insights from interviews with the local people, etc.

Principal Findings and Significance

The real value of this project is that it is island-specific. We have confirmed that some concerns are relevant in all islands, but have also identified certain issues that are significant only in some islands and communities. As such, they might not have been recognized by a less comprehensive investigation. The principal findings are listed in the following outline, with remarks as to whether they are applicable only on some islands.

- Drinking water is obtained by capturing of rain. On all islands surveyed, nearly every family compound has own rainwater catchment and storage system. The general setup involves tin roof of a house (used for catchment) with a gutter that collects water runoff and pours it into a storage tank made of fiberglass or concrete (Fig. 2b, 2c). People who live in local-style houses, whose thatch roofs are unsuitable for catchment of rain, may rely on wooden-framed structures with sloping and guttered sheets of corrugated tin. Families that do not capture or store enough water for their needs rely on neighbors or relatives with greater reserves.

- Under normal circumstances, all drinking water and most cooking and dishwashing water is provided by catchments. Each family tries to maintain at least one good tank for those needs.

- Most catchment roofs are at least slightly rusted and many have significant amounts of rust. This is not considered a health hazard but may cause the captured water to have an unpleasant metallic taste. Water collected by concrete roofs is not considered fit for consumption at all (Fig. 2d). People may use it for washing and other purposes, but not for drinking. This is presumably because microbial biofilms form on concrete much more readily than on metal surfaces and contaminate rainwater as it is captured.

- Efficiency of capturing rain can be improved. Rooftop catchment systems almost invariably utilize only a portion of the total available roof area. Typically, only one side of the building has gutters so rain is caught by no more than half of the roof. Most gutters are leaky because they have holes in decayed metal or are rigged together with insufficient materials and have gaps at connection points between elements. In general, Lekinioch, Moch, and Ettal have gutters with relatively few leaky portions and seem to be regularly cleaned. Gutters in Kuttu, Oneop, and Satowan appear less regularly maintained and tend to accumulate more organic debris.

- Storage tanks are made of concrete or fiberglass. The most common shape is cylindrical. Typical size for concrete tanks is 10 ft diameter, 6~7 feet in height, ~3,500 gallons volume. Typical size for fiberglass tanks is 3~4 feet in diameter, 6~7 feet in height, ~1,500 gallons volume.

- The large concrete tanks are the most popular, because they are good in isolating water from solar heating. Though they keep water cool and pleasant to drink, they are more difficult to maintain than non-concrete tanks. To prevent contamination and extend time before cleaning is needed, people use wire mesh, plastic webbing, and other materials to filter plant debris and other solid particles at rainwater entry point into storage tanks. However, when organic material does make its way inside the tank, it cannot be removed unless the whole tank is

drained and cleaned. This is not something that residents can not afford outside the peak of the rainy season. Even when a tank is fully drained, people cannot easily clean it because many concrete tanks were built without easy or large enough access point. As a result, many tanks are allowed to sit uncleaned and with time fall into disrepair, break open, and are just left to decay. For that reason, there are many unused concrete tanks in various states of disrepair.

- Each island has more water storage tanks than are actually in use. Many concrete and some fiberglass tanks are abandoned because they developed fractures and leak water. For example, many blue fiberglass tanks donated by FSM Congress (via congressional projects) have cracked, despite the fact that they are less than 15 years old. In many cases, damage is repairable but is never repaired. In addition, some structurally solid and usable tanks are not attached to a catchment system and not maintained because owners are off-island. This can mean very long periods of time (months, years). Numbers and ratios of used tanks, damaged tanks, and abandoned tanks vary on different islands, but properly maintained and regularly used water storage tanks are invariably a subset of significantly larger number of tanks present.

- Other than individual families' purchases or construction of own storage tanks, usual sources of tanks are municipal government, USDA Rural Development, and Federal Emergency Management Agency (FEMA). The general approach is to donate new tanks to an island as part of a relief campaign after a drought. At such times, no old tanks are removed. Consequently, a stock of abandoned (broken or not) tanks grows. This pattern results in eyesores and health hazards deriving from presence of permanent stagnant water. Overall, however, there are fewer neglected tanks in the Mortlocks than in the Outer Islands of Pohnpei because Mortlock islands do not have the rampant emigration problem. Certainly, there is diaspora in Chuuk, Pohnpei, and Guam, but this has not lead to depopulation of the home islands. All islands surveyed have lively and growing communities. Only Ettal has significant number of empty houses, but they are well taken care of by relatives. Tanks in such houses do become a problem, as they provide stagnant cesspools needed for development of mosquitoes and other disease vectors.

- People do not conserve water when there is ample rain. At such times, rainwater is used for tasks beyond drinking and cooking, notably for washing laundry (Fig. 3a). However, within several weeks without rain, most households consume half of all water they are able to store. When reduction becomes apparent, people stop using rainwater for purposes other than drinking. This allows the latter half of stored water to last longer than the first half. Even so, if drought lasts between one and two months, virtually all households' water reserves are used up.

- When household reserves are up, people seek short term relief from neighbors and relatives. After that, they turn to larger water storage tanks that may be available to the whole community. Public tanks are generally associated with church, school, or municipal buildings where catchment and storage capacity is large but background consumption is low. Availability of such sites is not the same on all islands. Kuttu and Satowan have 3 communal tanks and Lekinioch and Ettal have 2 communal tanks. Only Moch and Oneop islands do not have any public rainwater storage that people can turn to when their own reserves are up.

- The most recent drought lasted about 2 months from January until March 2010. On Kuttu, Moch, Lekinioch, Ettal, etc. most tanks became empty and the islands almost completely ran out of stored rainwater. People were very concerned until it rained again. No action was undertaken in the aftermath.

- Groundwater is used regularly for needs other than drinking and cooking, and also as emergency source of drinking water during major droughts. It is extracted from shallow, hand-dug wells. The wells generally have concrete casing and a circular, partly covered, opening. On most islands, nearly every compound has its own well. Moch has fewer wells than other islands, and several families sharing one is the norm. Residents of Lekionioch indicate that until 10~20 years ago there existed deeper wells on their island. Nobody could explain what was the origin of those wells or give any reason for their abandonment.

- Wells are located near houses, especially on the lagoon-facing side of each island, within 50 and 200 feet from the shore. Wells are uncommon on the ocean facing side, and where they do occur, it is not within 100 feet from the shore. There may also be wells in the interior of the island (around the taro patch). There are no wells considered public or communal property.

- Most freshwater wells are consistently used and are in good condition (Fig. 2e). Residents use the water on a regular basis for showering and washing laundry. Other regular or semi-regular uses include water for dishwashing, toilet flushing, and drinking water for domestic animals. Water from wells is sometimes used for cooking, but only for a specific purpose: the boiling of taro (Fig. 3b). No residents use water from wells for drinking unless the island is experiencing a major shortage. At such times, groundwater is consumed only after being boiled. No other techniques of disinfection (e.g., adding bleach) are being used.

- During major droughts, groundwater level may drop and cause some wells to become dry. The last time this happened was apparently in 1996/1997. At that time, people whose wells have dried up shared water obtained from wells of their neighbors.

- Quality of water in wells is generally good. No well has salty water, though between 25% and 35% of the total number of wells on each island are commonly described as brackish (*neru*, in Mortlockese language). Those wells are mostly located in topographically lower areas inland, near the taro patch. Oneop and Satowan islands have a lower proportion of brackish wells, <20%. Water levels and salinity vary with the tidal cycle. In general, people describe water as fresh and clean, though foreign residents (Peace Corps volunteers) have described the smell as sulphur-like. Organic pollution arises in wells that are not maintained for a while. People associate poor smell of water in a well with lack of cleaning and state that quality can be restored almost immediately by emptying a well of debris and water and letting it replenish itself. Nevertheless, nobody considers groundwater a suitable drinking water source due to characteristic taste, saline content, and that fact that it must be boiled before consumption.

- The regular use and good maintenance on wells in the Mortlock Islands is in contrast with what we observed on some Pohnpei State atolls, where people do not clean and maintain wells for extended periods of time whenever rainwater is available. People in the Mortlocks seem to appreciate the value of groundwater and importance of protecting it. Few abandoned wells were seen, generally the result of owners no longer residing on premises and having sufficient access to wells elsewhere, and not because the well was considered unfit for some reason.

- Coconuts are used as hydration source in addition to water. Their consumption is irregular and a matter of personal preference and local availability. They are not conserved, but neither are they drunk daily. Other than Kuttu, where it is generally agreed that there are plenty of coconuts on island, people on all other islands stated that there are not enough coconuts to provide for the entire island, although families with larger estates indicated that they have enough for themselves. It is a general consensus that coconut trees are not flowering enough or producing as much "as they used to."

- There is another minor source of drinking water currently available: saltwater evaporation stills from Japan, recently donated by Rotary Club. Each island received about 20 units. The municipal leaders distributed them to people with intention of keeping them in circulation as public property and available to all residents. However, interest in the community waned when it was realized how slow the desalination by evaporation process is, so the people who initially got the units from the municipality ended up keeping them as there was no further demand. Few people use these units, and most just keep them in their homes. The units are composed of black plastic measuring about 2.5' x 3.75' x 1' deep on one end, to 1.5' deep on the other end. The lid is an inclined sheet of thick Plexiglas. It seals to the plastic using long strips of a spongy, porous material, which lines the rim of the container. The unit is used by removing the lid, pouring in the saltwater, and then putting the lid back on tightly. The evaporation process is said to be very slow, so the units cannot be considered as efficient emergency source of drinking water. Dehydrated salt made as by-product could be used for human consumption, but the local people do not agree and utilize commercially available refined salt instead.

- There is a widespread and strong sense among islanders that seawater is encroaching on land and that this is negatively affecting their lives. The greatest source of distress is gradual intrusion of saltwater into taro patches and consequent effects on food supply. There is also fear of occasional powerful waves and exceptionally high tides that can flood the island. Finally, there is much concern regarding coastal erosion and loss of land.

- Taro is a fundamental food source in Micronesia. Taro patches on every island we examined are extensive and intensively used (Fig. 3c). Unfortunately, residents report several recent changes and problems associated with them. Ideally, taro patches undergo short and long term wetting and drying cycles. The former is caused by tidal changes, which at time of high tide can elevate groundwater table near or above the topographically low land surface within the taro patch. However, in some areas water accumulations remain in depressions both at high and low tides, which exposes excessive water to solar heating and harms taro plants. On annual scale,

taro patch is wetted during the wet season and left dry during the dry season. Unfortunately, residents now report standing water even during the dry season. This impedes maintenance work and prevents planting of new taro plants which cannot be soaked in water.

- In addition, people allude to yet another highly significant problem: the intrusion of saline water from soil into the taro patch. Nearly every family interviewed on every island indicated that their personal taro section was suffering from some salt-water problem. On Kuttu, "springs" of saltwater arising in the taro patch and killing plants have been reported. On all islands people indicate that taro patch has shrunk in some areas (extreme ends), that salinity of water has increased, and the yield of taro has decreased. Outside observers describe the majority of the taro patch as still healthy and well maintained.

- In addition to intrusion of saltwater from the ground, taro patches may be affected by seawater inserted overland as a result of large waves or high tides and surges. Taro patch in Kuttu was severely damaged by a wave in 2004 and the taro died in large parts of the patch and were replaced by wild vegetation (Fig. 3d). Moch was swamped by a large wave in 2006, and localized flooding occurred in Lekinioch in March 2006 and December 2008. On Kuttu, a very high tide flooded lower sections of the island on lagoon side in January 2011. Water extended up to 30 ft inland and remained in puddles several inches deep.

- A concrete viaduct was built on Oneop in late 1980s to drain excess/standing water from taro patch into the ocean. The approach seems effective and residents of several other islands have indicated wishes to construct similar structures. However, it has recently come to attention that the viaduct may defeat its own purpose during very high tides. At such times, it actually serves as entry point for saltwater into the taro patch.

- Erosion is apparent on lagoon side of every island surveyed. This can be seen by fallen coconut palms, dying vegetation, erosional scars on beaches, etc. Some islands have a seawall on the lagoon side, and this sea wall is being destroyed. On Moch, seawall runs for about 75% of the length of the lagoon side and has been breached in several places. The broken portions have opened up land to erosive action of waves, and there are now permanent tidal pools between the standing portions of the wall and the eroded beach. Seawall on Kuttu is also extensively damaged. On southern end of the island, people build "docks" made from coral rocks, stacked approximately 6 feet above ground, and fill the empty space between them with sand in order to control coastal erosion. On many islands, people break pieces of reef and place them on the lagoon-facing beach as support for trees to prevent them from toppling over. Lower lying areas of some islands, notably Kuttu, have puddles of salt water appear from the ground at high tide.

- Organic waste that cannot be consumed by pigs, all inorganic household waste, and any other solid waste is burned or thrown into holes in the ground dug for that purpose near the houses. When filled, the holes are covered with dirt. On Kuttu, inorganic household waste is discarded between docks on the lagoon side or inland from the sea wall. On Moch, Lekinioch, Satowan, and Ettal, some families living close to the lagoon throw inorganic household waste into lagoon

waters. In Moch, high tide tends to take this material out to sea, but in Lekinioch and Ettal, the garbage often stays put because the shapes of the islands are such that no strong currents carry debris out of the lagoon. This results in visible localized pollution of lagoon waters. On inter-island trips, local people routinely discard plastic bags and bottles, including any canisters used to keep motoroil or gasoline, and any other type of waste over the side of the boat or ship.

- Though there are still many simple pit toilets (locally known as "benjo"), toilets with septic tanks are the norm on all but one island surveyed. Most households have a separate, outdoor toilet house equipped with a water-sealed toilet. (Water-sealed toilets were installed all over Chuuk state following cholera epidemic of 1983.) This site may or may not be combined with or immediately adjacent to the bath house, where people take showers using buckets of water. Beneath the toilet house is a septic tank that is constructed with cement or is a buried metal drum. The volume of septic tanks ranges from ~50 gallons (drums) to over 1000 gallons (concrete). Septic tanks may be located within 20 feet of wells and there does not seem to be a spatial relationship pattern that is followed during choice of sites.

- On Lekionioch island, human waste disposal is done mostly by means of overwater toilets. They are wooden structures with a hole in the floor, constructed over lagoon water (Fig. 3e). The shape of the coastline and flow of current along the lagoon coast is not such as to promote rapid natural evacuation of waste from close proximity to the island. At low tide, waste sits exposed atop of sediments. At high tide, it is consumed by fish and other marine organisms that tend to congregate under the toilet houses. Those fish are often targeted by small children and youth who fish from shore using simple lines with hooks. Consuming animals that feed or come to contact with human waste is a health hazard. Contagious diseases, notably cholera, are transmitted by water and food contaminated by human waste. Indeed, Lekinioch was the site of several cholera epidemics in the past.

- Other than old sites from the Japanese era, there are no designated cemeteries. Deceased are buried within the confines of the households they lived in, typically right next to the houses (Fig. 3f). This does represent a potential groundwater contamination and health hazard. Graves are generally made of cement but may also be without any lining. People do not seem to be concerned that burial sites are located near wells.

- Pigs are kept on every island examined. The number of animals reported is 50-75 per island, with double that number in Lekinioch. Pigs are not allowed to roam free. They are kept tied to trees away from roads, behind homes, adjacent to the forest or lagoon water. Other domestic animals kept are dogs, cats, and chickens.

- Kuttu was the site of a shipwreck in 1998, when Korean-flagged "Golden Pacific" ran aground on the reef. No action was undertaken. Two years later, the ship started leaking oil. There was no cleanup operation. The ship is still decaying on the reef. Coral killed by mechanical impact or subsequent oil spill remains dead within 30-m radius in every direction from the wreck.

- An illness of unknown nature occurs on Satowan. Its main symptom is characteristic skin condition that develops on legs of people who spent extended periods of time working in the taro patch. This condition is locally known as "SPAM" disease, because of pinky, swollen lesions that break out on the exposed and contacted skin. It is thought to be associated with unexploded ordinance left by US forces during World War II. In recent years, a team of doctors has visited Satowan to study this health problem and collect water samples from the taro patch. The island residents do not know where this team came from and what the results of their research are. Anecdotal evidence indicates that this malady also occurs on Lekinioch island.

- All islands are affected by plant pest that appears as white powdery fungus growing on the undersides of leaves of food plants (banana, breadfruit, taro) and decorative plants. Local people refer to it as *muuni*. It causes a plant to stop flowering. Local knowledge does not include any way of curing a plant from this affliction.

- Surprisingly, residents indicated bats as pests to trees. This complaint is due to bats removing foliage from roost trees and consuming fruits that humans consider own prerogative. Mortlock Islands fruit bat (*Pteropus phaeocephalus*) is indigenous and endemic to the Mortlock Islands. It is not found in Chuuk Lagoon or anywhere else in the world. It is threatened by habitat loss. Local people should be educated about its conservation status and role in the ecosystem.

- Public buildings made of concrete (churches, schools, etc.) serve as typhoon shelters on each island. Since typhoon Pamela in 1976, many private homes have also been made of concrete.

- Meteorological data are collected only on Lekinioch. Person in charge measures rainfall and records wind speed and direction using electronic anemometer. In addition, he estimates wave height and frequency, which is also done on Ettal. Data are reported to weather station in Weno.

- Over the course of this project and our previous work in the Outer Islands, it has become obvious that different researchers visit the islands from time to time to engage in a wide spectrum of scientific, social, medical, and humanitarian work. The purpose of each visit is surely communicated to the leadership and the local people may understand it at the time it is happening, but in retrospect individual communities have no information of who visited them, when exactly, and what kind of work was done. More importantly, the results of work do not get communicated back to the island residents. In addition, various research groups are not aware of each other's activities because their projects are done in disparate scientific fields at different times. However, it is clear that information gained and conclusions made by one group can be relevant in the work of others. For the purpose of keeping track of research done in the Outer Islands, making researchers aware of each other's work, and maintaining local people well informed about what scientific projects are done in their home areas and presumably for their benefit, we recommend that some sort of web-based registry is developed to record scientific activities in the Outer Islands, serve as a point-of-contact between researchers and local people, and act as a venue for dissemination of publications and research results to the wider public and island residents.

Fig. 2:
(a) A view of Lekinioch from an approaching boat within the lagoon represents the typical appearance of Micronesian low islands.
(b) Rooftop catchment system with a fiberglass tank and no guttering, on Satowan island.
(c) Rooftop catchment system with a concrete tank and a gutter, on Satowan island.
(d) Impromptu catchment of water from concrete roof into a plastic barrel.
(e) Regularly maintained well on Lekinioch.

Fig. 3:
(a) Washing laundry using rainwater, Oneop.
(b) Cleaning of taro for cooking on Satowan.
(c) A small and healthy taro pit discontinuous from the main taro patch on Moch.
(d) A destroyed part of the taro patch on Kuttu, where taro has died due to flooding and has been replaced by native (non-food) vegetation.
(e) Lagoonside toilet in Lekinioch.
(f) Graves adjacent to a home on Ettal.

USGS Award no. G10AP00092 Hydrogeological Database for Northern Guam

Basic Information

Title:	USGS Award no. G10AP00092 Hydrogeological Database for Northern Guam
Project Number:	2010GU192S
Start Date:	4/20/2010
End Date:	12/31/2010
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Congressional District:	N/A
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Water Quantity, Water Supply
Descriptors:	Groundwater Database, Aquifer Management
Principal Investigators:	John Jenson

Publications

There are no publications.

PROJECT SYNOPSIS REPORT

Project Title: Hydrogeological Database for Northern Guam

Problem and Research Objectives
The objective of this ongoing project is to construct a comprehensive database of all the hydrological, hydrogeological, and engineering data related to the Northern Guam Lens Aquifer, which will be accessible and useful to groundwater resource professionals, including scientists, engineers, managers, and regulators. For the immediate future, the database supports the ongoing 3.5 year collaborative Guam Groundwater Availability Study, the objectives of which are to (1) obtain a better understanding of the regional groundwater flow system, (2) estimate groundwater recharge, and (3) estimate the effects of selected withdrawal scenarios using a numerical model that will be supported by the database.

Methodology
Phases of the study include (1) a review and analysis of existing data from previous studies, drilling records, production records, water quality records, observation wells and other hydrologic data collection stations, maps, imagery, and all other data related to the occurrence, production, and quality of water from the aquifer, (2) ongoing collection of hydrologic data from existing platforms and installation and collection of data from new platforms, (3) water budget computation and, (4) development of a numerical groundwater flow and transport model.

Principal Findings and Significance
Findings: This is an ongoing study. To date, a large amount of data has been collected and assembled in electronic formats. These include scans of historical records, spreadsheets containing hydrogical data on existing and new wells. Numerical data are assembled in spreasheets that are being organized for easy search and access. Geographical data are being assembled in GIS formats for ready access and construction of maps and geo-spatial analyses of aquifer properties.

Significance: This project directly supports ongoing development of the aquifer in anticipation of the planned military buildup on Guam as well as continued improvements in water production to support growth of the civilian economy and improvements in quality of life for the island's entire population.

Information Transfer Program Introduction

WERI's research activities focus predominantly on local water resources problems and issues identified largely through discussions with regional stakeholders at our annual advisory council meetings. Disseminating the results of these investigations to appropriate governmental agencies, environmental managers, policy makers and other local decision makers in the water resources business, has the highest priority and is accomplished in various ways. Institutional technical reports remain a strong vehicle for transmitting such information to our target audiences, many of whom are remotely situated and do not have access to the scientific literature, or require a greater degree of detail than is normally permissible in a standard journal publication. WERI faculty have also become increasingly more interactive with audiences overseas in recent years by sharing their research findings at professional meetings, conferences and workshops at the national and international level. Our recently improved website is gaining increased popularity among professional circles, both at home and abroad, and is now accessible to the great majority of our stakeholders throughout the region. Our annual Advisory Council meetings in Guam, the CNMI and the FSM are highly effective information transfer mechanisms, bringing together people who typically have little to no contact with one another during the rest of the year. These meeting serve as a valuable forum of information exchange and discussion on common issues, problems and needs in the water resources arena. We remain strong in our commitment to teaching and training the up-and-coming water resources professionals of tomorrow, in addition to conducting workshops, courses and seminars for those currently employed in this area. WERI faculty also continue to be major and effective participants in water related law and policy making on Guam by serving as committee members and chairs on numerous governmental boards and by giving testimony at legislative oversight hearings.

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

Basic Information

Title:	Presenting 'Guam Water Kids': Public School Outreach and Teacher Relations Program
Project Number:	2010GU167B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	N/A
Research Category:	Not Applicable
Focus Category:	Education, Non Point Pollution, Conservation
Descriptors:	Water Resources, Aquifer, Groundwater, Surface Water, Watershed, Guam, Hydrological Cycle, Ground Water, Non-source Pollution, Non-point Pollution, Conservation
Principal Investigators:	Arretta Ann Card

Publications

There are no publications.

PROJECT SYNOPSIS REPORT

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

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

Methodology
Specifically, we followed the Guam public schools' chain of approval, scheduled presentations to 6th grade students and their teachers at six public middle schools and the public alternative school. The presentations were followed with an evaluation by educators who are involved in teaching subjects related to water resource issues. Procedures included:

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

communication with educators.

4) Analyze and report survey results.
5) Make any appropriate adjustments to existing "Guam Water Kids" materials indicated by educators' assessments.

Principal Findings and Significance

School Presentations were made available to 6th grade classes in the public middle schools on Guam. Presentations were conducted by grantee Ann Card and teacher consultant Jennifer Berry. The format was presentation of the narrated slide show and student participation Q&A session of approximately 50 minutes.

Superintendent of the Guam Department of Education Dr. Narrissa Underwood endorsed use of "Guam Water Kids" in schools and after viewing the presentation and materials sent an email to middle schools principals and teachers recommending that time be found for this our visits.

The following presentations were made at six schools as per funding in the Fall 2010 semester:

Middle School	Date	Students Attending
Inarajan	9/23/2010	180 (6th, 7th & 8th)
F.B. Leon Guerrero	10/ 8/2010	210
J. P. Torres Alternative	10/15/2010	25
Oceanview	10/22/2010	120
Astumbo	10/28/2010	60
Benevente	11/5/2010	450
		1,045 Total Students

Forty-one classroom teachers attended the presentations. (See survey results below). In addition, principals, librarians, and classroom aid workers also participated. At one school the Chamorro language teacher attended.

In addition, the Guam Water Kids materials were presented at the following gatherings and in the media:

Event	Date	Attendance
University of Guam Conference on Sustainability	9/3/2010	Booth: 1,500 Left Contact Info: 42
International Reading Assn. Guam Chapter	9/11/2010	Booth: 300 Break Out Session: 24
4-H Extension Services Volunteer Leadership Forum	10/9/2010	Booth: 400

Chalk Talk Radio, K-57 8/21/2010 Unknown number of listeners

Survey Results: Teachers attending the presentation of Guam Water Kids in the Guam Public Schools during fall 2010 were emailed the following survey on 12/7/2010. Five (12%) responded. *Survey questions 1-8, results and comments follow.*

1. The 'Guam Water Kids' presentation was made at your school this fall. Did you attend this presentation?

	Number of Response(s)	Response Ratio
Yes. I am a teacher/ school staff member who attended the presentation.	5	100.0%
No. (If you did not attend the presentation, you may skip this survey.) Thank you	0	0.0%
No Responses	0	0.0%
Total	5	100%

2. The presentation focused on teaching middle school students about the value of fresh water as a natural resource. How would you rate the overall effectiveness of the materials for middle school students on Guam?

	Number of Response(s)	Response Ratio
Very effective	3	60.0%
Somewhat effective	1	20.0%
Neutral	0	0.0%
Somewhat ineffective	1	20.0%
Ineffective	0	0.0%
No Responses	0	0.0%
Total	5	100%
2 Comment(s)		

2 Responses 10 per page Update

Answer	Respondent
I felt that the presentation lacked some "middle school feel" such as i felt maybe if the actual water kids were there to do a song and dance about water I think the students would have enjoyed it a little more.	dolphins_mendi@yahoo.com
The focused of the presentation is extended information to what is presented in class. Presented was very informative utilizing Guam's resources enhanced student teaching and learning skills.	lydpaul@guam.net

3. The presentation included photos, maps and illustrations of Guam in presenting information about the source of Guam's fresh water. How would you rate the following materials?

Top number is the count of respondents selecting the option. Bottom % is percent of the total respondents selecting the option.	Very Effective	Somewhat Effective	Neutral	Somewhat Ineffective	Ineffective
Animated illustration of the Water Cycle	4 80%	0 0%	0 0%	1 20%	0 0%
Maps of Guam showing fresh water resources	4 80%	0 0%	0 0%	1 20%	0 0%
Animated illustration of the Ugum River water shed	4 80%	0 0%	0 0%	1 20%	0 0%
Cutaway illustration of the Northern Guam Aquifer	3 60%	2 40%	0 0%	0 0%	0 0%
Photos and illustrations of sources of household pollutants	3 60%	1 20%	0 0%	1 20%	0 0%
Photos and illustrations of tips for saving water in daily life	3 60%	1 20%	0 0%	1 20%	0 0%
Photos of places and scenes of Guam	3 60%	2 40%	0 0%	0 0%	0 0%
Photos of Guam students as peer demonstrators	3 60%	1 20%	0 0%	1 20%	0 0%
0 Comment(s)					

4. In addition to the school presentation, a companion website offered Teacher Materials and other options to learn more about fresh water on Guam. Please evaluate these elements.

Top number is the count of respondents selecting the option. Bottom % is percent of the total respondents selecting the option.	Very Effective	Somewhat Effective	Neutral	Somewhat Ineffective	Ineffective
Overall Impression of the Guam Water Kids website	4 80%	0 0%	1 20%	0 0%	0 0%
Self-paced slide show about the Water Cycle	3 60%	0 0%	1 20%	1 20%	0 0%
Self-paced slide show about the Northern Guam Aquifer	3 60%	0 0%	1 20%	1 20%	0 0%
Self-paced slides shows about the Surface Water and Ground Water	3 60%	0 0%	1 20%	1 20%	0 0%
Self-paced slide show about what kids can do save Guam's Fresh Water	2 40%	1 20%	1 20%	1 20%	0 0%
Activity: Online Quiz about Guam's Fresh Water	4 80%	0 0%	1 20%	0 0%	0 0%
Activity: Become a the Guam Water Kid certificate	4 80%	0 0%	1 20%	0 0%	0 0%

0 Comment(s)

5. Downloadable Teacher Materials were provided on the website. Please rate the value of these educational tools.

Top number is the count of respondents selecting the option. Bottom % is percent of the total respondents selecting the option.	Very Useful	Somewhat Useful	Neutral	Little Need	Not Needed
Teacher Lesson Plans (2)	3 60%	1 20%	1 20%	0 0%	0 0%
Chamorro glossary	1 20%	2 40%	2 40%	0 0%	0 0%
Word Bank (Vocabulary)	2 40%	2 40%	1 20%	0 0%	0 0%
Correlation of Lesson Plans to Guam Standards	3 60%	1 20%	1 20%	0 0%	0 0%
Reproduction master of the Water Cycle for easy copying	3 60%	1 20%	1 20%	0 0%	0 0%

1 Comment(s)

Answer	Respondent
my apologies I have yet to view the website	dolphins_mendi@yahoo.com

10 per page Update

6. How likely are you to use the Guam Water Kids materials in future school terms?

	Number of Response(s)	Response Ratio
Very likely	2	40.0%
Somewhat likely	2	40.0%
Neutral	0	0.0%
Somewhat unlikely	1	20.0%
Very unlikely	0	0.0%
No Responses	0	0.0%
Total	5	100%

0 Comment(s)

7. How likely are you to recommend the Guam Water Kids materials to a colleague?

	Number of Response(s)	Response Ratio
Very likely	3	60.0%
Somewhat likely	1	20.0%
Neutral	1	20.0%
Somewhat unlikely	0	0.0%
Very unlikely	0	0.0%
No Responses	0	0.0%
Total	5	100%

8. Do you have any suggestions for improving the Guam Water Kids presentation to schools or the Guam Water Kids web site?

2 Response(s)

Answer	Respondent
As i mentioned earlier it would be nice if the actual water kids were part of the presentation rather than the slides itself.	dolphins_mendi@yahoo.com
dont use powerpoint. use animation	jreyes@gdoe.net

10 per page | Update

Following is a selection of images of the materials presented and photographs from the presentation in the schools and the community, which were developed during under the previous grant. *Figures 1-13 follow.*

Fig. 1 Title Slide "Guam Water Kids," a :20 minute narrated slide show

Fig. 2 Selection of slides from the presentation.

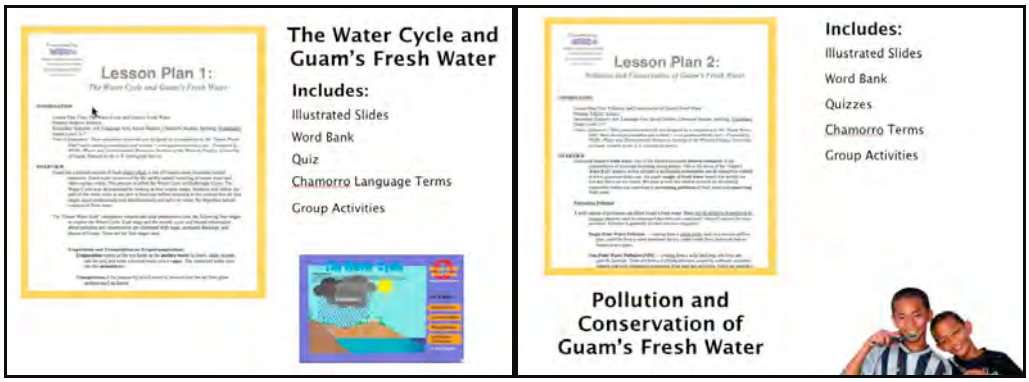

Fig. 3 Teacher materials are downloaded from the website and a CD of the presentation and master copies for duplication were also left with each school's media librarian.

Fig. 4 Academic vice principal accepts master copy of education materials on behalf of school at the beginning of a presentation.

Fig. 5 Sixth graders and their teachers gathered in school cafeterias or libraries to see the presentations. Students were attentive and willing to interact at appropriate points during the presentation even though some groups were large.

Fig. 5 After the students had an opportunity to ask questions at the close of the media presentation, the project educational consultant Jennifer Berry conducted a review of the materials.

Fig. 6 Students were able to answer questions and talk about how they might be able to conserve fresh water and avoid polluting.

Fig. 7 Ann Card and Jennifer talked about the upcoming visits to schools on a long-running Saturday morning radio show for educators called *Chalk Talk.*

Guam Council International Reading Association

September 2010

AN AFFILIATE OF THE INTERNATIONAL READING ASSOCIATION
PROMOTING READING ON GUAM SINCE 1968

Volume 19, Issue 1

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'Guam Water Kids' Offered To Public Middle Schools

Public middle schools are being offered a guest presentation of "Guam Water Kids," to explore the natural resource of fresh water on Guam. Project manager Ann Card said the presentation includes a multimedia show with animated segments and provides teachers with additional materials which are all specific toGuam and are DOE approved.

"We use our model 'Guam Water Kids' to ask their peers to think about the importance of fresh water. All the photos, maps and illustrations about the fresh water in Guam's aquifer, rivers and lakes and how we can protect it," Card said.

"Guam Water Kids" is a presentation of WERI: the Water and Environmental Resources Institute of the Western Pacific, University of Guam, with funding from the U.S. Geological Survey.

Free teacher materials supplied with the presentation include a CD copy of the slide show, two teacher lesson plans, follow up activities, and a glossary of related terms in Chamorro. The supplemental materials are also downloadable at www.guamwaterkids.com, the companion website where students can explore information about Guam's fresh water on their own.

Prepared by consulting teacher Jennifer Berry, the lesson plans are correlated to Guam standards and are applicable to Science Language Arts, Social Studies, Chamorro Studies, Spelling, Vocabulary and Art, grades 3-7. The Guam DOE has approved the materials for use in elementary and middle schools.

For information about scheduling a presentation, please contact Jennifer Berry at 483-6161 or 472-2466 or email jberry2466@gmail.com or Ann Card at 565-2213 or email ann@cardandcard.com.

Kenn Nesbitt's Visiting Schools

The following schools have earned a visit by Author Kenn Nesbitt by their commitment to literacy, their outstanding participation in RAT 2010 and their continuing support of the fund raising efforts of the International Reading Association, Guam Council.

Agana Heights Elementary
Astumbo Elementary
H.S. Truman Elementary
Liguan Elementary
Ordot Chalan Pago Elementary
Cpt. H.B. Price Elementary
Saint Francis Catholic
San Vicente Catholic
St. Paul's Christian, North
Talofofo Elementary
Upi Elemementary
Wettengel Elementary

Don't miss the October Newsletter

Reading in Many Languages

Inside this issue:

Read-A-Thon 2011: "Read to Succeed"	2
IRA Website Features	2
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Guam Water Kids	3
Kenn Nesbitt to Visit Guam Schools	3
St. Francis Goes Green	3

Association Newsletter | September 2010
Guam Chapter International Reading Association

Fig. 8 The Guam Chapter of the International Reading Association published an article about "Guam Water Kids" in their newsletter and invited use to their fall meeting.

Fig. 9 Many teachers visited our booth during the IRA vendor fair and the small group break out session where we shared the presentation was standing room only.

Fig. 10 Our booth at the University of Guam's Conference on Sustainability showcased two educational projects sponsored by WERI and funded by the US Geological Survey, "Guam Water Kids" and the corresponding program for the general public "Protect Guam's Fresh Water." Dr. John Jenson and Dr. Gary Denton represented WERI at the well-attended conference.

Fig. 11 Many educators from both Guam and the CNMI were among the attendees at the Sustainability Conference.

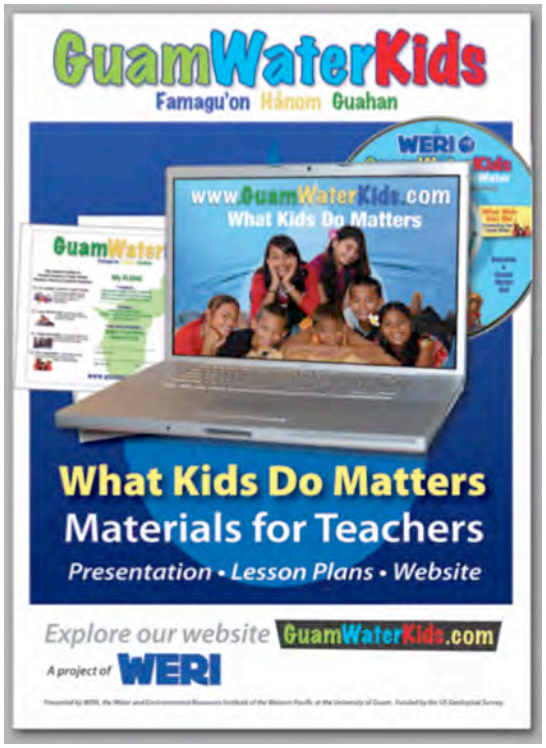


Fig. 12 Poster gave educators in attendance a quick overview.

Fig. 13 High school students who were also presenting at the conference checked out the presentation.
(end)

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

Basic Information

Title:	CNMI Water Kids: An Educational Resource for Teaching Children about Fresh Water and How to Protect It (An Adaptation of Guam Water Kids)
Project Number:	2010GU173B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	N/A
Research Category:	Not Applicable
Focus Category:	Education, Non Point Pollution, Conservation
Descriptors:	Water Resources, Aquifer, Groundwater, Surface Water, Watershed, CNMI, Saipan, Rota, Tinian, Hydrological Cycle, Ground Water, Non-source Pollution, Non-point Pollution, Conservation, Students, Teachers
Principal Investigators:	Arretta Ann Card

Publications

There are no publications.

PROJECT SYNOPSIS REPORT

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

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

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

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

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

Principal Findings and Significance
The project has accomplished the following stated objectives.

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

In addition, we have met with Rita A. Sablan, Comissioner of Education and the head of the public school system of the Commonwealth of the Northern Mariana Islands. Dr. Sablan has agreed to review the CNMI Water Kids educational materials and make them available to middle school principals in Saipan, Rota and Tinian.

The interim president of Northern Marianas College has reviewed the Guam version of these materials. President Lorraine T. Cabrera has requested that a presentation the CNMI Water Kids to education majors in the NMC School of Education.

A grant proposal is pending (following the Guam model) for onsite visits to present these materials to each of the middle schools in the Commonwealth of the Northern Mariana Islands. If funded, the presentations will be made to all sixth grade public school students and their teachers. A copy of materials will be left with teachers and/or the media resources librarian.

The following images from the materials developed for the CNMI Water Kids project. *Figures 1-12 follow below.*

Fig. 1 CNMI Water Kids website homepage

Fig. 2 Web page about "What Kids Can Do!: Protecting Our Fresh Water"

Fig. 3 Slide and sound show introduces the concept that fresh water is a natural resource and introduces the purpose of the presentation.

Fig. 4 Presentation demonstrates the importance of fresh water with a variety of local images.

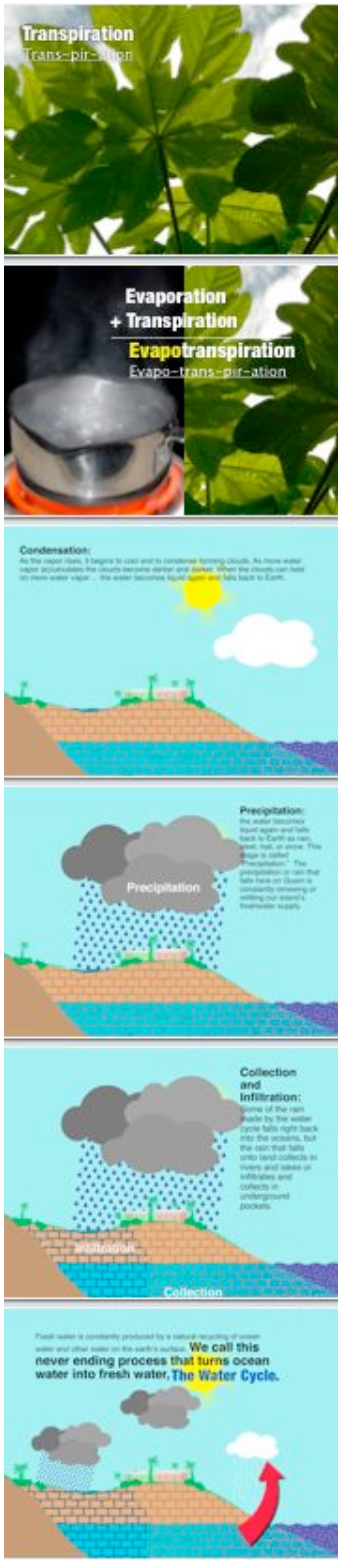
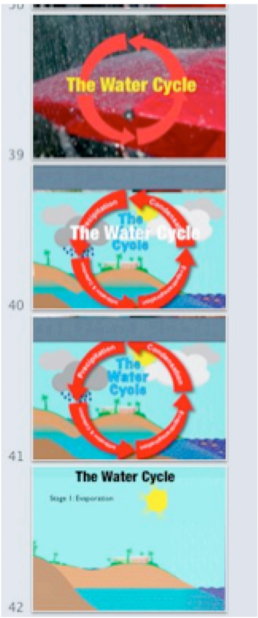


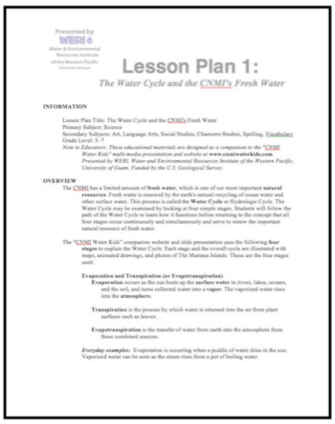
Fig. 9 Flash animation is used in the slide presentation to demonstrate the water cycle, a drainage basin, surface water and ground water.

Teacher Materials



- Downloadable Materials
- Lesson Plan 1: The Water Cycle and CNMI's Fresh Water
- Lesson Plan 2: Pollution and Conservation of the CNMI's Fresh Water
- Supporting Slides
- Handouts

Fig. 10 Downloadable teacher materials include two lesson plans with vocabulary, activities, and Chamorro language glossary.



The Water Cycle and the CNMI's Fresh Water

Includes:

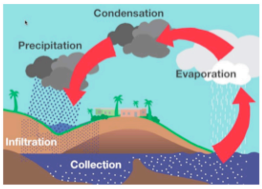
Illustrated Slides

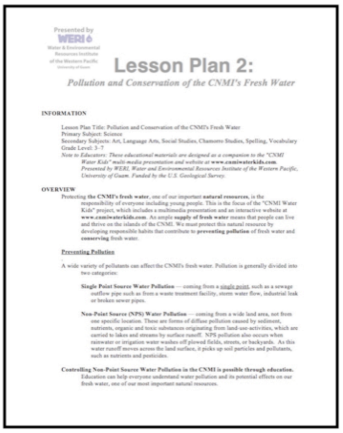
Word Bank

Quizzes

Chamorro Terms

Group Activities





Pollution and Conservation of the CNMI's Fresh Water

Includes:

Illustrated Slides

Word Bank

Quizzes

Chamorro Terms

Group Activities

Fig. 11 Two lesson plans with teacher orientation, activities, vocabulary, and Chamorro glossary and may be downloaded from the website.

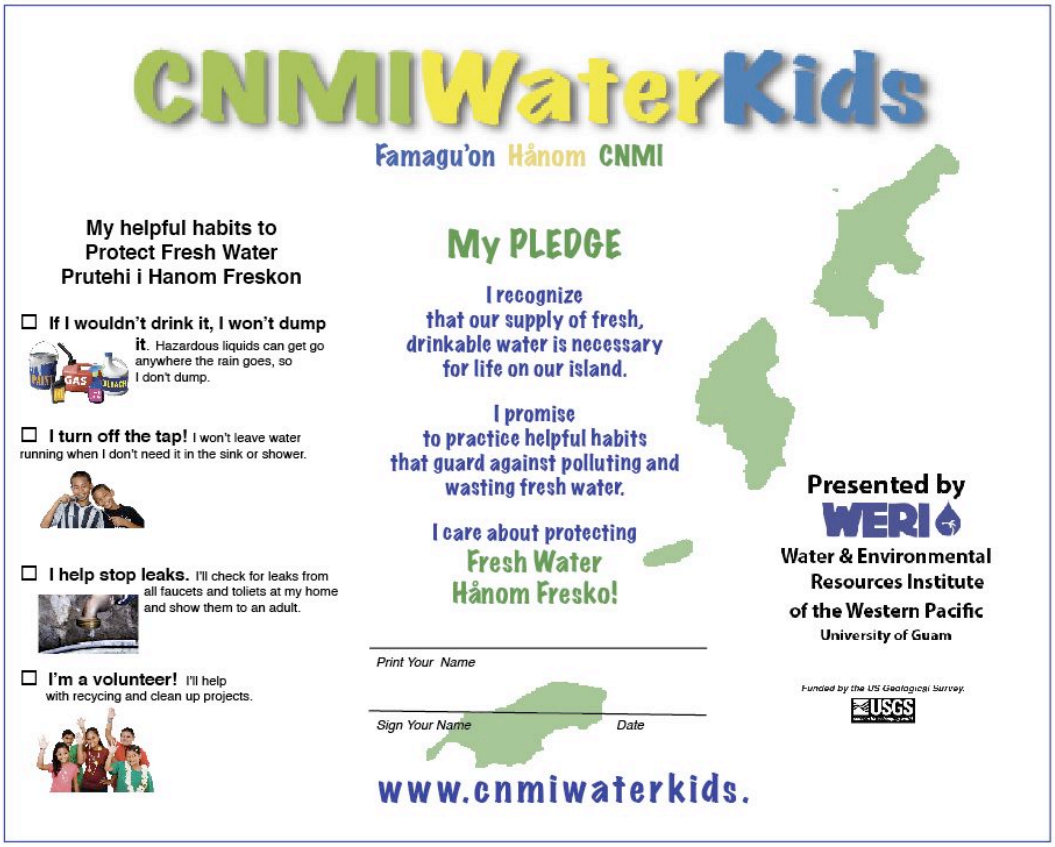


Fig. 12 Students who visit the CNMI Water Kid website may download a copy of a certificate to remind them of the "helpful habits" presented on the website and in the presentation.

(end)

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

Basic Information

Title:	Atoll Island Sustainability: Information Transfer and Training for the Federated States of Micronesia (FSM)
Project Number:	2010GU179B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	N/A
Research Category:	Not Applicable
Focus Category:	Groundwater, Hydrology, Models
Descriptors:	Atoll Island Aquifers
Principal Investigators:	John Jenson

Publication

1. Bailey, Ryan, 2010, Sustainability of Atoll Island Water Supply, Water Resources Pamphlet, Water & Environmental Research Institute of the Western Pacific, University of Guam, Mangilao, Guam, 2 pp. Available at: http://www.weriguam.org/reports/list

PROJECT SYNOPSIS REPORT

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

Problem and Research Objectives

This was an information transfer project, specifically a workshop conducted in response to the request of FSM water managers at the 2009 WERI Advisory Council meeting. The workshop built upon instructional services provided the previous year (Bailey, 2008). In summer 2009, the authors of WERI's atoll groundwater model (Bailey et al., 2009; Bailey et al., 2008b) trained FSM users on how to operate WERI's atoll island spreadsheet groundwater model (Bailey et al., 2008a, 2010) to estimate the responses of atoll island aquifers in the Caroline Islands to expected types of seasonal and inter-annual changes in rainfall. This year, the authors of the model presented it at a workshop in conjunction with a national meeting of FSM water resource managers held specifically to address central concerns regarding the sustainability of life on atoll islands. Users of the model who were trained at the workshop include local government water resource managers, environmental staff, and educators. The objective of this year's workshop was thus not only to train additional end-users of the model, but also to demonstrate its application to questions of sustainability, such as the calculation of groundwater responses to sea level rise and changes in crop management practices. Such use may also include making forecasts of the effects of selected changes in rainfall on atoll islands affected by significant natural events, such ENSO-driven droughts, tropical storms, or wash-over events. A second objective was to cultivate an ongoing technical support relationship between the authors and end-users so that there will be a continuing dialogue to support continued successful use and application of the model to water resource management in the Federated States of Micronesia.

Methodology

The workshop consisted of two days of instruction, including basic island hydrology and "hands-on" application of the model on individual laptop computers. The model can run on lap-top or notebook computers, and makes use of a published WERI technical report that serves as an operator's manual for the model (Bailey et al., 2008a) and another that serves as an educational text on atoll island hydrology and modeling (Bailey et al., 2008b). The technical reports are also available on CD and on-line on the WERI website (www.weriguam.org/v2 /index.php). WERI instructors used the technical reports along with supporting PowerPoint presentations to deliver lectures on the basic aspects of atoll hydrology and conducted laboratory-type training on the use of the model. These sessions were complementary to instructional sessions on the nature and timing of sea level rise and the sequence of events that should be anticipated as low-lying islands are affected by rising sea levels. Furthermore, the training included results of employing the model to calculate the ground water resources of atoll islands in Yap, Chuuk and Pohnpei states for both typical seasonal conditions and drought conditions. These results were presented in the PowerPoint presentations as well as handouts. A pamphlet (Bailey, 2010) containing information about basic atoll island hydrology and recommended water

conservation practices was also prepared and presented at the training, for distribution among government agencies and high schools.

Principal Findings and Significance

The training from the workshop will enable FSM water resources managers and planners to make more reliable policies and plans to support or build sustainable communities with good quality of life on the atoll islands of the FSM. Improving water resources availability and sustainability on small island communities will promote economic and social stability, as well as preserving the preferred way of life for many current and future residents of the FSM. Participation of island science educators in the training provides a basis for improved long-term education of students as well as the public at large on island hydrology and water resources management in general, and atoll island hydrology and water management in particular.

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

Basic Information

Title:	Water System Leak Detection Training for Kosrae State, Federated State of Micronesia
Project Number:	2010GU181B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	N/A
Research Category:	Engineering
Focus Category:	Education, Water Supply, Management and Planning
Descriptors:	Water Resources, Training, Education, Operations and Maintenance
Principal Investigators:	Shahram Khosrowpanah

Publications

There are no publications.

PROJECT SYNOPSIS REPORT

Project Title: Water System Leak Detection Training for Kosrae State, Federated States of Micronesia (FSM)

Problem and Research Objectives:
Water system leakage is a serious problem for all utility agencies throughout the Western Pacific. It reduces the performance of the system and a big money lost for utilities. The development of the modern water distribution system for most of the islands in this area started in 1970. Since then the system has been upgraded through a series of US sponsored capital improvements projects. However, the system leakage for some of these islands is as high as 60%. Utility agencies are suffering from lost revenues and are not able to provide 24-hour water service to their customers. Leak detection is one of the most cost effective and efficient ways to reduce non-revenue water. In fact, a leak detection program should be the highest priority with each utility agency. It is cost effective, and has the immediate result of increasing the system performance. In response to these unique circumstances, a special training program was designed for FSM. The training concentrated on the water system leak detection training for the Kosrae Utility Corporation (KUC). The specific objective of this training was to increase the technical understanding of system leakage theory, application of leak detection, how to manage the leakage, and use state of the art leak detection equipment. Since other utilities in FSM were experiencing similar problems, the training gave an opportunity for other utility personnel from the FSM utilities to attend the training. This specific training was requested by the Kosrae Utility as part of the WERI advisory council meeting held in October 2009.

Methodology:
The training project consisted of a one week long workshop that provided an understanding the leak detection theory, causes, and how to find leaks and fix them. As can be seen from the schedule below, the training provided a mix of classroom, laboratory and field site instruction and hands-on activities. The Kosrae Utility Corporation provided the required classroom and shop space required to carry out the training. The instructor who led the training was Mr. Scott Wicklund, Director of field services/training from Utility Services Associates. This company is based in Washington and they are specialized in leak detection. As a part of this training, a state of the art leak detection equipment (LD-12 "professional's plus" water leak detection with optional accessories sensors) was purchased for the Kosrae State to use.

Training Activities:

A. <u>Classroom Training covering the following topics (Approximately 1.5 day)</u>

1. Introduction to a leak detection program/theory.
2. Explanation of how leak sounds originate. Discussion of leak sound transmission through different types and sized of pipe.
3. Explanation of "Acoustic Leak Survey" & each type of survey including permanent monitoring. Introduction to survey tools/ equipment and the benefits of each.
4. Leak sounds exercise – (class did very well with this test)
5. Discussions and recommendations of paperwork / reporting practices that may be utilized in the field. Distributed field forms to attendees for consideration.
6. Hands on experience to cover the operation of the LD-12 leak detector

7. Started discussion on correlation theory and explained how a correlator locates water leaks.
8. Discussed three rules of correlation, best contacting practices and the correlation formula that enables the correlator to measure time delay.

B. <u>Field Training covering the following topics (Approximately 3.5 days)</u>

1. Demonstration use of equipment.
2. Hands on training and field practice on pinpointing leaks, estimating leakage, reporting, and review.

C. <u>Equipment</u>

The following equipment was used during the training:

1. Subsurface Leak Detection LC2500 leak noise correlator
2. Fluid Conservation System S-30 leak noise surveyor
3. Subsurface Leak Detection LD-15 leak noise detector
4. Subsurface Leak Detection LD-12 leak noise detector
5. Subsurface Instruments PL-2000 pipeline locator
6. Subsurface Instruments ML1 Ferrous locator
7. Probe rods
8. Audio and visual media presentations

Principal Findings and Significance:

Total of Nine (9) people working at the Kosrae Utility Corporation and other related agencies from Kosrae State completed the training. The training covered leak detection theory, and how to determine when a leaky survey is required, economic benefits of a leak detection survey, how to incorporate a leak detection survey and/or permanent leak detection crew for your water facility, how to become familiar with various sounds created by leaks and type of leaks encountered, types of leak detection surveys and proper record keeping, get familiar with various leak detection equipment and techniques, and field demonstration and actual leak detection scenarios and exercises.

The net results of this training were to increase the knowledge of KUC personnel on water conservation and leak detection technology. The benefit will be reducing non-revenue water and better management of one of Kosrae island's most valuable resources, its water. As always our goal will be to help provide the local government with on-island capabilities to maintain water supplies that that can provide safe drinking water for the entire island on a 24-hour basis. After the training, Mr. Scott Wicklund, lead instructor submitted his observation and recommendation for future improvement of Kosrae water system that is attached.

Figure 1: Class room lecture presentation.

Figure 2: Evaluating student learning with end of course quiz

Figure 3: Hands-on experience in the field.

Figure 4: Field work assessing a real life 'water leak' situation

Information Transfer

Basic Information

Title:	Information Transfer
Project Number:	2010GU185B
Start Date:	3/1/2010
End Date:	3/28/2011
Funding Source:	104B
Congressional District:	N/A
Research Category:	Not Applicable
Focus Category:	Education, Management and Planning, None
Descriptors:	Information Transfer, Education, Water Resources
Principal Investigators:	Gary Denton

Publications

There are no publications.

PROJECT SYNOPSIS REPORT

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.

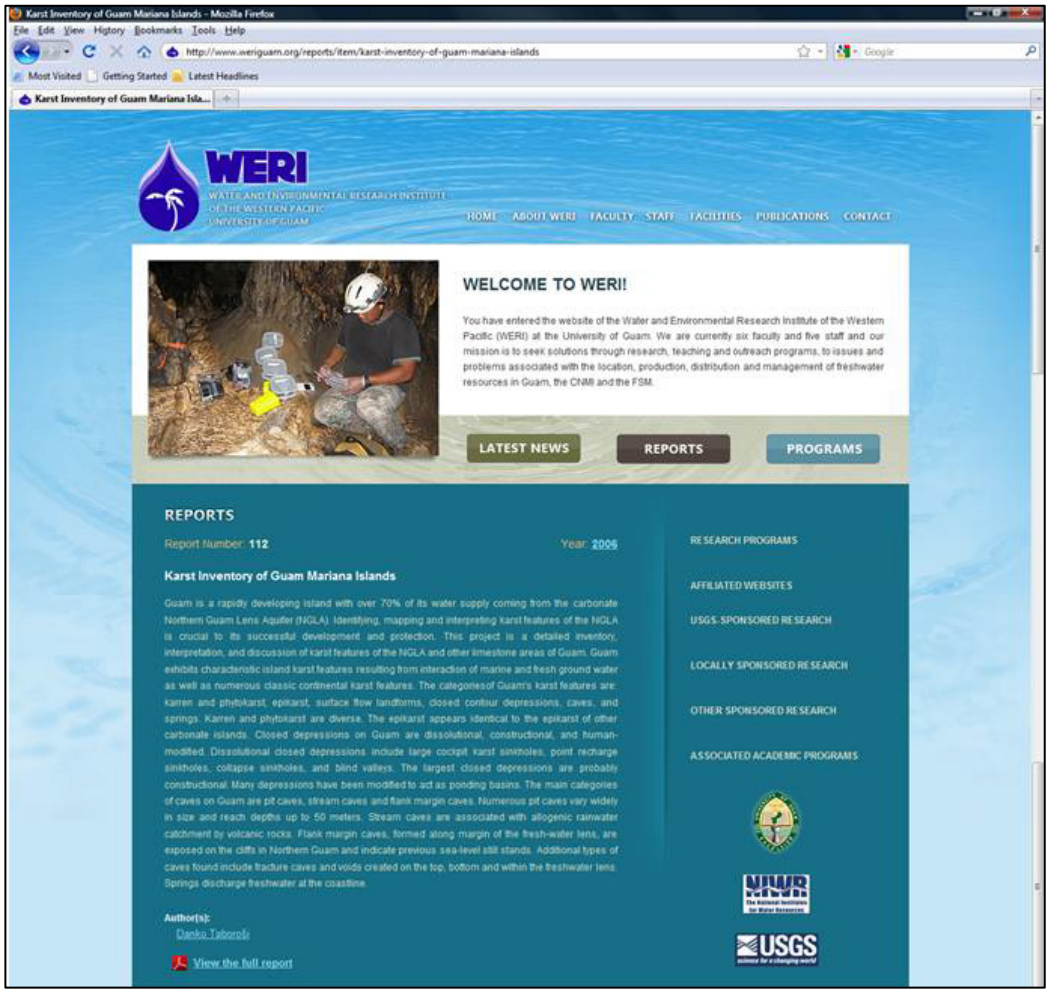
The WERI web-site is the Institute's primary Information Transfer/Dissemination mechanism. . This year's Information Transfer Project funded a significant improvement of the site in both format and design. The new home page, shown below, is located at http://www.weriguam.org/. It features informational links to WERI faculty, staff and Institutional facilities, our current research, education and train activities, primary sponsors and most recent publications. The new format is intended to increase visibility to the Institute's research programs and research projects underway in each. It is also intended to simplify the site and make it more user friendly particularly for our stakeholders in remote locations where state-of-the-art internet services and computer technology are often lacking

WERI Web-site Home Page

This project also funded the design, layout and printing of four (4) major technical completion reports resulting from USGS funded research projects. One hundred (100) hard copies of each

report were printed. All WERI technical completion reports are available in downloadable pdf format on the WERI web-site at http://www.weriguam.org/reports/list.

The technical completion report library was brought up to date with the inclusion of several new additions and a number of older volumes that were previously missing. We have upgraded the data base search engine process for accessing these reports on line. To this end, an 'Abstract' data base is used for key word searches, and searches based on 'Author' will search all authors in the author string not just the lead author as before. Upon selection of a particular report, site users are presented with the complete abstract, which may be viewed prior to downloading the main report. An example is shown below.



WERI Reports Page

Because of Guam's remote location, and the escalating costs of air travel, it is difficult and costly for researchers to present their findings at technical conferences and symposiums in other parts of the Globe. A portion of the current Information Transfer Project was earmarked for 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.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	1	0	0	0	1
Masters	5	0	0	1	6
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	7	0	0	1	8

Notable Awards and Achievements

For the third year in a row, WERI conducted the highly popular Groundwater Resources Management Training Course specifically for the inhabitants of island atolls in the FSM. This year the course was an adjunct to the WERI-FSM Advisory Committee meeting held in Pohnpei in early October. Once again, the workshop attracted island leaders and government officials and was well received by all. Participants were trained in the use of a high-resolution computer model of an idealized atoll aquifer to predict the sustainable management of their groundwater resources under various climatic scenarios. The training was so well received that WERI has currently committed to offering additional workshops on an annual basis, at least, for the time being.

Recent USGS-sponsored projects in hydrogeology enabled WERI to undertake foundational studies of the local geologic record of climatic variability in rainfall and drought. This past year, WERI was awarded $164,335 from the National Science Foundation for a three-year collaborative project with research partners at the University of Texas-Austin ($504,622). The NSF-sponsored project, “Collaborative Research: Holocene Hydrologic Variability across the Western Pacific Warm Pool” will use geochemical proxy data from speleothems and coral from across the western Pacific—including Guam, the Philippines, Borneo and Vanuatu—to indentify regional-scale spatial patterns as well as multi-decadal, centennial, and millennial-scale temporal trends in rainfall and drought for the western Pacific basin.

WERI faculty continues to engage both graduate and undergraduate students in their research activities. This year we are pleased to announce that WERI student, Ms. Maria Kottermair, graduated from the Environmental Science MS Program with distinction. Maria’s thesis project entitled Spatio-Temporal Dynamics of Badlands in Southern Guam: A Case Study of Selected Sites was initiated with USGS funds and leveraged continuation funding from the Guam Bureau of Statistics and Plans. The thesis provides vital information that is now being used by the bureau for the remediation and management of Guam’s badland areas in the southern half of the island and their impact on coral reef communities in adjacent coastal waters.

Publications from Prior Years

1. 2003GU22B ("Persistent Pollutants in Biotic Components of Tanapag Lagoon, Saipan, with Emphasis on Areas Impacted by Streams, Storm Water Runoff and Sewer Outfalls") - Water Resources Research Institute Reports - Denton, Gary R.W., Michael S. Trianni, and Michael C. Tenorio, 2010, Impact of Land-Based Sources of Pollution on Coastal Water Quality of Saipan, Commonwealth of the Northern Mariana Islands (CNMI): Arsenic, Mercury and PCBs in Popular Table Fish from Saipan Lagoon. Technical Report No. 130. Water and Environmental Research Institute, University of Guam, Mangilao, Guam, 98 pp.
2. 2005GU56B ("Developing Digital Watershed Atlas for Guam") - Conference Proceedings - Khosrowpanah, Shahram, Yuming Wen, and Danko Taborosi, 2010, Developing Digital Watershed Atlas of Natural Resources of Southern Guam, Proceedings of HIC, 2010, Tianjin, China, Proceedings of 9th International Conference on Hydroinformatics, Tianjin, China, September 7 – 11, 2010, pp. 1593-1598.
3. 2006GU70B ("Watershed Land Cover Change Detection in Guam") - Conference Proceedings - Wen, Yuming, Maria Kottermair, Mohammad Golabi and Shahram Khosrowpanah, 2010, Spatio-temporal Analysis of Badland Extent in Southern Guam, Mariana Islands Using Tonal Analysis, Proceedings ASPRS 2010 Annual Conference, San Diego, California, USA, April 26-30, 2010 (in press).
4. 2006GU70B ("Watershed Land Cover Change Detection in Guam") - Articles in Refereed Scientific Journals - Wen, Yuming, Shahram Khosrowpanah, and Leroy F. Heitz, 2011, Land Cover Change of Watersheds in Southern Guam from 1973 to 2001, Environmental Monitoring and Assessment (DOI 10.1007/s10661-010-1760-5, in press).
5. 2007GU95B ("Mercury Contamination in Garapan Lagoon, Saipan: An Evaluation of Potential Drainage Pathways and Impact on Fisheries Resources ") - Conference Proceedings - Denton, Gary R.W., Michael S. Trianni, Brian G. Bearden, Peter Houk, and John A. Starmer, 2010, Impact Determination of Unusual Mercury Source on Fisheries Resources in Saipan Lagoon, Saipan, Commonwealth of the Northern Mariana Islands: A Preliminary Assessment, in Proceedings Islands Environments and Resources International Symposium, University of the Ryukyus, Okinawa, December 18, 2010 (in press).
6. 2008GU140B ("Watershed Management for Pohnpei Island in the Federated States of Micronesia") - Conference Proceedings - Khosrowpanah, Shahram, and Leroy F. Heitz, 2010, Watershed Management for Pohnpei, the Federated States of Micronesia, in Proceedings Islands Environments and Resources International Symposium, University of the Ryukyus, Okinawa, December 18, 2010 (in press).
7. 2008GU146B ("Comprehensive Survey of the Current State, Infrastructure, and Usage of Freshwater Resources on Low Islands of Pohnpei State, Federated States of Micronesia") - Other Publications - Taboro¨i, Danko, John W. Jenson, Maricruz Sánchez, Mojca Zega, 2010, Abstract, Availability, Usage, and Threats to Freshwater Resources on Low Carbonate Islands in Micronesia, European Geosciences Union General Assembly ,Vienna, Austria, 2-7 May 2010.
8. 2008GU146B ("Comprehensive Survey of the Current State, Infrastructure, and Usage of Freshwater Resources on Low Islands of Pohnpei State, Federated States of Micronesia") - Other Publications - Taboro¨i, Danko, Mojca Zega, John W. Jenson, 2010, Abstract, Assessment of Coastal Erosion and Quantification of Land Loss on Western Pacific Atolls During the Last 50 Years, European Geosciences Union General Assembly, Vienna, Austria,2-7 May 2010
9. 2008GU146B ("Comprehensive Survey of the Current State, Infrastructure, and Usage of Freshwater Resources on Low Islands of Pohnpei State, Federated States of Micronesia") - Other Publications - Taboro¨i, Danko, John W. Jenson, and Blaz Miklavič, 2010, Abstract, Evaluating Coastal Dynamics of Coral Atoll Islands in the Western Pacific Over the Past Half-Century, First Joint International Conference of IGCP, Volume Preparing For Coastal Change: A Detailed Process-Response Framework for Coastal Change at Different Timescales: Hong Kong, 30 Nov-4 Dec 2010, INQUA

Coastal And Marine Processes Commission.

10. 2008GU146B ("Comprehensive Survey of the Current State, Infrastructure, and Usage of Freshwater Resources on Low Islands of Pohnpei State, Federated States of Micronesia") - Other Publications - Danko Taboro¨i and John W. Jenson, 2010, Abstract, Evaluating coastal dynamics of coral atoll islands in the Western Pacific over the past half-century. IGCP 588: Preparing for Coastal Change and INQUA 1001: Quaternary Coastal Change and Records of Extreme Marine Inundation on Coastal Environments. University of Hong Kong, Hong Kong, Nov. 30-Dec. 4, 2010
11. 2008GU132B ("Using Remote Sensing to Determine Changes in Soil Erosion and Sediment Loads from Guam Badlands") - Water Resources Research Institute Reports - Khosrowpanah, Shahram, Yuming Wen, and Maria Kottermair, 2010, Spatial Distribution of Badlands in the Ugum Watershed: Characterization and Temporal Analysis, Water and Environmental Research Institute (WERI), University of Guam, Mangilao, Guam, Report No. 126, 30pp.
12. 2008GU132B ("Using Remote Sensing to Determine Changes in Soil Erosion and Sediment Loads from Guam Badlands") - Dissertations - Kottermair, Maria, 2010, Spatio-Temporal Dynamics of Badlands in Southern Guam: A Case Study of Selected Sites, MS Dissertation, College of Natural and Applied Sciences, University of Guam, Mangilao, Guam, 117 pp.
13. 2009GU162B ("Influence of Stormwater and Wastewater Discharges on the Distribution and Abundance of Heavy Metals in Sediments from Saipan Lagoon") - Other Publications - Denton, Gary R.W., 2010, Abstract, Mercury and Lead Contamination Case Studies in Saipan Lagoon: Good News, Bad News! Proceedings 2010 Asia Pacific Academy of Science, Education, and Environmental Management General Meeting, December 8-9, 2010, American Memorial Park Auditorium, Saipan.
14. 2009GU153B ("Calibration and Application of LUOM (Luo, 2007) in Southern Guam Watersheds With and Without Flow Data") - Conference Proceedings - Luo, Qiang Charles, and Shahram Khosrowpanah, 2010, Developing the LUOM in Southern Guam Watersheds, in Proceedings of 4th International Workshop on Catchment-scale Hydrological Modeling and Data Assimilation, Lhasa, China, 21-23 July 2010.
15. 2009GU153B ("Calibration and Application of LUOM (Luo, 2007) in Southern Guam Watersheds With and Without Flow Data") - Conference Proceedings - Luo, Qiang Charles, 2010, An Ordering Scheme for Stream Networks with Channel Loops, in Proceedings of 9th International Conference on Hydroinformatics, Vol 2, Tianjing, China, Chemical Industrial Press, pp. 1697-1704.
16. 2009GU164B ("Prediction of Flow Duration Curves for Use in Hydropower Analysis at Ungaged Sites in Pohnpei, FSM") - Water Resources Research Institute Reports - Heitz, Leroy and Shahram Khosrowpanah, 2010, Prediction of Flow Duration Curves for Use in Hydropower Analysis at Ungaged Sites in Pohnpei, FSM, Water and Environmental Research Institute (WERI), University of Guam, Mangilao, Guam, Report No. 129, 26 pp.
17. 2009GU164B ("Prediction of Flow Duration Curves for Use in Hydropower Analysis at Ungaged Sites in Pohnpei, FSM") - Conference Proceedings - Khosrowpanah, Shahram; Leroy Heitz, 2009. Predicting Hydropower Potential on Ungaged Streams in Pohnpei Island, The Federated States of Micronesia (FSM), Proceeding of the American Water Resources Association 2010 Annual Water Resources Conference, AWWA Annual DDS Conference, Philadelphia, Pennsylvania, 9 pp.
18. 2009GU156B ("Impacts of Land Cover Change on Groundwater Quality in Guam") - Conference Proceedings - Wen, Yuming, 2010, GIS-based Analysis of Groundwater Quality in Guam, USA, Proceedings of 18th International Conference on Environmental Indicators & 2010 Annual Meeting of International Society of Environmental Indicators, September 13 – 16, 2010, Hefei, China.