Guam Hydrologic Survey (GHS)

&

Comprehensive Water Monitoring Program (CWMP)

FY 2012 Status Report

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

November 2012

GUAM HYDROLOGIC SURVEY (GHS) AND COMPREHENSIVE WATER MONITORING PROGRAM (CWMP)

FY 2012
STATUS REPORT

Prepared by

Gary R.W. Denton

November 2012

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

PROGRAM MISSION STATEMENT

The Guam Hydrologic Survey (GHS) and the Comprehensive Water Monitoring Program (CWMP) were created in 1998 by the 24th Guam Legislature under Public Laws No. 24-247 and 24-161 respectively. The Water and Environmental Research Institute (WERI) was charged with administering the annual legislative appropriations necessary to drive these two programs and facilitate, direct and implement their primary objectives. Both programs are now an integral component of the WERI water resources research, information dissemination, education and training mission, both on Guam and throughout the region.

PROGRAM GOALS

The purpose of GHS is to consolidate Guam's hydrological data gathered over the years by local and federal government agencies and consultants, and to conduct research on water related issues of local importance. GHS also funds a variety of water resource educational programs in various formats, including guest lectures and seminars at UOG and in the community, informational and training workshops for teachers and professionals from other government agencies, field trips and talks for schoolchildren, and the publication and distribution of educational posters, maps, and fact sheets.

The CWMP was created to collect data on saltwater intrusion and water lens thickness in Guam's sole source aquifer in the northern part of the island and stream flow and other parameters associated with surface waters in the south. The program builds on studies previously undertaken by the US Geological Survey (USGS) that were abandoned several years earlier because of a discontinuance of matching funds from the Government of Guam. The CWMP annual appropriations from the Guam legislature have facilitated the collaborative reinstatement of these studies with USGS under their 50-50 Federal/State-Territory cost-sharing program for water resource monitoring.

The foresight of the Guam Legislature in creating these two very important programs deserves special mention here. Through their efforts and continued support, we have consolidated and interpreted several vital water resources databases for Guam and revitalized the USGS water resources monitoring program. Our understanding of the complex physical, chemical and biological processes that influence Guam's water resources has broadened considerably and the increase in graduate student research opportunities provided by the programs has substantially added to the number of highly trained water resources professionals in the island's work force.

PROGRAM FUNDING AND FY'12 OBJECTIVES

GHS and CWMP appropriations written into each public law are $204,200 and $173,948 respectively. Local budgetary constraints saw a 6% reduction in funding support for both programs in FY'09, i.e., $192, 307 and $163,817 awarded for GHS and CWMP respectively. These shortfalls continued through FY'13. An additional 5% reduction was levied against each account by Governor Calvo in FY'12 and is continuing through FY'13. This reduces the total awards to $182,694 for GHS and $155,626 for CWMP. The information presented herein summarizes all GHS and CWMP program objectives and related activities undertaken in FY'12.

PROGRAM OUTCOMES FOR FY'12

GUAM HYDROLOGIC SURVEY (GHS)

In FY'12, GHS provided funding the continued maintenance, repair and upgrading of instrumentation in the WERI *Computer Analysis and Geographic Information System* (CA-GIS) *Laboratory*. Almost every water research project carried out by WERI involves a GIS analysis and mapping component. The GIS laboratory provides the required hardware and expertise in GIS analysis and serves as a data archive for GIS generated databases. WERI also works closely with various Government of Guam and Federal Agencies in sharing GIS data that become available.

Graduate students in WERI CA-GIS Laboratory

GHS provides limited stipends and tuition fees for research by graduate students working on their MS degree in Environmental Science and partial summer salaries to WERI faculty advising those students. It also pays for undergraduate field and lab assistants working on water resources projects on Guam, and the salary of one full-time Staff Hydrologist charged with operating WERI's complex and sophisticated computer analysis and GIS facility.

GHS Sponsored Research Projects Completed in FY'12:

With anthropogenically induced global warming now at the forefront of climate change research, WERI has focused on Guam's caves and corals to unlock climatic secrets of the past for this part of the world. Three such studies sponsored wholly, or in part by GHS funding are described below.

1. ***Reconstructing the Wet Dry Cycles and Sea Level History of Guam***

   Initial funding and ongoing support by the Guam Hydrologic Survey enabled WERI faculty and graduate students to begin collecting monthly chemical data from dripwaters, cave air, and calcite deposits beginning August 2008, from caves on northern Guam. Funding by the GHS has enabled progress that earned additional sponsorship from the National Science Foundation for a three-year collaboration beginning January 2011 with geochemists at the University of Texas-Austin. Scientists and students at the University of Guam and UT-Austin are now engaged in a detailed world-class hydrologic and paleoclimatic study of the entire Western Pacific region.

WERI research assistants collect cave dripwaters for chemical analysis.

Modern rainwater, cave dripwater, and cave stalagmite chemistry in northern Guam are used along with similar data from caves in the Philippines, Borneo, and Vanuatu to reconstruct climatic history of the region for the past 10,000 years. Detailed cave records from Guam so far indicate the existence of droughts of decadal length, more severe than any experienced since records have been kept.

WERI research assistant measures drip rates from a stalactite. The underlying stalagmite 28,000 year old and provides a record of ancient regional climate

Evidence from cave records also indicate that century-length dry conditions may have prevailed on Guam from about 5,000-6,000 years ago Understanding the past pattern of wet and dry climatic shifts on Guam will provide a basis for more reliable diagnosis or prediction of current and future climatic conditions and trends, most especially decadal and longer shifts between wet and dry conditions on Guam. Such knowledge is essential for reliable predictions of recharge and salinity conditions in the drinking water from the Northern Guam Lens Aquifer.

WERI paleoclimate research assistant inspects Guam cave site for sample analysis

Related work on the adjacent fossil reef platform deposited some 120,000 years ago when the ocean stood some 6 to 8 meters higher is also enabling WERI researchers to get a better understanding of the history of sea level changes around Guam and of the rates of evolution for the systems of caves that are part of the natural "plumbing" of Guam's aquifer (Miklavic et al., 2012). The caves on Guam that are the subjects of these studies are the only tropical caves in the world to date from which monthly data have been and are being collected. Moreover, because of Guam's location at the edge of the West Pacific Warm Pool, the history of the climate in this region is of particular interest to researchers studying natural global climate change. The results from this study are therefore not only of local value for determining the natural conditions that affect Guam's and the region's water resources, but also the history of global climate.

2. ***Reconstructing the Modern Sea Temperature and Rainfall Drought History of Guam***

Coral from Guam's coastal waters contain chemical records of sea-surface temperature, which is correlated with the decadal and longer cycles of storms and drought in the Western Pacific region. Understanding the past long-term cycles and trends on Guam will allow us to predict and model the future climate trends with much greater confidence, most especially the natural cycles of storminess and drought, which determine the long-term availability of fresh water resources, not only on Guam, but in the surrounding region of the western Pacific.

Porites **coral heads such as the one shown here are extremely slow growing and store critical data related to Guam's past climate**

In summer, 2010, WERI researchers extracted coral cores in using a uniquely designed pneumatic drill. A specimen analyzed at the geochemical laboratory at the University of Texas, in the fall of 2010 produced a record of local climate trends for past 60 years on Guam, which will enable WERI researchers and their colleagues at the University of Texas to match the historical record with the coral record, thereby gaining a reliable means for accurately interpreting prehistoric coral records. The work to date has produced successful MSci thesis in the University of Guam's Environmental Science Program, two WERI technical reports. Initial findings have shown that modern local sea surface temperatures in Apra Harbor, where coral are readily accessible and their environmental conditions can be easily monitored, match the regional records from other data sources. Prehistoric records of sea surface temperature can therefore be reliably inferred from ancient coral records. The coral record of the past 60 years in Apra Harbor shows a steadily rising water temperature of about 0.8° C, punctuated by sharp inter-annual variations apparently related to El Nino/Southern Oscillation cycles. Current research at WERI, in collaboration with colleagues at the UOG Marine Laboratory and the USGS Pacific Coastal and Marine Science Center, Santa Cruz, California, are studying the effects of coral growth rates on the chemical signals from which water temperatures are inferred.

WERI research assistant, and support team remove a 1m carbonate core from living ***Porites*** **coral head for analysis**

3. ***Analysis of Salinity Trends in the Northern Guam Lens Aquifer***

The Northern Guam Lens Aquifer (NGLA) provides 80% of Guam's drinking water. Current withdrawal by all producers is about 45 million gallons per day (mgd). The anticipated addition of new US Marine Corps activities during the next decade is expected to require an additional 4-6 mgd to support the new military activities alone, and additional economic growth on the island will certainly further increase demand for municipal and private production as well. There is thus an ongoing need to: (1) precisely track and analyze the current trends in salinity in Guam's aquifer and drinking water production wells during the past decade, (2) assess the possible causes of historical and new trends, and (3) recommend appropriate responses to documented trends to promote sustainable development of additional capacity.

The Northern Guam Plateau (background) as seen looking northwest from the summit of Nimitz Hill. Rainwater falling on the plateau recharges the limestone aquifer underneath.

This project comprised a two-year study of the 38-year records of salinity and groundwater management data from production and observation wells on northern Guam. These included historical and current WERI/USGS data collected through the Guam Comprehensive Monitoring Program, along with Guam Waterworks Authority data on production rates and chloride concentrations. Spatial relationships and trends were identified and evaluated to determine not only the current distribution of relatively low- and high-chloride zones in the aquifer, but also the historical spatial and temporal trends in the relationships between chloride concentrations in Guam's freshwater lens and production wells on the one hand, and spatial and historical trends in production rates and recharge on the other hand.

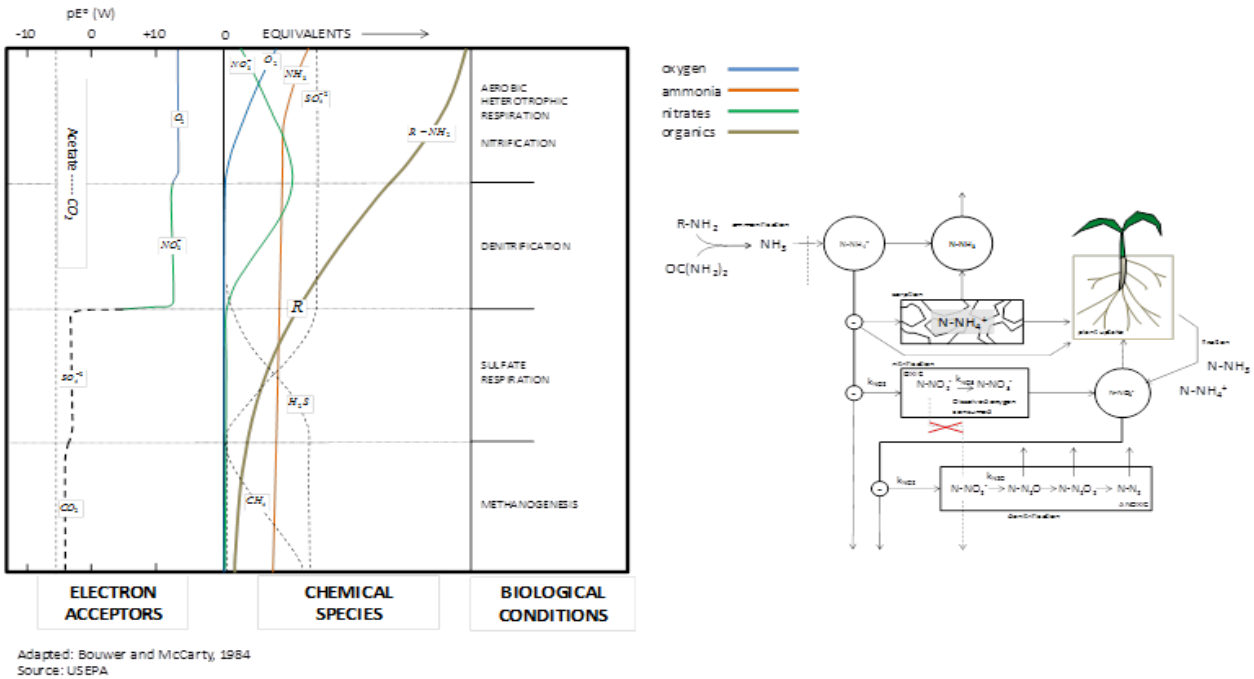
Results of the study have shown that there are (1) significant increasing groundwater chloride trends at about three-fourths of the production wells, (2) correlations with local precipitation and mean sea-level trends, (3) thinning of the freshwater lens by 2 to 16 meters between 2005 and 2009, (4) seasonal fresh water lens fluctuations of up to 70 meters in the Hagatña Sub-basin between 2005 and 2009, and (5) increasing chloride trends in the supra-basal groundwater zone—which indicates meteoric and/or man-made chloride sources other than over-pumped or over-deep wells. Key recommendations include: (1) installation of additional observation wells across the aquifer, (2) use of dedicated conductivity, temperature, depth (CTD) probes to continuously monitor salinity fluctuations and freshwater lens thickness, (3) studies of candidate natural and man-made sources of chloride in recharging waters, and (4) well-design guidelines for production wells in supra-basal zones and near the saltwater toe of the lens.

GHS Sponsored Research Projects Ongoing in FY'12:
Three ongoing research projects pertaining to the management and sustainability of the N Northern Guam Lens Aquifer are currently sponsored wholly or in part by GHS and are on the brink of that yielding significant. The significance and current status of each of these studies are outlined below.

1. ***Development of Vadose Contaminant Transport Model for Northern Guam***
   Modeling the percolation of wastewater nitrogen from septic tanks and sewage spills through the deep karst vadose zone into the NGLA is a particularly complex and challenging process. WERI is tackling this problem using a modification of its recently developed AQUA CHARGE program. Originally designed to simulate the delivery of moisture through the vadose zone, this program has been modified to model the mass transport of wastewater nitrogen to the water table. The modified program is called, appropriately, the AQUA CHARGE-N model.

   This two stage program utilizes vertically aligned cell storages connected in a series and is programmed into a numeric algorithm. As wastewater nitrogen mass passes through each cell series of a designated effluent source, sorption and chemical kinetics for nitrification and denitrification are applied to account the chemical transformations in its life cycle. The Stage 1 program modifications were completed last year. This year's focus was upon Stage 2.

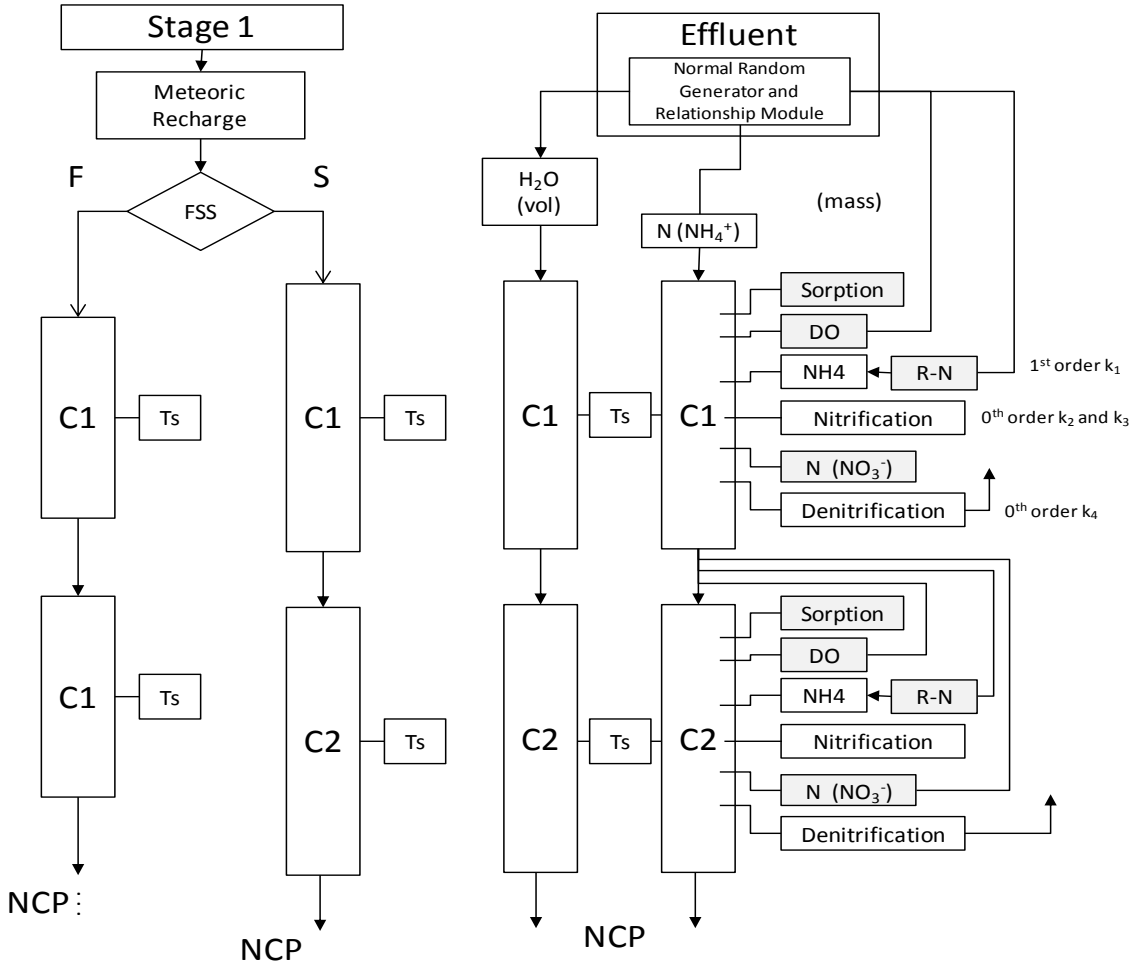
   The possible life cycle of nitrogen in wastewater percolation through the vadose zone of the NGLA is shown in the diagram below. The fate of percolating wastewater nitrogen is designed in accordance with these conceptual models. The left image is the equivalent transformation of involved chemical species. The image on the right is the flow conceptual model of the subsurface nitrogen cycle.



Adapted: Bouwer and McCarty, 1984
Source: USEPA

Possible life cycle of nitrogen in wastewater percolation through the vadose zone of the NGLA.

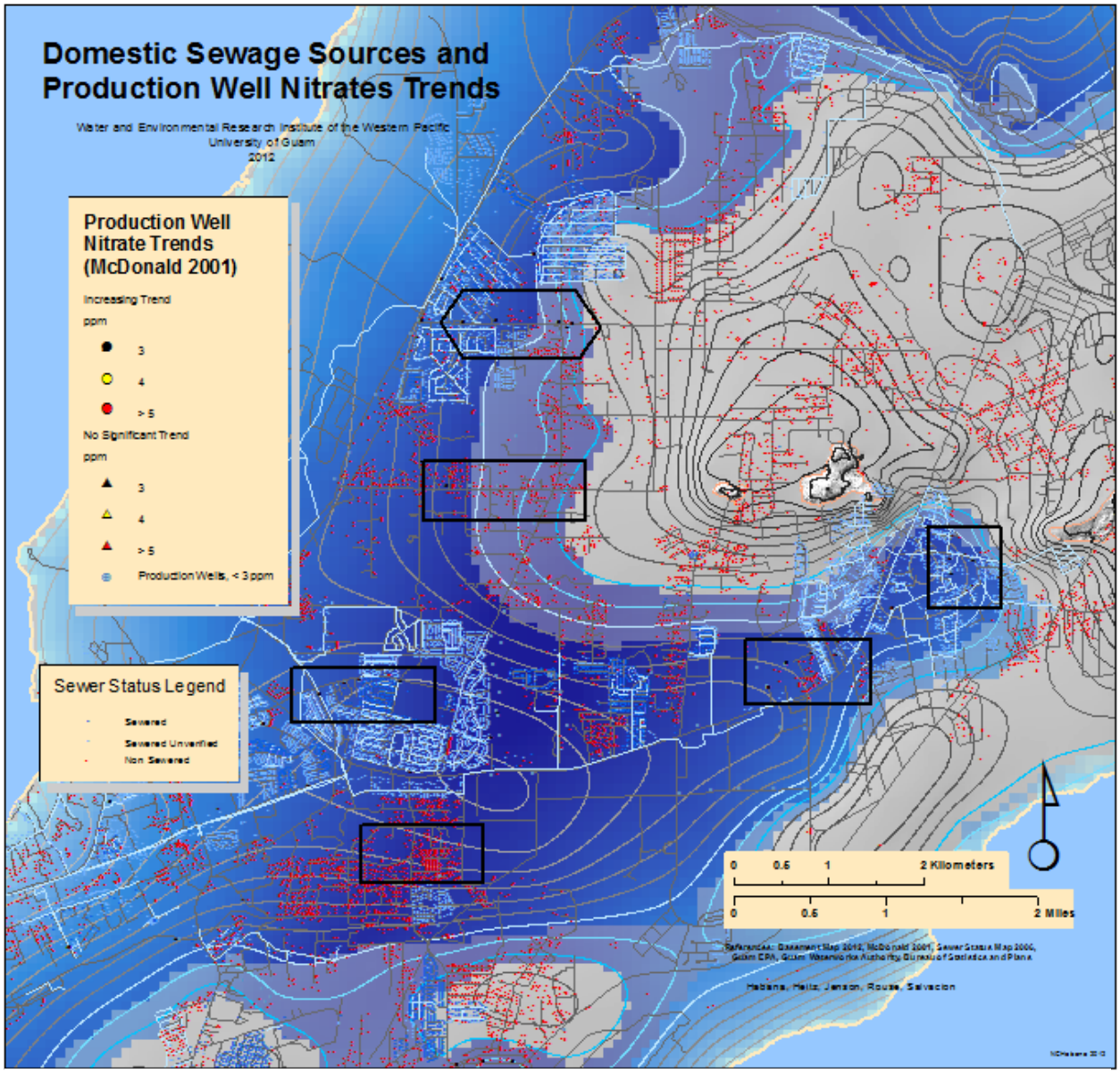
A program flow chart of the design component of AQUA CHARGE-N is presented below. The router is used to synthesize a moisture and constituent mass hydrograph. The computed results may be in forms as the transport of total wastewater nitrogen mass or individual wastewater nitrogen species (ammonium, nitrates, and nitrites) as well as the concentration of each constituent. The results are then coupled to a separate two dimensional finite element solute transport, phreatic model to simulate the plume dispersion of such constituents.



Flow chart schematics of the Stage 1 design component of the AQUA CHARGE-N model

The diagram shows the router transfer and transport of moisture and chemical species of a node-watershed designated with a septic tank system. In each cell in the mass transport router, the sorption and chemical kinetics account for the transformation of the wastewater constituents. The effluent is parallel in time in storage and number of cell phases as with the slow flow router.

This program is a solute transport model, providing insight into the possible contamination of our valuable groundwater system. An example of how the model simulations it will be used to support ongoing projects and protective measures to preserve the chemical and biological integrity of the NGLA is in the diagram below. In this instance, study domains in the NGLA with suspected production well vulnerabilities to domestic wastewater discharge are illustrated.

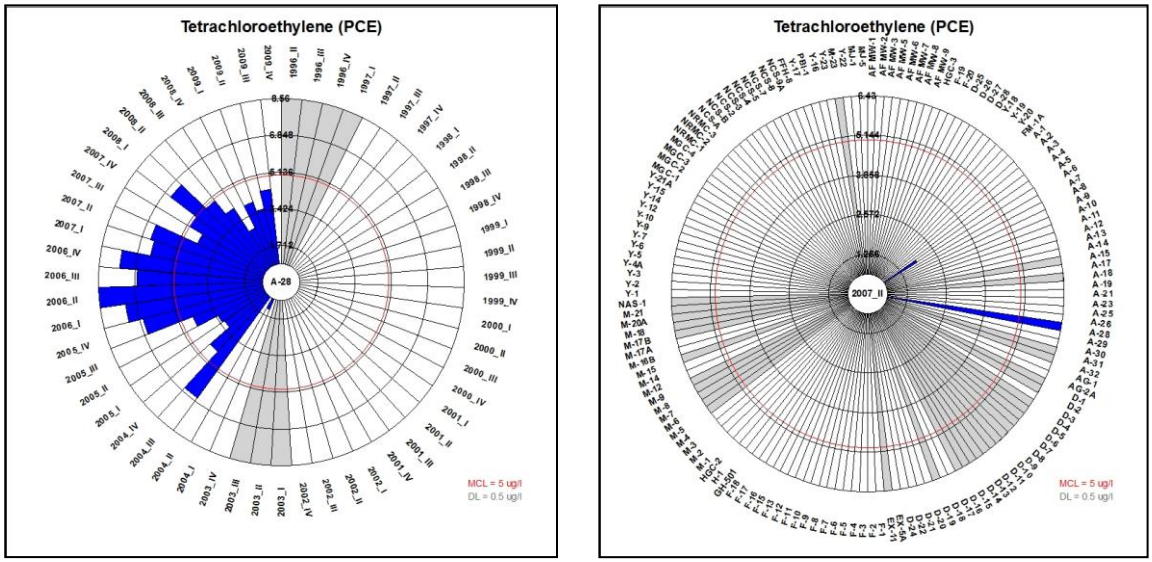


Several model domains (shown in black outlines) of interest contain production wells of possible increasing nitrate trends, surrounded by non-sewered buildings (red points), sewered buildings (blue and light blue points), or a combination of both

2. ***GIS Based Space and Time Analysis of Guam's Groundwater Quality***

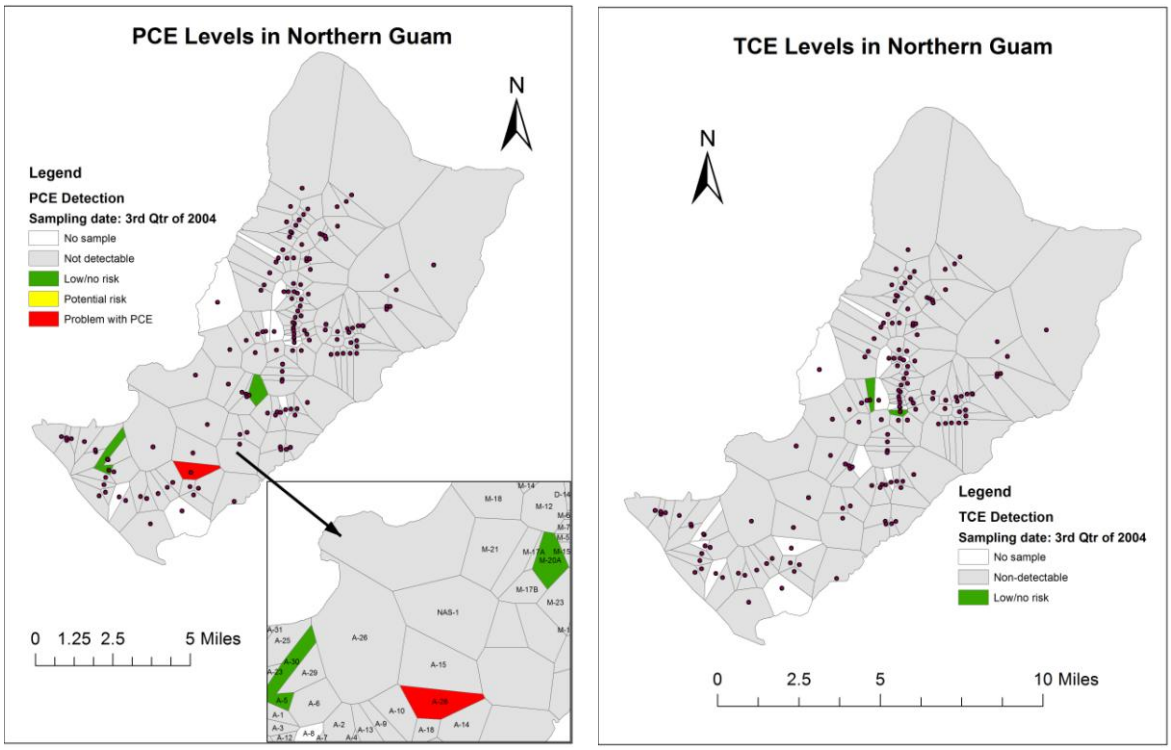
Since 1996, the Guam Waterworks Authority (GWA) has regularly monitored Guam's groundwater resources for all contaminants listed under the Safe Drinking Water Act. A substantial bank of data now exists from which certain space- and time-dependant trends are emerging. Previously, the 1996-2009 water quality data collected by GWA was converted to GIS format for further processing and analysis.

One novel outcome of this research was the use of *Clock Diagram Graphics* to visualize space and time changes in key contaminant concentrations in the NGLA. This intriguing technique allows GWA to quickly visualize water quality data for a single contaminant in a single well over extended periods of time, or a single contaminant in all wells over a specific time frame (see diagram below). The technique was showcased at the WERI *2012 Advisory Council Meeting* and applauded by GWA managers and Guam Environmental Protection Agency regulators alike.



Clock Diagram Graphics **developed at WERI to display temporal and spatial changes in Guam's groundwater quality characteristics. LH diagram shows temporal changes in PCE levels in GWA well, A-28. RH diagram shows spatial difference in PCE levels recorded during 2007 for all actively pumping wells. Blue bars = detects; grey bars = non-detects; colorless bars = no data; MCL = maximum contaminant level; DL = detection limit**

In the current study, a spatial estimation method employed *Thiessen Polygons* to establish proximal areas and create distribution surfaces for determining distribution patterns of potentially problematic contaminants in GWA's drinking water production wells. The advantage of this method is that the wells are superimposed upon a map of northern Guam. Thus, well locations are easy to see and color coding can be used to represent degrees of contamination. In the diagram shown below, for example, PCE and TCE were evaluated for all actively pumping wells during the third quarter of 2004. GWA wells are represented by dots within each of the polygons.



Thiessen Polygons provide a convenient means of identifying problem wells in the NGLA and together with the Clock Diagram Graphics visualization concept developed by WERI provide a very powerful and effect way of highlighting and evaluating problematic wells in the NGLA.

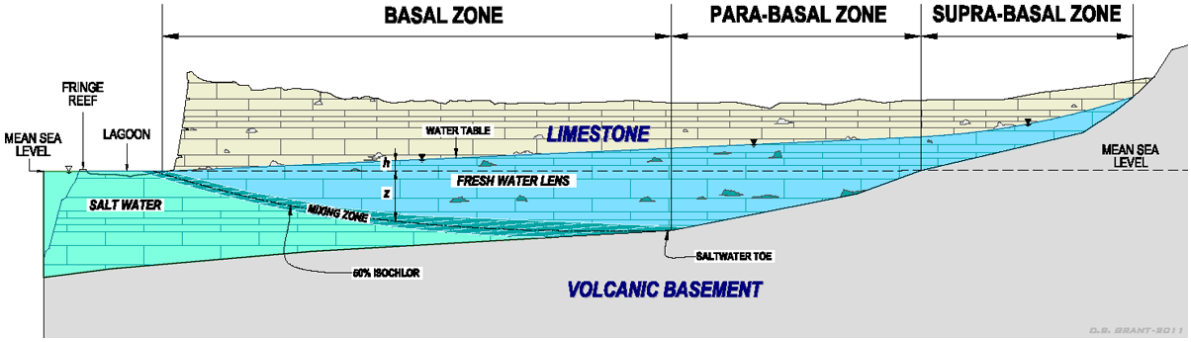
By marrying the *Thiessen Polygon* technique together with the *Clock Diagram* visualization concept, one therefore has a very powerful management tool for highlighting contaminated wells and evaluating water quality trends in the NGLA.

3. ***Basement Map of the Northern Guam Lens Aquifer***

By far the single most important tool for successfully locating new wells that will deliver abundant high quality water from the Northern Guam Lens Aquifer is an accurate and precise map of the volcanic basement rock that forms the floor of the aquifer. The volcanic rock beneath the water-bearing limestone partitions the aquifer into semi-contiguous subterranean catchments, or *basins*. On the slopes of the basement rock standing above sea level, where the base of the aquifer thus lies above sea level, downward percolating fresh water becomes concentrated in basement valleys and at the base of the slopes, where it enters the lip of the fresh water lens. The rim of fresh water thus concentrated along the boundary of the volcanic basement and the water-table near sea level is underlain by volcanic

Sinking new NGLA wells

rock rather than sea water. This *para-basal* water is thus fresher, thicker and much less vulnerable to salt-water contamination than the *basal* water downstream, which floats on the underlying sea water and becomes progressively thinner and saltier until it discharges at coastal springs and seeps. Water flowing down the flank of the volcanic slopes above sea level, designated *supra-basal* water, is the freshest of the water in the aquifer and is completely invulnerable to contamination by sea water.



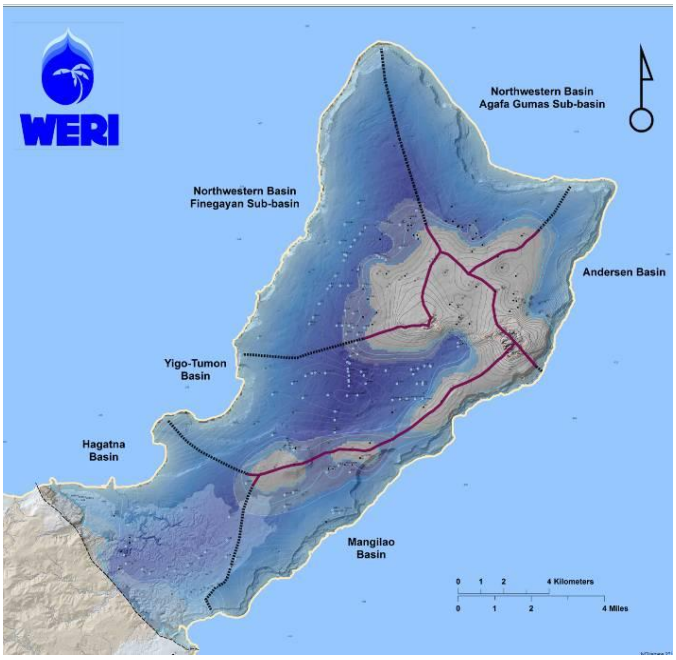
Volcanic basement beneath limestone aquifer defines three groundwater zones: 1) the basal zone, where the fresh water lens is underlain by sea water, 2) the para-basal zone, where the fresh water is underlain by the volcanic rock, and 3) the supra-basal zone, where the fresh water moving down-slope toward the para-basal zone is lies above sea level.

Outcrop of weathered basalt on the summit of Mt Alutom, which gives its name to the entire unit of basement rock beneath the limestone plateau of northern Guam.

The first detailed map of the basement topography was produced as part of the 1982 Northern Guam Lens Study. Beginning in 1998, with the establishment of the Guam Hydrologic Survey by the 24th Legislature, WERI began updating and revising the 1982 map based on new data and insights acquired by exploratory drilling, the emplacement of new monitoring wells, and other data obtained incidental to ongoing local aquifer development and military installation environmental remediation projects.

Most recently, the exploratory drilling program undertaken by the US Navy in 2010 in support of the anticipated military build-up provided additional new control on the elevation of the basement in crucial locations. Moreover, the new Guam Groundwater Availability Study led by the USGS Pacific Islands Water Science Center, in collaboration with WERI, has provided additional funding to update the database that supports the map. An accurate map of the basement topography is an essential prerequisite for building accurate and reliable groundwater models, which is one of the goals of the groundwater availability study.

WERI anticipates publishing the latest revision of the basement map in early 2013 along with technical reports that will describe the supporting data and database, explain how the data were interpreted in developing the latest revision of map, and highlight its strengths and limitations. The new map will actually consist of a set of maps, which will show the basement topography in relation to aquifer geology, surface topography, and the locations of drinking water production wells and aquifer observation and monitoring wells. These maps will be available to other geologists and engineers in the public and private sectors, for which they will enhance the success and thereby reduce the cost of ongoing aquifer development. They will also be essential tools to environmental scientists, regulators, and policy-makers seeking to develop appropriate regulations for aquifer protection and sustainable management.



Revised contour map of the volcanic basement underlying the limestone plateau in northern Guam.

SUMMARY OF FY'12 EXPENDITURES FOR GHS APPROPRIATION

Below is a composite summary of all expenditures lodged against the GHS account during FY'12. As in past years, budgetary shortfalls arising out of austerity measures implemented by the Guam Legislature have so far been covered by carryover funds from GHS allotments received in previous years. As these reserves are limited they cannot be expected to sustain the program at its current high rate of activity for too much longer. This notwithstanding, we gratefully acknowledge the Guam Legislature for their continued interest in and support of the GHS program and all associated water resources related research, education and training activities carried out at WERI.

Expenditure Summary for FY'12

Category		*Expenditure*
1.	**Salaries and Wages:**	**$78,878.34**
2.	**Fringe Benefits:**	**$6,996.57**
3.	**Tuition Fees**	**$0.00**
4.	**Supplies:**	**$1,547.00**
5.	**Computer Hardware/Software:**	**$1,650.00**
6.	**Equipment:**	**$11,810.00**
7.	**Projects/Consultant Fees:**	**$75,064.11**
8.	**Postage/Long Distance Phone:**	**$587.17**
9.	**Printing:**	**-$165.00**
10.	**Subscription/Dues:**	**$0.00**
11.	**Administrative Fees*:**	**$18,269.40**
Total FY'12 Expenditures:		**$194,637.59**
Total FY'12 GHS Allotment Rec'd:		**$180,444.00**
Balance:		**-$14,193.59**

* University of Guam cost sharing administrative fee of 10% levied against all special appropriations received from the Guam Legislature.

COMPREHENSIVE WATER MONITORING PROGRAM (CWMP)

The United States Geological Survey (USGS) has monitored our island's water resources since 1951. Unfortunately, during the 1990s they were forced to downsize this program because matching support from the Government of Guam was discontinued. This resulted in the abandonment of all deep monitoring wells needed to monitor saltwater intrusion in the north, and most of the stream gages in the south by the mid-1990s. In 1995, the USGS closed its field office at Naval Station, but continued to run a limited monitoring program (out of its Saipan and Honolulu offices).

In August, 1998 the CWMP was made a permanent part of WERI's program when Governor Gutierrez signed PL 24-247. This resulted in the refurbishment of the deep monitoring wells and a renewed program of water resource monitoring on Guam. The intent of PL 24-161 was to restore, and then to expand, as needed, the discontinued monitoring program in order to help Guam manage and safeguard all of its freshwater resources, now and in the future. Under PL 24-161, WERI/UOG and the USGS entered into a memorandum of understanding to administer and fund this program on a 50/50 cost-sharing basis. The CWMP is a permanent investment in Guam's future.

A well-designed long-term CWMP can save communities millions of dollars, and even human lives, by providing critical information for water-supply, culvert and bridge design, delineating flood-hazard areas, and tracking effects of climate change. The USGS started a water-resource monitoring program in Guam in 1951 with installation of stream gages at Pago, Lonfit, and Tolaeyuus and a rain gage near Fena dam. At the same time, measurements of discharge from Almagosa Springs and water levels in Fena Reservoir started. Since 1951 about 22 continuous streamflow, 8 rain, and 16 groundwater monitoring stations have been operated, providing reliable information on the water resources and hydrologic hazards of Guam.

Currently, USGS monitoring on Guam consists of 6 continuous-recording streamflow gages, 8 continuous-recording groundwater wells, 7 groundwater wells where the thickness of the freshwater lens is measured, and 8 continuous-recording rain gages. From a broad perspective, the program provides long-term information on the hydrologic cycle of Guam so that its water resources can be understood and sustainably managed. The bulk of the monitoring stations on Guam are funded as part of a Joint Funding Agreement between the USGS and WERI.

Locations of USGS monitoring stations on Guam

Stream Gages for Water Availability and Flood Planning in Southern Guam

Most freshwater used in southern Guam comes either from streamflow or wells that withdraw water from near the banks of streams. Data from USGS stream gages provide information needed by managers and engineers to properly manage the long-term sustainability of these water resources. Statistical analysis of long-term streamflow data are needed so the effects of abnormally wet or dry years can be understood and planned for. For example, USGS gages provide information that can be used to assess and manage the sustainability of surface water from the GWA Ugum Treatment Plant. Other gages, funded in cooperation with the U.S. Navy, are used to manage withdrawals from Fena Reservoir.

Long-term streamflow information is needed for flood planning. This information is used to delineate flood zones, estimate the magnitude of floods and frequency with which they could be expected to occur, and design bridges and culverts. For example, information from 11 stream gages and 3 other sites was used to assess the flood peak magnitude and recurrence interval following Typhoon Chataʻan in 2002. FEMA uses information from USGS stream gages to determine the level of financial aid from FEMA after storms. Currently, the WERI-USGS CWMP funds the operation of 3 stream gages at key locations in southern Guam.

Flow in Pago Stream has been measured since 1951

Well Monitoring of the Northern Guam Lens Aquifer

WERI field assistant measures water levels in the Northern Guam Aquifer

Monitoring wells operated as part of the USGS-WERI CWMP provide information to assess the health and sustainability of the Northern Guam Lens Aquifer. This aquifer is the most important source of freshwater on the island. Currently, the program includes 8 wells where water level is continuously measured and 7 wells where the thickness of the freshwater lens is measured biannually. Collectively, this information allows scientists at WERI, GEPA, GWA, and USGS to understand the flow of water through the aquifer and refine sustainability estimates of this resource. This information is used to understand how current levels of pumpage are affecting the aquifer and how future changes in climate and groundwater production may affect the sustainability of groundwater resources. Coupled with detailed geologic mapping and modern hydrologic tools such as groundwater flow models, information from this long-term program will be invaluable as additional water is needed to support increasing economic development on Guam.

Rainfall Data to Estimate Water Supply Recharge and Flood-Water Distribution

The USGS currently operates 8 rain gages on Guam, 6 of which are funded by the WERI-USGS CWMP. Rainfall data are fundamental to understanding the water supply and threats from flooding. Information from these gages is used to evaluate the extent of drought during El Nino events and the severity of flooding during typhoons. Information from rain gages is also essential in determining how much freshwater infiltrates past the ground surface to reach the water table. This water, known as recharge, is the source of freshwater in the Northern Guam Lens Aquifer and only by measuring rainfall can its abundance be accurately estimated.

What does it cost to operate a stream flow and other gages?

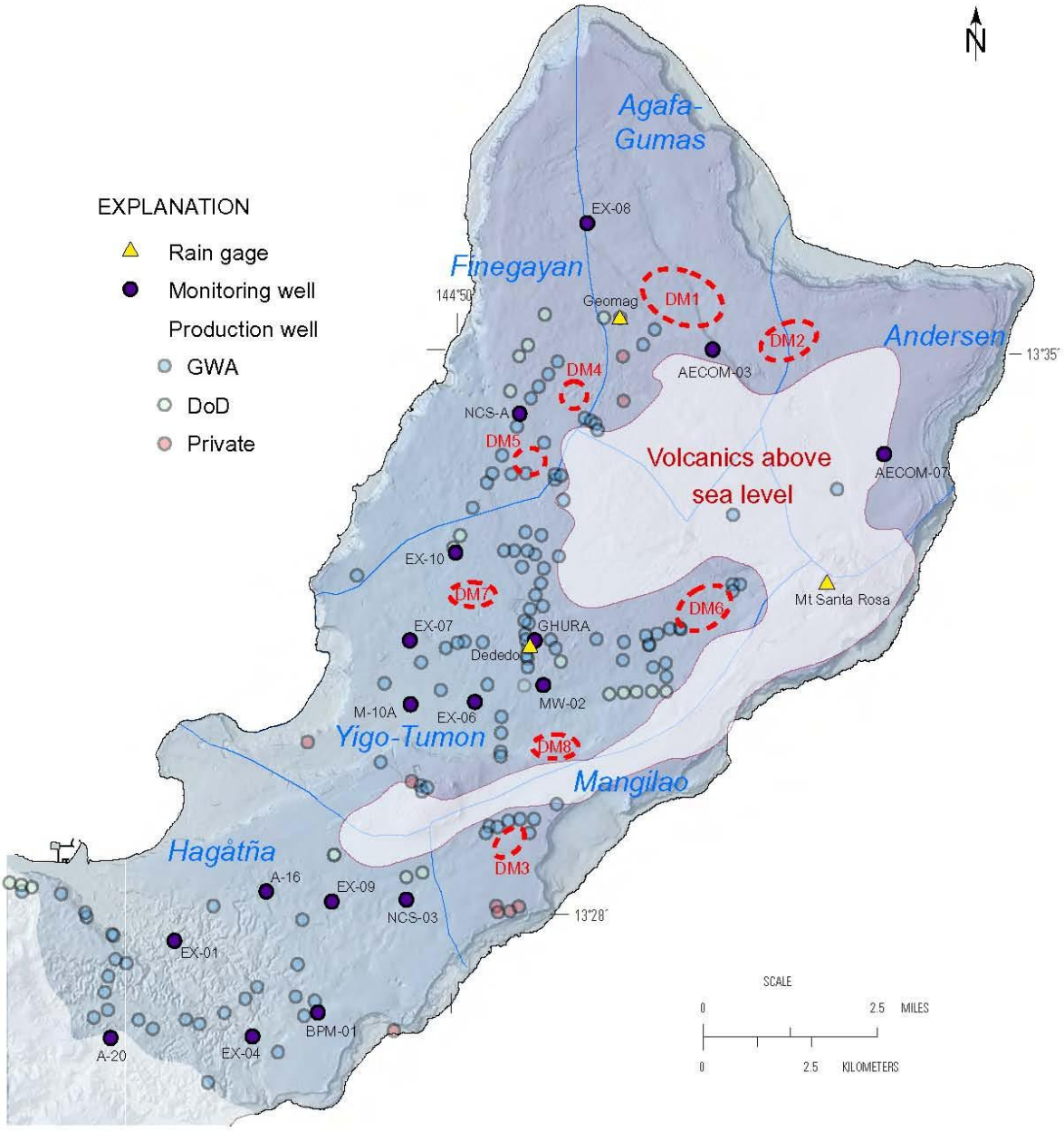
In fiscal year 2013, the cost to operate a continuous-record streamflow gage will be $23,000. This includes all operation and maintenance, site visits, field data collection, data analysis, and computation of the flow record. Gage operations are frequently reviewed and upgraded as improvements become available. Other gages, such as rainfall ($10,900) and groundwater ($7,000), require less funding. With over 100 years of experience, USGS procedures ensure that data are reliably collected, analyzed, and publicly available

How can one get USGS water resource information?

Most data from USGS gages are readily available on the internet. As part of CWMP between WERI and the USGS, historic data and other hydrologic information for Guam are consolidated and made publicly available at: http://hi.water.usgs.gov.

New deep monitor wells and expanded monitoring for the Northern Guam Lens Aquifer

Accurate and detailed data on aquifer hydrology and geology is the foundation for sustainable management of groundwater resources; especially on the island of Guam where fresh groundwater is limited and vulnerable to saltwater intrusion. Given the anticipated expansion of groundwater production from the Northern Guam Lens Aquifer during the coming decades, expansion of the existing hydrologic data collection network needs to begin in FY 2013. Baseline data are critically needed in areas targeted for development. These data will enable managers to evaluate and consider seasonal and long-term changes in rainfall, groundwater levels, and salinity in relation to sustainable groundwater production from the Northern Guam Lens Aquifer. The successful application of modern management tools, especially numerical groundwater models such as the one currently under development in cooperation with the U.S. Marine Corps, is crucially dependent on reliable aquifer-wide data on the responses of the freshwater lens to changes in the amounts and distribution of recharge and production. Proposed intensive development creates a need for additional data that the existing network cannot provide. Approximate locations where eight new deep monitor wells are needed are identified on the map below. The precise location of each new well will be constrained by landowner access, land use, and local hydrogeological factors. The cost of design and construction for each new deep monitor well is estimated to be $100,000. The prioritization and cost share agreement for well installation and monitoring will require inter-agency cooperation as defined in the Memorandum of Understanding between the Guam Waterworks Authority and the U.S. Navy dated July 16, 2011.



Location of monitoring and production wells and rain gages in the Northern Guam Lens Aquifer

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(BBMR PFS-1)

Government of Guam
Fiscal Year 2013 Budget
Program Fiscal Summary

FUNCTION: EDUCATION & CULTURE
AGENCY: UNIVERSITY OF GUAM
PROGRAM: WATER AND ENVIRONMENTAL RESEARCH INSTITUTE (WERI)

Budget Account Allocation		FY2011		FY2012	FY2013				
FUND TITLE	**Fund**	Actual Appropriation	Percent of Program	Authorized Appropriation	Current Service	Program Plan	Governor's Recommendation	**FY2014** Projected	**FY2015** Projected
General Fund Appropriation		$826,643		$877,727	$877,727	$930,390		$986,213	$1,045,386
Guam Hydrologic Survey (Local)		$182,694		$182,694	$182,694	$182,694		$204,200	$204,200
Guam Water Monitoring Project (Local)		$163,000		$155,626	$155,626	$155,626		$173,948	$173,648
Guam Water Monitoring Project (Federal)		$139,020		$118,600	$118,600	$91,896		$91,896	$91,896
USGS Water Institute Program (Federal)		$277,005		$277,005	$277,005	$277,005		$277,005	$277,005
USGS Supplemental Program (Federal)		$24,963		$19,976	$19,976	$19,976		0	0
ENSO Application Center (Federal, National Weather Service		$259,248		$267,598	$267,598	0		0	0
National Science Foundation (Federal)		$56,891		$52,619	$52,619	$54,023		0	0
GWUDI Program (Local)		$11,537		$57,683	$57,683	0		0	0
GWUDI Program (Federal)		0		$14,957	$14,957	$29,913		0	0
Total Program Appropriations		**$1,941,001**		**$2,024,485**	**$2,024,485**	**$1,741,523**		**$1,733,262**	**$1,733,262**
Performance Indicators	**Type**								
Undergraduate Courses Taught	WKLD	3		3	3	3		3	3
Graduate Courses Taught	WKLD	10		12	8	8		8	8
Thesis Committees served (chaired)	WKLD	21(11)		18(9)	15(9)	15(9)		15(9)	15(9)
Projects Initiated	WKLD	15		13	12	12		12	12
Projects completed	WKLD	11		12	12	12		12	12
Technical Reports	WKLD	10		8	5	5		5	5
Journal Articles/Conference Proceedings.	WKLD	17		23	10	10		10	10
Professional Presentations	WKLD	12		21	10	10		10	10
Workshops/Conference Presentations	WKLD	3		4	2	2		2	2