

**Water and Environmental Research Institute of the Western Pacific
University of Guam**

**Annual Technical Report
2019**

Project Title: Program Management

Project Type: Administration

Project ID: 2019GU067B

Project Impact:

WERI serves three constituencies: Guam, the Commonwealth of the Northern Mariana Islands (CNMI), and the Federated States of Micronesia (FSM). It thus has advisory councils in each, and uses Program Management funds to engage the venues, pay for supplies and correspondence, and support travel of faculty, staff, students, and advisory council members to the annual meetings. At each meeting, principal investigators and research assistants deliver reports on their previous, ongoing, and proposed projects. The WERI director presents the current WERI Research Agenda. Council members provide feedback, suggestions, and advice regarding project execution and research directions. Normally, the CNMI meeting is held in Saipan each September. The FSM meeting is held on one of the four island states each October. The Guam meeting is held each November. For the FSM meeting, travel is supported for one representative from each of the three island states the one where the meeting is held. The FY2019 FSM Advisory Council meeting was held October 21-26, 2019 on Kosrae, the easternmost and most remote of the four island states of the FSM. In addition to supporting advisory council meetings, WERI program management funds supported the director's travel to the annual NIWRR directors meeting in Washington DC, February 10-12, 2020.

Products

N/A

Student Support

N/A

Notable Achievement and Awards

N/A

Project Title: Information Transfer
Project Type: Information Transfer
Project ID: 2019GU063B
Project Impact:

WERI's Information Transfer Program sent two talented WERI student research assistants—a graduate student in environmental science, and an undergraduate chemistry major—to the *AquaVeo Groundwater Modeling System (GMS) Training Course* in Provo, Utah, March 10-13, 2020. Both research assistants are working on groundwater projects funded by the WRRRA program. The graduate student is using AquaVeo GMS as the modeling platform for his thesis research project to construct a high-resolution, state-of-the-art phreatic groundwater model of the Yigo-Tumon Basin, the largest, most highly developed, most vulnerable—and most threatened—of the six groundwater basins in the Northern Guam Lens Aquifer (NGLA). Guam draws 90% of its drinking water from the NGLA, and almost half of NGLA production comes from the Yigo-Tumon Basin. In spite of being the most developed basin, however, the Yigo-Tumon Basin may contain substantial reserve. The undergraduate student is doing statistical time-series analyses of nitrate concentration trends in the production wells in this important basin and mapping the relationship between nitrate concentrations in wells and their locations with respect to sanitary sewer lines and the number and densities of septic tanks in unsewered districts. WERI Information Transfer Program also supported attendance of WERI hydrogeologist (and director), Dr. John Jenson, at the *National Groundwater Association Summit*, Las Vegas, Nevada, December 3-5, 2019. Dr. Jenson gave two presentations: one on sustainable management of island aquifers, and one on the outcome of a hydrogeological study to support rehabilitation of Santa Rita Spring, a classic karst contact spring in southern Guam.

Products
N/A

Student Support
2 Students

Notable Achievement and Awards
N/A

Project Title: Comprehensive Guam and CNMI WERI-Web-Based Rainfall Data Utility

Project Type: Research, Outreach

Project ID: 2019GU064B

Project Impact:

Rainfall data for Rota, Tinian, Saipan and Guam were collected and archived. Rainfall data for Saipan have several problems. Beginning in 2006, data for Saipan International Airport (SIA) archived at the National Climatic Data Center (NCDC) were ingested from the Automated Surface Observing System (ASOS). For many years (including the ASOS era), a NOAA-sponsored cooperative observer has been manually recording the daily (and monthly) rainfall at SIA. The ASOS rainfall data are always lower than the manually observed data (by 10-30% on the monthly tallies). There is also a trend of increasing shortfall in the ASOS data. For Guam, a time-consuming effort was undertaken to assemble a comprehensive archive of daily rainfall and temperature at Andersen Air Force Base (AAFB) and Guam International Airport (GIA). From the hundreds of thousands of hourly Meteorological Aerodrome Reports (METARs) at AAFB and GIA during 1948 to present, the project PI filled in hundreds of missing days in the NCDC record for AAFB and GIA. Problems in data archiving, effects of station moves, and failures of automated equipment were discovered. The complete daily and monthly climatic record for Guam and the CNMI is slowly being populated into a digital archive. The enormity of the task (e.g., the need to cross-check official daily climate observations against the roughly 1 million hourly reports in the historical METAR record) was unanticipated and unabated. The problems discovered with the data are of sufficient magnitude to substantially alter analyses of trends used for studies of climate change.

Products

Several spreadsheets containing archives of historical climate data for Guam and the islands of the Commonwealth of the Northern Mariana Islands (CNMI) have been created or are still being developed. The premier example of these is the completed archive from 1948 to present of the daily climatic record (temperature and rainfall) for Andersen Air Force Base, in which hundreds of missing days were filled in and entries in the National Climatological Data Center (NCDC) publicly available Global Historical Climatological Netw (GHCN) climate data were cross-checked using a massive archive of over 1-million aviation hourly airfield reports. Similar comprehensive spreadsheets for climate data for other stations on Guam and for stations on the islands of the CNMI are in various stages of construction, with continual updating for current conditions.

A refereed publication is under review that was sponsored jointly by this project and the Pacific Islands Climate Adaptation Science Center (PICASC):

Lander, M. A., C.P. Guard. and B. Bukunt, 2020: State of the Climate for Oceania during 2020. In special 2020 State of the Climate edition of the *Bulletin of The American Meteorological Society* (in press).

Student Support

Mentoring of Weather Forecast Office, Tiyan Guam, Journeyman Forecaster Brandon Bukunt.

Notable Achievements and Awards

Notable Achievements and Awards

N/A

Project Title: Improvements to Sewage Treatment on Yap: Hydroponics and Composting of Waste Sludge
Project Type: Research
Project ID: 2019GU064B

Project Impact:

WERI research in Yap focused for several years on improving treatment in Yap's municipal sewage treatment plant. Work this year concentrated on continuation and maintenance of low-cost, environmentally sustainable treatment for both raw sewage and the residual sludge. In the preceding few years, the project focused on pilot testing to ascertain the safety of making and using compost from the sludge. This year, the process was run at full scale in collaboration with the treatment plant operators and Yap EPA. *E. coli* was measured in compost test piles, and all were found safe as a Class A (i.e., good for direct human use) product. When the success was reported to the public upon YEPA's certification of the results, the entire stock of sludge was immediately picked up by eager farmers and gardeners. This project is of manifest benefit to the local community in that not only is a hazardous waste product (i.e., raw municipal sludge) rendered safe, but moreover that it is converted into a valuable and sought-after resource (i.e., fertilizer). Due to the unexpected passing of the original principal investigator (Dr. Joe Rouse), Dr. Myeong-Ho Yeo took over this project in November 2019. Future phases of the project will focus on optimizing composting procedures, quality control and product safety, public education and outreach, and the supervision of the composting operation, which requires considerable manual labor for mixing, and careful control of temperature and humidity during composting to produce an effective and safe product.

Products

N/A

Student Support

N/A

Notable Achievements and Awards

N/A

Project Title: Hydrological Features and Analysis in the Finegayan Area

Project Type: Annual Base Grant

Project ID: 2019GU067B

Project Impact:

This project undertook an inventory of hydrogeological features in the Finegayan Basin, focusing on sinkholes, and exploring correlations between their proximities to relevant conditions, especially groundwater salinity, and how the proximities between features and conditions might relate to spatial and temporal variability of the conditions. The Hydrogeological features are identified and characterized from DEM and other mapped data, and include sinkholes, faults, changes in surface slope, and locations of groundwater zones (i.e. basal v. para-basal v. supra-basal). Conditions of interest include groundwater salinity (as conductivity or chloride), turbidity, pH, and hardness at production wells; daily, monthly and annual precipitation; land-use zoning, land cover and land-cover change. Analysis of salinity indicates that certain wells (F-10, F-6 and F-13) were consistently high in salinity, while other wells (F-19, F-4 and F-12) showed variable salinity. Additional work is required to explore the causes of variability, but one candidate hypothesis is proximity to concentrations of descending supra-basal water. Analyses of sinkhole-well proximity suggest that the water quality of wells may correlate with proximity to sinkholes to some degree, e.g., some high-salinity wells have substantially developed sinkholes within 150 m of them, but additional work is needed to identify relevant sinkhole characteristics. Regression of well production against chloride concentration shows mixed results—positive correlations in some cases, negative correlations in other cases. Additional work is needed to examine the attributes of some of the historical data more closely, and explore the influence of other factors, such as well depth and efficiency.

Products

Part of the findings for this research has been published in the following.

Wen, Y. and J. Jenson. (2020). Impacts of Sinkholes on Salinity Level of Groundwater in Finegayan Area, Guam, USA, EPJ Web Conferences **237**, 08010 (2020): *ILRC 29*, downloadable from <https://doi.org/10.1051/epjconf/202023708010>

Student Support

One graduate student was supported by this research project.

Notable Achievements and Awards

N/A

Project Title: Phase-II of N-baseline data and abatement methods for the Northern Guam Lens Aquifer

Project Type: Research

Project ID: 2019GU068B

Project Impact:

Increasing nitrate in groundwater, and appropriate steps for mitigation are matters of increasing concern on Guam. Septic tanks are commonly used over the aquifer and their risks and contributions to the incidence of nitrate in groundwater are matters of debate. Understanding the occurrence and implications of nitrate begins with identifying its initial conditions and the processes that control its chemical evolution and fate within the aquifer. Four active production wells were sampled, two (Y-3, Y-6) in sewerred areas, and two (Y-15, Y-5) in non-sewerred areas. A multi-probe analyzer in each well measured nitrate-N and ammonia-N, along with pH and temperature, every 2 weeks from July 2017 to April 2018. Wells Y-15, Y-3, and Y-5 averaged less than 3 ppm nitrate-N. Y-6, next to a home, averaged 3.6 ppm, rising to 4.4 ppm on rainy days. Effluent data from two septic tanks showed considerable variation, with total-N of 83 and 33 mg-N/L, ammonium of 70 and 29 mg-N/L, and nitrate of 0.1 and 0.1 mg-N/L, respectively, suggesting that no nitrogen cycling was occurring. Conversely, in the same area, two sampling events approximately one year apart, of one packaged treatment unit—which admittedly had not been well maintained—demonstrated total-N of 30 and 6.3 mg-N/L, ammonium of 3.8 and 0.1 mg-N/L, and nitrate of 22 and 3.2 mg-N/L, respectively, at the beginning and end of the sampling year. These values suggest that considerable nitrification and, potentially, denitrification were occurring. This exploratory project indicates that the chemical environment in this aquifer is complex.

Products

Publication

N/A

Presentations

Guam Advisory Council Meeting and Inter-Agency Workshop

Information Transfer Program

N/A

Student Support

2 Students

Notable Achievements and Awards

Legislative and scientific advisory supports

Project Title: Development of GIS based imagery database for groundwater recharge areas and key reaches of streams on Guam Phase II

Project Type: Research

Project ID: 2019GU069B

Project Impact:

To effectively manage a region's water resources, water managers and water resources researchers must have accurate baseline data and subsequent time-series information on the geomorphological and ecological health of surface water streams and groundwater recharge areas. Recent advances in commercially available sUAS (Small Unmanned Aerial Systems) technology have made it possible to provide this baseline and follow-on time-series data with low cost, accurate, sub-meter-resolution aerial imagery. Phase II of this project began by installing at WERI an EOS Arrow Gold differential correction (RTK) base station and antenna system. The second step was calibration of the base station and extensive testing to confirm rover coordinates for ground control points match coordinates used in base maps available in WERI's GIS system. The third step was development of georeferenced ortho-maps and digital elevation models of test areas in northern and southern Guam. The detailed georeferenced aerial data provide baseline information on location, size, and potential pollution sources in sinkholes located in the northern Guam groundwater recharge areas. In southern Guam, we can accurately plot stream cross-sections, determine erosion potential and possible sediment loading, and identify other sources of environmental contamination. The final step will be development of a data management scheme for the imagery and other digital data gathered by the project. The data management scheme will be compatible with WERI's existing on-line water resources data retrieval system.

Products

Publication

Habana, N.C., Heitz, L.F., Ziobro, M. (2019) Development of a GIS Based Imagery Database for Groundwater Recharge Areas and Key Reaches of Streams on Guam. Technical Report 169, Water and Environmental Research Institute of the Western Pacific, Univ. of Guam, Mangilao, Guam.

Presentation

N/A

Information Transfer Program

N/A

Student Support

1 Student

Notable Achievements and Awards

N/A

Project Title: Guam Waterworks Authority (GWA) production-well rehabilitation assessment: Lessons Learned Report & Manual for Well Exploration and Development

Project Type: Research

Project ID: 2019GU070B

Project Impact:

GWA operates about 120 production wells, of which about 100 are on-line at any given time. Over the past few years, GWA has undertaken a systematic rehabilitation program for its non-performing (closed) wells. Investigation of these closed production wells showed there are three main categories for why the closed wells originally failed: 1) deterioration due to age; 2) contamination of water at the site; and 3) historically poor performance. Aging problems include broken or corroded well casing, stuck pumps from previous maintenance failures, and screen deteriorations. Contamination problems include saltwater contamination and the occurrence of contaminants originating from surface activities. The latter includes contamination by chlordane, PCEs and PFOS. Wells closed for chronic underperformance or mis-performance appear to have been installed in locations where geologic conditions produce large seasonal variations in local storage and water levels. Drilling of adjacent replacement wells showed that well performance can vary greatly between identical boreholes located only a few tens of feet from one another—reflecting the high local-scale heterogeneity in the hydraulic properties of the Northern Guam Lens Aquifer (NGLA). Well rehabilitation data are being collected to prepare a Lessons Learned Report & Manual for Well Exploration and Development. This report will help local drillers better manage site selection, well installation, preventive maintenance, and rehabilitation.

Products

N/A

Information Transfer Program

N/A

Student Support

N/A

Notable Achievements and Awards

N/A

Project Title: PFOS trend monitoring in Saipan production wells

Project Type: Research

Project ID: 2019GU073B

Project Impact:

Perfluoroalkyl substances (PFAS) have received attention as emerging contaminants in drinking water sources. The US EPA UCMR3 result revealed that drinking water contamination by PFAS in Saipan is more prevalent than in the Continental US states. The Commonwealth Utilities Corporation (CUC), the public water and utility agency in Saipan, had collected water samples from 24 drinking water entry points. As the result of PFAS analysis, PFOS was detected in 5 wells and reservoirs. In particular, the production well IF-208, located within the Saipan International Airport (SIA) has been contaminated with PFOS in the range of 4900 ~ 7000 ng/L, a value that is one hundred times higher than the US EPA's lifetime health advisory concentration (70 ng/L). As a preliminary step 10 soil samples were collected for the analysis of UCMR3 PFAS. The Airport Rescue Firefighting Facility (ARFF) area in the SIA was selected as a sampling area because there was evidence of spraying firefighting foams for firefighter training. The result showed that all soil contained significant amounts of PFAS. The highest PFOS and PFOA concentrations detected were 6.57 ug/soil-kg, and 6.98 ug/soil-kg, respectively. Significant amounts of PFHpA, PFNA, and PFHxS were also detected. Concentrations of PFHpA, PFNA, and PFHxS ranged 0.16 - 10.40 ug/soil-kg, 1.77 - 7.78 ug/soil-kg and 1.06 - 4.26 ug/soil-kg. PFBS was not detected in all soil samples. Distribution of these species is complex and poorly understood. Further investigations will be conducted to characterize the degree and distribution of PFAS contamination in this area.

Products

Presentation

Y. Kim, "Groundwater contamination by perfluoroalkyl substances in Guam and Saipan", the CNMI Advisory Council Meeting, Saipan, September 2019.

Y. Kim*, M. Duenas, J. Becanova, L. Lohmann, N. Habana, M. Lander, G. Denton, J. Jenson, "Potential PFASs contamination sites in Guam", Per- and Polyfluoroalkyl Substances: Second National Conference, Boston, Massachusetts, June 2019.

Information Transfer Program

N/A

Student Support

One master student's tuition has been supported.

Notable Achievements and Awards

N/A

Project Title: Workshop Series on Guam Groundwater Resources

Project Type: Outreach

Project ID: 2019GU072B

Project Impact:

The military buildup and ongoing economic growth anticipated on Guam over the next decade have raised concerns regarding sustainable management of Guam's groundwater resources. Besides educating policymakers and agency heads, it is essential that island water resource professionals and educators be equipped with an accurate and up-to-date understanding of the island's aquifer and the factors that must be considered to frame and implement sustainable management practices. Professional people in the water resources industry, from technicians to engineers, managers, agency heads, and policy-makers have extremely limited time to engage in professional development education opportunities. In FY 2019, WERI offered a two-day professional workshop on the Northern Guam Lens Aquifer (NGLA). It was held on 31 January and 7 February 2020. The affiliations of the participant included Guam EPA, Guam Bureau of Statistics and Plans, and private firms including EA Engineering, GHD, APDI, and AECOM. The workshop covered WERI's aquifer database containing hydrogeological, engineering, and management data. The salinity histories of wells and the relations to well operation, construction, and location were also addressed. The workshop also introduced ongoing studies of salinity, PFOS, and nitrogen analyses, hydrologic modeling of groundwater production capacity, and concepts for sustainable management of the NGLA. Nine WERI faculty taught a total of nine sessions of the workshop. Four one-day professional tours of the NGLA were planned in FY2019, but the tours were cancelled due to the COVID-19 pandemic.

Products

Publication

Professional Field Trip of the Northern Guam Lens Aquifer, 4th edition, University of Guam, 2019.

Presentation

Y. Kim*, "WERI workshop and aquifer tour", Guam Advisory Council Meeting, Guam, (November 2019).

Information Transfer Program

A two-day WERI professional workshop of the Northern Guam Lens Aquifer (NGLA) was offered to local engineers, hydrogeologists, public agency staff, and policymakers. It was held on 31 January and 7 February 2020. The workshop covered an aquifer database containing hydrogeological, engineering, and management data. The salinity histories of wells and the relations to well operation, construction, and location were also introduced. Affiliations of the participants included Guam EPA, Guam Bureau of Statistics and Plans, and private firms including EA Engineering, GHD, APDI, and AECOM.

Student Support

N/A

Notable Achievements and Awards

N/A

Project Title: Sand Filtration Training for Yap State Public Service Corporation (YSPSC)

Project Type: Education and Training

Project ID: 2019GU065B

Project Impact:

There are four independent water authorities in Yap: FSM-Yap State Public Service Corporation (YSPSC), Map Municipality Water Authority, Gagil-Tamil Water Authority, and Southern Water Authority. This four-day training incorporated in-class lectures and hands-on practice sessions as well as field trips. This training was the first training in which the different water authorities participated together. Operators from three water authorities, agents from Environmental Protection Agency (EPA), and the agents from the Project Management Office, Yap State, attended this training. Although the original training objective was to have been only slow sand filtration, participants advised the trainer that YSPSC has a rapid water treatment system, and asked for instruction and advice on basic hydraulics, techniques, and equipment operation. The trainer therefore adjusted the curriculum to provide information and tools appropriate for current local conditions and resources. The training thus included the following information and more: 1) introduction to water system hydraulics, from water sources to storage tanks to customers; the parts of pumps and how best to operate and maintain them; and 3) how to operate and maintain disinfection systems. This spontaneous course of instruction was very well received, and now is in constant demand. The success of the training is explicitly documented in the survey collected at the end: 69% marked it *excellent*, and 16% scored it *very good*. Regarding how applicable the training is to their work, 58% of the attendees said *very applicable*, and 21%, *applicable*. A certificate of the completion was given to each attendee, and was uniformly highly appreciated.

Products

N/A

Student Support

N/A

Notable Achievements and Awards

N/A

Project Title: Guam Water Kids: Protecting Guam's freshwater

Project Type: Outreach

Project ID: 2019GU071B

Project Impact:

This year's Guam Water Kids program continued to build on the success of this well-received collaborative effort between WERI and K-12 educators in the local community. Activities included 1) a Guam Water Kids service-learning collaboration with two Guam Department of Education (GDOE) central district schools: Tiyan High School and P.C. Lujan Elementary School; and 2) presentations and activities at the Pay-Less (groceries stores) Summer Camp and University of Guam's 52nd Charter Day community outreach events. The primary goal achieved this year was building the partnership between officials and educators from GDOE, Tiyan, and P.C. Lujan Elementary School to implement the Guam Water Kids service-learning modules. Representatives from both schools acknowledged the limited off-the-shelf resources and materials available to help visualize local geology, hydrology, and pollution sources in their classrooms. Teachers welcomed the program's assistance to motivate students to be productive citizens and good stewards of the environment. Timely communication and logistic deliberate logistical planning aided in the Tiyan-P.C. Lujan service learning success in October 2019, despite Super Typhoon Hagibis' passage over Guam the day before. One notable success from this event is the quality of retention young students developed from the presentation of concise scientific explanations of local natural features and from subsequent hands-on activities. Several fifth-graders astounded the Tiyan High School ambassadors when they consistently answered content questions during the service learning visit. These students were also summer school participants received instruction over a span of three months—from a July summer presentation to the service-learning presentation in October. WERI and Guam Water Kids are preparing training kits for educators and students using local rocks, gravels, and sands.

Products

Freshwater Safety pamphlet

Freshwater Safety presentation

Student Support

N/A

Notable Achievements and Awards

N/A