Guam Water Resources Management Review

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This study was conducted to analyze effective water resources management and stewardship on Guam. The study was conducted independently by Travis Hylton to satisfy a requirement of the Naval Facilities Engineering Command Leadership Development Program. Therefore, the views and opinions offered through this study are solely those of Mr. Hylton and do not imply or represent any official position or endorsement by the Department of the Navy. Furthermore, nothing in this study is intended to affect in any way existing DoD and US Federal Reserved Water Rights on Guam.

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Author's Note

As noted in the Introduction, this document is simply a snapshot of where the science and art of water resources management was at the time that I completed my research – March 2012. I offer this document as a summary of the community's efforts to that time, and as a resource for those who continue to be involved in natural resources management in Guam. In addition to the data compilation and analysis presented, space permitting I have tried to include key documents in the appendix for easy reference. The document is not exhaustive, definitive, or in any way prescriptive, but is offered so that stakeholders can build a common understanding of what potential courses can be plotted to protect Guam's water resources.

My involvement in the subject came through my position with the Guam Program Management Office of Naval Facilities Engineering Command (NAVFAC) Pacific, where I served as the Water Resources Programs Manager. My role was primarily as a technical resource for drinking water and wastewater issues related to the Military Buildup on Guam. Through the welcoming collegiality of water resource professionals of Guam, I was able to facilitate discussions on the future of water for Guam, mainly in relation to performing a series of technical studies on these issues for the Military Buildup Environmental Impact Statement.

There were many people involved in helping this document be created. This document satisfies the development project requirement for my membership in NAVFAC's two-year Leadership Development Program (LDP). I would like to express my appreciation to NAVFAC Pacific's LDP Coordinator, Mr. Rodney Takeshita; my program mentor, Jennifer Mustain; my supervisor Steve Barker; my mentee Dawn Szewczyk; and the NAVFAC legal and public affairs staff for making this possible. I would also like to thank those that served on the Guam Water Resources Management panel discussion at the 2011 Water Resource Sustainability Issues on Tropical Islands conference: Dr. John Jenson of the University of Guam Water and Environmental Research Institute (WERI), Martin Roush of the Guam Waterworks Authority (GWA), and Bill Tam and Manabu Tagomori as Hawaii State Water Commissioners. I can't begin to thank all those that participated from the various stakeholder agencies: Guam EPA, USEPA, GWA and the Guam Consolidated Commission on Utilities, NAVFAC Marianas, WERI, and the USGS.

I would like to dedicate this document to the memory of Benny Cruz of Guam EPA, who was always a stalwart protector of Guam's water resources.

Chapter 1 Introduction

To say that water resources are at a crossroads in Guam is cliché and perhaps an overstatement. However, the fact remains that pressures on water resources are greater now than any time in Guam's history. With the Military Buildup and planned developments in Guam's future, these pressures can only be expected to increase. This environmental setting may be seen as an inflection point where water resources stakeholders have a precious and vital opportunity to reflect and consider potential enhancements to the existing operational organizational structure for water resources management.

Water resources management is currently diffuse and can be disjointed on Guam. Both Department of Defense (DoD) and Guam Waterworks Authority (GWA) run separate surface and groundwater-sourced drinking water systems and wastewater systems with ocean discharges. Regulatory authority for various water resource areas (drinking water, wastewater, stormwater, groundwater, floodplain management, etc.) is divided between the US and Guam Environmental Protection Agencies. The University of Guam Water and Environmental Research Institute (UoG WERI) is the clearinghouse for all hydrogeologic data on island, and has produced over 125 academic technical reports covering a broad variety of water resource issues over the last few decades. There is no formal Water Code for the Territory of Guam, nor is there a formalized commission on water resource management for the territory. Although GWA prepared a "Water Resources Master Plan" in 2006 in response to a USEPA court-ordered mandate, the document concentrates on planning for drinking water and wastewater capital improvement projects rather than integrated comprehensive water resources management and planning. Water resources working groups have worked together more and less formally over the years in Guam. The US Marine Relocation to Guam Military Buildup is forcing closer coordination between DoD and the public sector of Guam as demands on the primary source of drinking water, the Northern Guam Lens Aquifer, are increasing towards the limits of established sustainable yields. In response to these challenges, DoD and GWA have signed a MOU on water resources planning, pledging a cooperative effort to steward water resources on Guam. As required by the Guam Military Buildup EIS, a Civilian Military Coordination Council is being formed with a component working group focused on water issues and their role in Adaptive Program Management.

These pressures parallel the situation in Hawaii around the time of Statehood, when competing demands on the Pearl Harbor aquifer between the Navy, Honolulu Board of Water Supply, and the Sugar Cane industry forced the development of the Hawaii State Water Code and the State Commission on Water Resources Management. These Hawaii institutions can be used as a sounding board when the water resources community on Guam considers what the next logical evolution of the water resources management organizational structure should be for the island.

The overall description of the study approach, which included interviews, an issue survey, a stakeholder meeting, and a water resources conference panel discussion, is included as Appendix A. This review report is organized to provide the reader an overview of the current water resources management

organizational structure on Guam, and the possible directions available for refinement of this structure. Chapter 2 provides a background, with a brief overview of Guam's water resources environmental setting and a history of water resources management on Guam from the earliest inhabitants to the present day. Chapter 3 gives an overview of the current management setting, with a review of the planning documents and process, institutions, and the water resources focus related to the Military Buildup. As part of the review of the planning process, a description of the Hawaii State planning process is given to compare and contrast with Guam's process, offering the perspective of what has been organized in another US tropical island community. Chapter 4 provides a snapshot of water resource issues and actions from the Guam water resources community itself. This chapter takes a look at a survey conducted on water resources issues, summarizes a professional conference panel discussion focused on Guam water resources, and provides perspective from the kickoff meeting of the Northern Guam Lens Aquifer Advisory Group. Chapter 5 provides descriptions of the current water resource management structure on Guam, as well as four additional inter-related organizational structures that could be pursued to give a higher degree of definition to the water resources management operations on the island. Finally, Chapter 6 lists potential courses of actions (COAs) that could be pursued by the water resources community on Guam to strengthen resource management. It should be noted that these potential COAs are not recommendations, as this document is not intended to advocate any particular actions, strategies, or solutions with respect to managing Guam's water resources. These COAs are presented solely for consideration by the professionals, institutions, and stakeholders involve in water resource issues as potential paths toward the common objective of protecting and enhancing water resources on Guam.

Purpose

The purpose of this study is to provide a snapshot of the current organizational framework of water resources management on Guam, and to provide potential courses of action to widen the basis for sound leadership in water resources stewardship on Guam into the future. Organizational frameworks considered include:

Current "Networked Program" structure with responsibilities and authorities distributed throughout existing agencies (Status Quo)

A new or imbedded "Technical Entity" responsible for maintaining the 3-D NGLA/recharge model and other advanced analytical tools for Guam that would run planning scenarios based on key resource challenges

An "Interagency Model" with technical experts informing Guam and DOD leadership, such as the current Utilities Working Group reporting to the Civilian Military Coordination Council or the Northern Guam Lens Aquifer Advisory Group

A new "Water Resources Master Plan" document to be updated on a recurring basis

A new "Commission" entity with elements similar to the Hawaii State Commission on Water Resource Management, possibly based on enactment of a Guam Water Code

Chapter 2 Background

Guam Water Resources Overview

There are many sources available to provide a detailed description of the water resources, hydrology, and hydrogeology of Guam. This discussion is intended to provide a brief overview.

Guam is the southernmost and largest of the Mariana Islands, a group of 15 islands located in the western Pacific, and is an unincorporated territory of the United States. The island is approximately 30 miles long, and the width varies from about 8 miles at the northern end to about 4 miles near the center to roughly 12 miles in the south.

Guam is warm and humid throughout the year. The average monthly air temperatures range between 80 and 83^{o}F. Relative humidity typically ranges between 65 and 100. The average annual rainfall ranges from 84 to 116 inches per year across the island. About one-third of the annual rainfall occurs during the dry season months, (January through June – up to 8 inches per month), and about two-thirds during the wet season months season (July through December – 5 to 18 inches per month) when the island is also subject to torrential typhoon systems.

Hydrogeologically, Guam can be thought of as two different island types linked together in the middle. The roughly northwest-to-southeast trending Pago-Adelup Fault located at the waist of the island sharply divides the two distinct geologic provinces. North of the fault lies a limestone plateau. A volcanic upland lies south of the fault. Volcanic units were created first geologically, and then limestone was deposited on top of irregular volcanic topography primarily in the north. The land surface is comprised of four major physiographic land forms: limestone plateau, volcanic uplands, interior basin, and coastal lowlands.

The southern half of the island is mostly rugged volcanic uplands that have been shaped by streams and springs. The highest point on Guam, Mt. Lamlam at 1,332 ft, is on the narrow mountain ridgeline of limestone that caps the volcanic uplands. The terrain west of the ridgeline is footed by coastal lowlands. Limestone plateaus also fringe both the east and west coasts in places. An interior basin extends inland from Talofofo Bay to Fena Reservoir, and further up the bordering rolling hills to the volcanic uplands.

The northern half of the island is a broad limestone plateau bordered by steep cliffs and coastal lowlands. The plateau slopes from about 600 feet in elevation in the north to less than 200 feet near the central area of the island. Volcanic rocks protrude through the limestone plateau at points and also underlie the limestone as a volcanic basement. The plateau lacks stream channels, but the Karst limestone topography has many closed contour depressions and sinkholes.

The northern half of Guam is a groundwater province with its most important resource being the Northern Guam Lens Aquifer (NGLA). The NGLA system consists of freshwater lens in the high-permeability limestone rocks of northern Guam that floats on saltwater and is separated from saltwater

by a transition zone of brackish water. Groundwater discharges to the ocean from the freshwater-lens system through diffuse seepage near the coastline.

Water resources were generally defined in the Final Environmental Impact Statement (FEIS) for the Guam and CNMI Military Relocation as "sources of water available for use by humans, flora, or fauna, including surface water, groundwater, nearshore waters, and wetlands." Surface water resources are concentrated in southern Guam, and include stormwater, lakes, streams and rivers, which are important for economic, ecological, recreational, and human health reasons. Groundwater resources are concentrated in northern Guam, and may be used for potable water, agricultural irrigation, industrial applications, and most importantly is the primary source of potable water used to support human consumption on the island. Nearshore waters are defined as all coastal waters lying within a defined reef area, and all coastal waters of certain depths and distances offshore where there is no defined reef area. Nearshore waters are susceptible to pollution from land-based sources, and are important for human recreation and subsistence. Wetland communities are habitats found throughout Guam that are subject to permanent or periodic inundation or prolonged soil saturation, and include marshes, swamps, shallow ponds, or pond or lake edges. A detailed description of each of these water resource types and their occurrences and qualities on Guam are located in Appendix B, which is an excerpt from the Water Resources chapter of the FEIS. In addition to the descriptions of the water resources, applicable Federal and Guam regulations are summarized as well.

Guam Water Resources Management History

The information presented here is compiled from several publicly available sources. Most notably, much of the early information has been drawn from the 1979 University of Guam Water Resources Research Center (now WERI) Technical Report No. 8, "Freshwater Use Customs on Guam: An Exploratory Study," by Rebecca A. Stephenson. This document gives great insight into historical water uses and pressures on Guam. Other data sources were other WERI documents and information from the GWA website and the Guam Military Buildup EIS. One common theme throughout Guam's water resources history is that as population and development pressures have increased over time, the resource management challenges and solutions needed have in response grown in scale and complexity.

Prehistory: Pre-Latte Phase 2000?BC to 500 to 800AD

Populations centered on freshwater resources; rivers and streams in the south and caves and springs in the north. Small self-sufficient populations subsisting on abundant wild plants, fish, and seafood. Subsistence accomplished with reasonable ease, as indicated by variety of complex decorative ornaments found from the period. Intermittent use of some areas as habitation, perhaps on a seasonal basis due to freshwater availability.

Prehistory: Latte Phase 800AD to 17th Century

Vast increase in population up to 50,000 to 100,000, with latte found at sites throughout the island. Populations still centered on freshwater resources; rivers and streams in the south and caves and springs in the north. About 40% of the pre-contact sites were in the rocky coastal shelf of the northern plateau, and the other 60% were scattered around the bases of mountains near the ocean or in interior river valleys. Sites in the north were much larger and extensive than in the south. In the north, the availability of freshwater was concentrated in caves, and population densities were centered on these resources. Smaller sites were spread along the more abundant streams and rivers in the south, and no wells were recorded in these areas. In northern Guam, other water sources were wells dug into the ground, or coconut tree rain catchments systems with vessels placed next to, or dug into, the tree. Large stationary ceramic vessels also served to store water transported in bamboo or smaller ceramic vessels. Sites with only seasonal water availability may have either been only inhabited seasonally or created reciprocal ties with sites that did have year-round water. Villages reached populations of up to a thousand or more people. Ancient Chamorro gardens included yams, taro, breadfruit, sugar cane, coconut palms, and rice, and sufficient irrigation to grow these foods.

The Spanish Era (1565-1898)

Ferdinand Magellan arrived to Guam on March 6, 1521, and anchored in Umatac Bay. Immediately thereafter was the first documentation of water sharing on Guam between Chamorros and Europeans. Magellan's crew was in dire need of freshwater, and they drew this water from the springs of Umatac. Subsequent other expeditions documented replenishing their stores of fresh water and food on Guam. Some mentioned there being large houses serving as water supply arsenals. Some ships traded iron for water and other supplies.

Guam and the other Mariana Islands were formally claimed by the Spanish Crown in 1565 by Miguel Lopez de Legazpi. Father Diego Luis de Sanvitores established the first permanent Spanish mission on Guam in 1668, and at this time there were thought to be 50,000 to 100,000 Chamorros living in 180 villages on island. The Spanish-Chamorro wars reduced this population to less than 5,000. From 1668 to 1815, galleons on voyages between Acapulco and Manila were required to stop in Guam for water and provisions, and for this the Spanish crown directed Mexico send 34,000 pesos annually to Guam. It is thought that these requests did not deplete any local supplies and that fresh water availability was not a problem during this era.

Kotzebue, of the Russian Navy, stopped on Guam in 1817 near Agana and noted that, "An inconsiderable stream, which flows through the town, supplies the inhabitants with water."

Around 1823, British and American whalers stopped on Guam at Umatac, and reprovisioned their food and water supplies.

The first documented attempt of hydromodification on Guam occurred around 1830, when the Agana river was diverted from its natural outlet. The objective was to drain Agana swamp in order to use the area for agricultural purposes. Diversion dikes made of rough stone are still in evidence today from this operation, though the river was returned to its original channel after bombing in World War II. Notes from a Governor of the era remark that the river was used for "laundry work and all other ordinary purposes by the people of the city, except that they do not drink from it, either because it is thick and brackish, or because they have some scruple about doing so. Moreover, they have better drinking water in wells conveniently near their houses." Other records note that the wells near the area houses were brackish and also used for clothes washing, while other vessels contained the drinking water. Drinking water sources in the period were thought to be rainwater, public wells, and upper reaches of rivers. Water was transported in carabao carts or in sections of bamboo.

The American Naval Period (1898-1941)

Guam was ceded to the United States by the Treaty of Paris that ended the Spanish American War in 1898. The island was then purchased from Spain for $20 million in 1899. At the time, the local population of Guam was about 10,000 inhabitants. U.S. President William McKinley issued an executive

order placing Guam within the administration of the Department of Navy, and most of the accounts of water development from the period come from Navy records. The only places where water availability was considered problematic was Agana. Other areas were adequately supplied by fresh water streams, which were considered of good quality. Agana was initially serviced only by catchments, private wells, and the Agana river. A water distilling plant was ordered built in 1901 by the Navy Governor. The distilling plant pumped the water into a small iron tank on top of a wooden tower, and the water was distributed by gravity to government facilities and Navy housing. About the same time, an ice plant was placed into operation.

Unsanitary conditions prevailed in Agana as human and animal waste eventually seeped into the water table supplying local wells. In 1906, the Governor issued an Executive Order requiring outhouses to be built, and household premises to be kept clean.

In 1909, a water system was developed from the Fonte River. A small dam and a 33,000 gallon reservoir were constructed in the Fonte Valley above Agana, and connected to the town by a piping network. Any household could make arrangements for piped water service. The water was thought to be exceptionally pure, and the area around the reservoir was fenced in to protect water quality. In 1910, piped water service was extended to Piti. With a reliable supply of water developed, the Governor ordered all old wells to be closed. By 1912, water systems had been extended to, or developed for, the villages of Sinajana, Asan, Merizo, and Umatac, and construction of a sewer was underway in Agana. However, 1912 was also one of the driest years in history, and water was rationed from the ice plant a pint at a time. Development of water systems continued in 1913 with gravity piping of a nearby spring to the Fonte reservoir, significantly improving the quantity and quality of available water. Public health improvements were documented. Water lines to Anigua and Agat were underway. In 1914, pumps were installed at the Agana Spring to delivered more water to the town. Even so, the reservoir level dropped and citizens were advised exercise the greatest economy in their water use. In 1915, pumps were installed at Asan Springs, and again notices were issued urging conservation, reexamination of attitudes towards water use, and setting more stringent rules for water use coupled with the penalty of discontinuation of service for violators. A large latrine was also built for the people of Agana. Elsewhere on the island, a water system and public bathhouse were built in Inarajan, and rainwater catchment water cisterns of wood or concrete were built in Dededo, Sumay, Barrigada, Talofofo, and Yona.

Mechanical difficulties and the unpredictability of rainfall patterns (both exceedingly intense storms and arid seasonal stretches) led to continued problems of water shortages. Water taxes, insular patrolmen, and repeated conservation notices were issued control water demands. It is interesting to note that The Guam Recorder of March 5, 1924 included a Naval Executive Special Order with the following message:

> The shortage of water in Agana fresh water supply necessitates its serious consideration and the cooperation of all people to avoid waste of fresh water. The town is now issuing an average of about 72 gallons for every man, woman, and child in town. That is excessive and needless. The

> Fonte reservoir is empty, and most of the water used is pumped from the Agana Spring. That pumping is expensive.

The message is interesting when compared to challenges that confront today's water utility managers. Demand management is still a major concern, but today's demands on Guam can easily reach three times the 72 gallons per capita per day (gpcd) rate that was thought to be excessive in 1924. In fact the 70 gpcd range is the modern target for the most water efficient new facilities on Guam. Another factor that has not changed is the expense of pumping water. Optimization of power requirements for pumping water on Guam is still a main concern of water utility managers on Guam.

Almost one hundered years after the Agana River was first diverted, in 1927 two large channels were cut through the Agana marshlands. This resulted in draining of most of the area and the noticeable lowering of the local groundwater level. This flood protection measure also increased the flow of the Agana River during dry periods.

Also in 1927, two small concrete dams were built at Mt. Santa Rosa to provide water to Yigo. Without significant surface water sources, water was scarce in the Northern Guam plateau. Large reservoirs had been constructed in Barrigada to help farmers who otherwise had to transport water over long distances by livestock in the dry season.

June 1937 changed the outlook for Northern Guam with the headline of the Guam Recorder stating, "Water Found at Barrigada." A drilling machime had been brought in, and after 23 days of drilling, fresh water was found at a depth of 289 feet, six inches. Pumping began immediately and plans were made to explore for groundwater at Dededo, Yona, and Talofofo. That same year, the Navy engaged the U.S. Geological Survey to conduct an investigation between the geology and the water resources of Guam. A wide range of water development and system modernization efforts were begun in this year, including chlorination of water systems for public health protection, metering of some water service connections, and construction of public bathhouses and latrines. At the end of 1937, Almagosa Springs were discovered and routed by gravity piping to the Agat reservoir.

The Japanese Period

Little was done to improve the existing water systems on Guam during the Japanese occupation from December 1941 to July 1944. The Americans did not destroy any of the water systems prior to the Japanese invasion, but there were some system disruptions when the Japanese salvaged some metal from the piping systems. Approximately 11,000 Guamanians moved away from Agana during wartime, while about 18,500 Japanese troops occupied Agana during the war and utilized the existing Agana water system.

Post World War II

As the Americans were retaking Guam from the Japanese at the end of World War II, the lack of water affected their strategy, making it essential to capture Barrigada as quickly as possible to gain possession of the well that provided 30,000 gallons per day of potable water. Once the island was secured, one of the first priorities was ensuring an adequate water supply for the military and the local population. The Navy fleet and shore activities demanded two to four million gallons per day of fresh water. The battle to retake the island had taken a toll on the water systems. Springs, reservoirs, and piping had been damaged and contaminated. Restoration began immediately after conditions were safe since it was feared that Japanese soldiers hiding out in the jungle would try to poison water supplies. Repairs began with Almagosa Springs, Maanot and Agat reservoirs, and associated piping throughout central Guam and the Orote peninsula. The work was done by the Navy Construction Battalions (Seabees) largely without the aid of heavy machinery, with most of the eight to ten inch lines moved by hand in the rainy season. Approximately 40 days after the end of organized resistance, the Seabees has rebuilt seven miles of transmission pipelines and restored functionality to the major water systems on island.

In 1946, the Agana River was altered to its present course, and several stream channels were diverted for water supply and flood control purposes.

In 1948, the Navy constructed the Fena dam and reservoir at the headwaters of the Talofofo river as a major water supply project. The project was also fed by the Almagosa and Bona Springs.

Self Determination through the Turn-of-the-Century

The Organic Act passed in 1950 allowed Guam to become self-governed. Water supply continued to be a challenge for the Government of Guam. The Fena Reservoir met the Navy's water supply needs, and additional supplies were provided to the civilian community in central and southern Guam. This arrangement continues to the present day. Growing civilian demands were met by new groundwater wells in the north.

The local public water responsibility predecessor for PUAG originated June 30, 1950 when the Congress of Guam Passed Public Law 1-12, which gave the Department of Public Works the authority to administer all utility services. In response to increased water demand and a need to expand utility services, the 1st Guam Legislature passed Public Law 1-88 on June 6, 1952 that created a new entity called the Public Utility Agency of Guam. PUAG consisted of the telephone, power, water and wastewater utilities. At that time, the PUAG was delivering 250,000 gallons per day (0.25 Million gallons per Day [MGD])to its customers.

In 1954, a monthly meter-reading service is established by PUAG with 4964 water customers. This count would rise to 8306 water customers by 1964. Sewer customers would be recorded as numbering 9068 in 1976.

Daily average water consumption continues to increase from 0.25 MGD in 1952. By 1958, water consumption was 2.24 MGD. In 1963, it was recorded at 3.8 MGD. By 1968 it was 7.0 MGD and by 1975 it had risen to 11.0 MGD. Most all of the new demand is met through new wells in the northern Guam lens aquifer. Work on sewer system improvements and planning for wastewater treatment facilities continued throughout this period.

Guam adopted the Water Resources Conservation Act in 1967, stating that, "comprehensive planning and regulation must be undertaken for the protection, conservation, and development of the water resources of Guam." The Act names over-pumping of wells, depletion of surface and groundwater, saltwater intrusion, and sewage contamination as threats to water resources driving the Act. 1967 also saw the telephone division and power authority separate from PUAG.
In 1976, hydrogeologist John Mink arrived at a deliberately conservative estimate for sustainable yield of about 50 MGD, and recommended a more detailed study before further extensive development.

In 1979, a Guam Comprehensive Development Plan is prepared, urging the people of Guam to, "recognize the limitations of Guam's water supply to meet future demand of the island's population." The Plan goes on to state:

The availability of water is one of the major constraints to the island's continued growth. The estimated dependable yield of water on Guam is 50 million gallons per day (mgd) from groundwater sources and 17 mgd from surface water sources.

Recent studies estimate that if more than 50 mgd is drawn from the northern water lens (which supplies almost 90% of current island needs), salt water may be drawn in and contaminate the underground lens. Improper land uses can accelerate contamination.

Currently, the water consumption on Guam is between 26 and 29 mgd. Of this 43-48% is consumed by the military. From 1966 to 1976, water consumption increased 3.5 times. This rate continues to increase. Since water consumption is determined by population growth, the island's supply capacity will be reached within the next 25 years.

In 1980, the Guam Environmental Protection Agency retained Mink to direct a comprehensive investigation to acquire new data, refine estimates of sustainable yield, and identify appropriate management practices. The full report was published in 1982 as the Northern Guam Lens Study (NGLS) and remains the central reference on the hydrology and hydrogeology of the Northern Guam Lens Aquifer (NGLA). Sustainable yield of the NGLA was estimated to be about 59 million gallons per day. In 1991, Mink employed an iterative analytical model to simulate responses to hypothetical rates of withdrawal and seasonal variations in recharge. Based on the results, he revised the NGLS sustainable yield estimates upward by about 20% (to 70-80 mgd).

Public law 23-119 established the Guam Waterworks Authority to be a semi autonomous, self-supporting agency in 1997.

September 1997 saw the initial creation of the Guam Hydrologic Survey program through Public Law 24-59, which mandated that WERI, "collect, organize, and evaluate data being collected by the Government of Guam and federal agencies regarding the availability and quality of fresh water on Guam, and maintain a centralized data base of key hydrologic information. " WERI's charge was expanded in April 1998 by Public Law 24-161, the Drought Management and Comprehensive Water Conservation Plan, requiring that WERI, "administer a Comprehensive Monitoring Program regarding data collection on salt water intrusion, water lens thickness in the northern part of Guam, stream-flow data in the southern part of Guam, and related matters." The Guam Hydrologic Survey was permanently established in August 1998 by Public Law 24-247, with the directive of consolidating and analyzing hydrologic data on Guam, conducting research into selected water problems, and producing regular reports on water use, trends, and key concerns regarding Guam's water resources. An initial report on the Guam Hydrologic Survey Program and Hydrologic Data Collection on Guam was produced for Fiscal Year 1998 in September 1998 (WERI Technical Report No. 83).

The Guam Watershed Planning Committee (WPC) was established in 1998 and consisted of representatives from 14 federal and local organizations and agencies. One of the WPC subcommittees focused on restoration of the Northern Guam Lens Aquifer (NGLA).

These planning efforts were reinforced by Guam Governors' Executive Orders. EO 99-09 established a "Water Planning Committee" to utilize "the watershed approach to protect and manage Guam's precious surface and ground water resources." EO 04-04 established a "Watershed Planning Committee" and required the implementation of a "comprehensive watershed planning process." Both orders are included in Appendix C.

The way the Guam Waterworks Authority is managed was changed in 2003 by creating an elected, non-partisan Consolidated Commission on Utilities(CCU) to oversee the operations of GWA and GPA. The five-member commission assumed policy responsibility of the two utilities from the Guam Legislature. When the CCU was sworn into office, they were faced with more than $25 million in debt and pending federal court lawsuits for numerous violations to the water and wastewater systems over the last few decades. In that year, GWA had a customer base of more than 38,000 for water and more than 24,000 for wastewater.

Guam Military Buildup Era

In May 2006 a Roadmap Agreement between the United States and the Government of Japan was prepared, which covered the strategic realignment of United States forces in Japan. In this roadmap, Japan agreed to contribute loans up to $740 million (in U.S. fiscal year (FY) 2008 dollars) for a Special Purpose Entity (SPE) to support utilities necessary for the realignment of approximately 8,000 Marine

Corps personnel and their associated dependents from Okinawa to Guam. Utility solutions were established the assumption that Marines and dependents would arrive Guam by 2014 .

Secretary of State Hillary Clinton visited Tokyo in February 2009 and signed the bilateral "Agreement between United States and Japan Concerning the Implementation of the Relocation of the III Marine Expeditionary Force Personnel and Their Dependents From Okinawa to Guam" that reaffirmed the "Roadmap".

In September 2009, the USEPA directed GWA to upgrade its wastewater plants to secondary treatment. GWA appealed the decision. In January 2012, the Environmental Appeals Court denied GWA's request to continue with its 301h waiver to continue to treat wastewater at the primary treatment standard and not upgrade the NDWWTP and the Hagatna WWTP to secondary treatment.

In US Fiscal Year 2010 (October to September), Gov Guam and EPA raised the need for a "One Guam" approach through the Military Buildup EIS process for the Buildup that not only addressed on-base demands but also the off-base demands associated with the Marine relocation.

During this time, the USEPA and all Guam stakeholders evaluate the potential of Ground Water Under the Direct Influence of Surface Water (GWUDI) as a treatment issue throughout Guam. A GWUDI determination would require all well water produced in Guam to be filtered which would significantly increase the cost to deliver potable water. Also at this time the US Marine Corps funds a multi-year USGS/WERI effort to model Northern Guam Lens Aquifer to manage and optimize the use of this critical resource. The effort involves collecting information from all wells past and present and using that information to model the aquifer to better predict new well locations, impacts from pumping rates and other factors that could affect the aquifer from both a qualitative and quantitative perspective.

In July of 2010, Memoranda of Understanding between DoD and GWA are signed, pledging information sharing and cooperative management of water resources on Guam. In September 2010, the Record of Decision is issued for the Guam Military Buildup EIS.

In April of 2011, the Government of Japan programmed $415.5 Mil to support utility improvements on Guam. Also in that month, the Guam Water Well Testing Study is completed, characterizing groundwater development potential of DOD lands in Northern Guam as being able to support the Military Buildup.

June 2011 saw the "2 + 2 Meeting" between the US and Japan Secretaries of Defense and State. The meeting reaffirmed commitment to the buildup, and relaxed the 2014 completion date.

In November 2011, a Court Order was issued directing GWA to proceed with the correction of long standing water and wastewater system deficiencies. The Court Order included the requirement for GWA to proceed with interim improvements at the NDWWTP to be completed in 2012.

Chapter 3 Current Water Resources Management Setting

Planning Documents

Guam has no current Comprehensive Water Resources Master Plan. Many documents have been produced over the years addressing a variety of specific water resource management issues. However, there is no overarching guidance document, (or coordinated series of documents) tying together the interrelated quality and quantity issues island-wide for groundwater, surface water, nearshore waters, water supply, wastewater treatment and disposal, etc. Two sets of documents broadly cover a significant portion of these issues, while many planning resource documents have been produced over the years. The water resources planning model used by the State of Hawaii offers a framework that could be adapted for use in Guam.

Water Planning Committee Efforts

In 1999, a document was produced by a consultant to Guam EPA entitled, "Guam Environmental Protection Agency's Protecting and Restoring Guam's Waters." This document is provided as Appendix D, as downloaded from the consultant's website. This document is presented in the appendix in its entirety as a reference resource, especially since no hard copies were found available during research for this study. The document focuses primarily on Clean Water Act issues, especially GEPA's non-point source pollution prevention programs. The document takes an integrated approach, expanding the focus from just point- and non-point-source pollution prevention programs to programs that involve many stakeholders throughout the island's watersheds to address root causes of water pollution. The overall approach is to set a strong baseline; implement monitoring, analysis, and reporting for groundwater and surface waters; apply problem solving; utilize and develop local expertise; creatively implement environmental priorities; and pursue compliance and enforcement.

Much of the effort was coordinated through what was a cooperative inter-organizational entity known as the Water Planning Committee (WPC). The WPC addressed several Clean Water Act and Coastal Zone Management Act topics, and ultimately produced the first component of the Clean Water Action Plan for Guam, a Unified Watershed Assessment (included as Appendix E). The group that produced this document was known as the Clean Water Action Work Group for Guam, but by necessity there was considerable overlap in membership with the WPC as both utilized water resource expertise across Guam agencies, the University of Guam, and the US military on Guam.

The focus of the Unified Watershed Assessment was to initially set and define the watershed boundaries throughout the island, and then to assess the health of each watershed and prioritize restoration activities. Work continues today at the University and Guam EPA in these efforts. Watershed delineation is relatively straightforward in the volcanic southern portion of the island, where topography divides watersheds. This process is more complicated in the northern half of the island which has a

gently sloping Karst surface topography. Not only are runoff patterns somewhat difficult to predict or model due to the irregular Karst features and sinkholes, but the portions of the Northern Guam Lens Aquifer (NGLA) that receive surface infiltration are divided by a volcanic basement topography hundreds of feet below the ground surface.

In an effort related to the Clean Water Action Plan and the Unified Watershed Assessment, WPC members formed a Northern Watershed Working Group, and produced a Northern Watershed Restoration Strategy (included as Appendix F). This strategy addressed efforts related to the Tumon Bay area being designated as Guam's highest priority watershed by the USEPA, requiring a Total Maximum Daily Load (TMDL) analysis to be developed to address pollutants entering the Bay. The effort addressed pollution from both storm water runoff as well as groundwater pollution from the NGLA's Tumon/Yigo sub-basin that discharges to the Bay. The WPC efforts tailed off after these initial products were produced.

GWA's Water Resources Master Plan

The second set of documents that covers a broad swath of Guam water resources issues is the 2006 Guam Water Resources Master Plan (WRMP), prepared by the Guam Waterworks Authority (GWA). This document focuses mainly on drinking water and wastewater utilities systems and was driven by the need to comply with a USEPA enforcement action. The WRMP addresses many planning issues necessary for a municipal water and wastewater utility including population forecasts, land use forecasts, water demand trends, a detailed condition inventory of all facilities, mapping of island water and wastewater utilities, hydraulic models, financial projections and plans, current and planned construction and rehabilitation projects, staff teaching and empowerment, and community activities.

The WRMP is organized into three volumes. The first volume, General Overview, includes elements on planning requirements, an organizational assessment, levels of service, asset management, GWA's capital improvements program, and a section on what was known in 2006 about the Military Buildup on Guam.

The second volume, Water System, covered drinking water elements such as regulatory issues, a water budget, water conservation and loss control, and water system inventory, assessment and planning. Excerpts from this volume are included as Appendix G. These excerpts include sections of the water regulatory issues chapter and the water conservation chapter. The regulatory chapter naturally covers all of the US Safe Drinking Water Act requirements that GWA must meet. It also addresses a Water Resources Management Program in Section 2.2.4. This section references Guam's 1985 Water Resources Conservation Act, which sets requirements for drinking water wells and sets the stage for several water resource management programs such as the Water Development and Operating Regulations, the Underground Injection Control Regulations, Wellhead Protection Standards, and Water Quality Standards. The Water Conservation chapter noted that at the time, GWA did not have a comprehensive water conservation program. The chapter went about describing the methodology

required to develop such a program. Such a program is vital in any island setting, but especially so on Guam where water systems have been known to have relatively large water loss rates. GWA has subsequently developed and implemented a Water Audit and Water Loss Control Program. The program uses American Waterworks Association standards to program the assessment (monitoring and leak detection) and implement loss control plan actions. GWA also developed a Potable Water Production Enhancement Plan (included as Appendix H) to augment the WRMP. The production enhancement plan analyzes both supply-side and demand-side solutions, and develops short term and medium term implementation strategies. The recommendations from the plan include making production increases the utility's highest priority and updating GWA's Deep-Well Chloride Action Plan to accommodate current operational challenges.

The final volume, Wastewater System, addresses regulatory issues, septic systems, water reuse and biosolids management, as well as wastewater system inventory, assessment and planning.

Once the WRMP was adopted in 2007, the Consolidated Commission on Utilities (CCU) required that the WRMP be utilized as a living document with updates every two years. The objective of the updates is to provide sustainable, reliable, robust and secure water service and environmental protection for generations to come. Although the Capital Improvements Projects (CIP) listing that was a main product of the WRMP has subsequently been updated, the WRMP document itself has not been updated.

Other Guam Water Planning Resource Documents

Many other water resource related documents have been produced over the years. The Guam Bureau of Statistics and Plans (BSP) has produced a North and Central Guam Land Use Plan that includes consideration of natural systems. The BSP's Guam Coastal Management Program has produced a Coastal Zone Management Act Section 309 Assessment and Strategy to protect and restore water quality in coastal zones. The University of Guam Water and Environmental Research Institute (WERI) has produced over 125 research reports since 1976, many collaborating with Federal agencies, covering such diverse water resource issues as groundwater occurrence and quality, coastal resources and wetlands, water quality and contaminant transport, watershed assessment, Karst hydrogeology, stormwater runoff and erosion, climatology, hydropower, and even rainwater catchment systems. WERI is continually developing reports and products of vital interest to the water resources community on Guam.

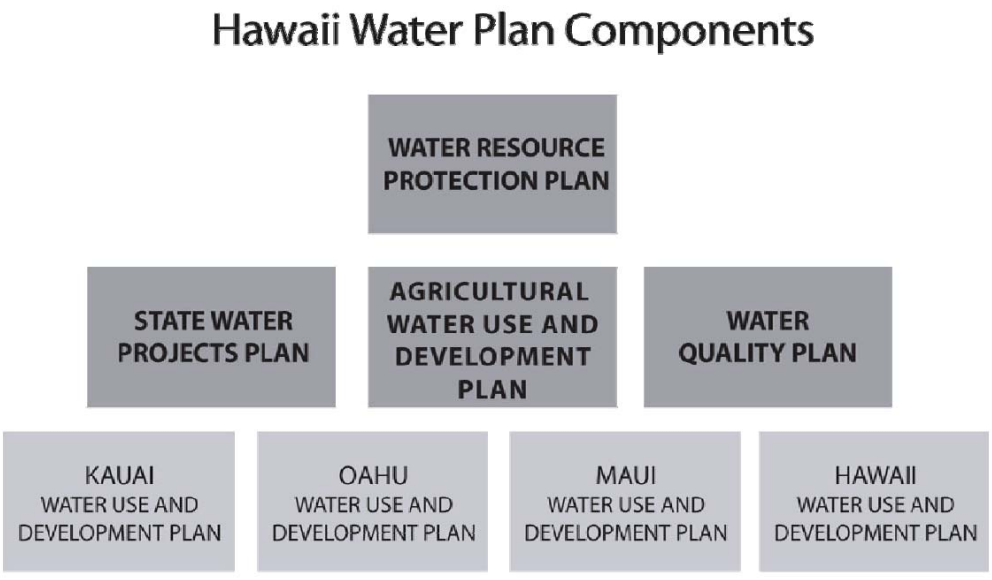
The Military Buildup and its associated Environmental Impact Statement (EIS) process has also produced several water resource studies of island-wide interest. In addition to the water resources analysis in the body of the Final EIS itself, several supporting stand-alone natural and water resource studies are included in the FEIS appendix. These include drinking water and wastewater utility studies prepared from a "One-Guam" perspective analyzing military and public systems, low impact development stormwater management studies, and sustainability studies. Other efforts that were initiated through the EIS process include the Guam Water Well Testing Study and Groundwater Availability Study for

Guam, both focusing on developing a better understanding of the NGLA. The Buildup also began Tumon Maui and Marbo Wells rehabilitation work to expand the production capacity available from the NGLA.

Hawaii Water Resource Planning

Since Guam has no central Comprehensive Water Resources Management Plan, the individual elements for water resource management are spread across several agencies and efforts as described above. This lack of centralized planning and regimented coordination between planning efforts necessitates the current "Networked Program" of water resource management as described in Chapter 5, where informal coordination between agencies and professionals on Guam is necessary to meet the objective of resource protection and restoration. As discussed in Chapter 4, a panel discussion was held at the 2011 Water Resources Sustainability Issues on Tropical Islands Conference, bringing together water resources experts from Guam and Hawaii. Coordination in preparation for the panel discussion offered the opportunity for these experts to share their respective experiences in water resources management.

Water resources management was formalized over the decades following Hawaii's achievement of Statehood in 1959. The Hawaii Water Plan is a collection of several interrelated planning documents. In its current state the hierarchy of Hawaii Water Plan components is arranged as such:



There are some significant differences between Guam and Hawaii that would require some reevaluation of this model if it were to be applied to Guam. Most obviously, Hawaii is an island chain with four counties, whereas Guam is a single island. Agriculture is not as developed on a large scale on Guam as it is in Hawaii, so the need for a separate Agricultural Water Use and Development Plan would not be as great. An agricultural plan could be integrated into a Water Projects Plan. The Hawaii State Water Projects Plan is primarily a programming document for projects related to industry, agriculture,

aquaculture, hydropower, water reclamation, and recharge. For Guam, the full Water Projects Plan itself could be integrated into a Water Use and Development Plan, simplifying the hierarchy of plans. It should also be noted that, at least for Oahu/Honolulu County, there is another supporting layer of plans. Oahu is separated roughly along hydrologic boundaries into several districts, and each district prepares its own Watershed Management Plan. For consideration, the Tables of Contents of the Hawaii Water Resource Protection Plan, the Hawaii Water Quality Plan, the Oahu Water Management Plan, and the Koolau Loa Watershed Management Plan are included as Appendix I. The Hawaii Water Code (included as Appendix J) gives the legal mandate for the planning efforts and details the coordination requirements of plan elements. Further, there are Hawaii Administrative Rules supporting the Hawaii Water Plan (included as Appendix K) detailing the mandatory contents of each plan element.

Reviewing each document, some observations can be made as to how such a compilation of planning documents could be related to Guam's unique water resources environment. The capstone document, the Water Resource Protection Plan, is prepared by the Hawaii State Commission on Water Resources Management (CWRM). No comparable agency exists on Guam, so either a commission would need to be created or the responsibility would need to be undertaken by one of the existing agencies. The Water Resource Protection Plan is most similar to the "Guam Environmental Protection Agency's Protecting and Restoring Guam's Waters" document in that it covers the subjects of water resource management principles and policies; inventory, assessment, and monitoring of water resources; watershed protection; water quality; and an implementation plan. The document also covers in detail regulatory programs, existing and future demands, resource conservation and augmentation, and drought planning.

The Hawaii State Water Quality Plan is prepared by the State Department of Health, which has been granted primacy by the USEPA over Safe Drinking Water Act and Clean Water Act enforcement. Guam EPA would be the closest such agency in that regard. The Water Quality Plan covers a broad range of issues related to drinking water, surface water, and groundwater, and sets standards and criteria for the State in each of those media.

As is the case with all four Hawaii counties, the Oahu Water Management Plan is prepared by the Honolulu County Department of General Planning, with significant input and cooperation from the Honolulu Board of Water Supply. In Hawaii the drinking water departments are typically separated from the wastewater (environmental services) departments, as opposed to Guam where GWA serves as a combined drinking water and wastewater utility. The Water Management Plan is similar to GWA's Water Resources Master Plan, in that it considers population and development projections in forecasting future water demands, develops water system improvement strategies, and presents the utility's capital improvement program.

On Oahu, the water department then takes the lead on developing Watershed Management Plans for each major district of the island as part of the overall county Water Management Plan. For each district, a watershed profile is developed; water supplies and demands are considered; and watershed

objectives, strategies, and projects are developed. This effort is similar in nature to what was done by the Northern Watershed Working Group in the Northern Watershed Restoration Strategy. However, implementing such a program of Watershed Management Plans on Guam would not be as straightforward on Guam as it is on Oahu. Oahu divides out very neatly into districts with population centers separated by clear topographic hydrologic divides. This is partially due to hydrogeology, but also has a cultural element. In ancient Hawaii, populations and districts were organized into "ahupua'a" which were individual watersheds. Water was of such importance to the Hawaiians that an ahupua'a system of water management was prevalent throughout the islands. Each ahupua'a extended from the top of the mountain ridge defining the uppermost boundary of the watershed out to the edge of the ocean reef system across the watershed's coastline. Along with providing clear territorial organization for the civilizations, watershed boundaries set the foundation for a complex code of water management practices from the upstream forest areas, through downstream terraced agriculture, and out into the ocean. These land and sea divisions helped to provide guidelines for sustainable ecosystem management.

Many of the principles of ahupua'a watershed management would translate directly into the Guam environment. In Guam, though, village boundaries do not necessarily conform as clearly to watershed boundaries. The Karst plains of northern Guam where village boundaries overlap subterranean aquifer sub-basins may require thoughtful coordination to organize and involve the citizenry in individual watershed/hydrologic sub-basin planning efforts. For example, the Yigo village spans the northern and extreme northeastern coastlines of Guam, covering several hydrogeologic sub-basins. A portion of the rainfall that infiltrates in the Yigo village flows into the subterranean Yigo-Tumon trough and impacts water quality as it discharges into Tumon Bay. It may take considerable education and outreach efforts to convince the residents of Yigo that activities in their relatively remote village can have significant water quality impacts in the highly developed resort area of Tumon Bay.

If Guam should consider developing a unified Water Code along with a concerted Water Resources Master Plan, its unique environment will require careful consideration of how to develop elements within the Code. Hawaii, like Guam, has few rivers, but does have many streams. Regulating stream water was one of the most important elements of developing the Hawaii Water Code, because significant quantities of stream water have historically been diverted from their natural watercourses to support agriculture. Characterizing instream uses and permitting diversions is a significant part of the Hawaii Water Code. In recent years, particularly as water-intensive sugar cane farming has declined, conflicts between established agricultural interests, native Hawaiians working to re-establish traditional aquaculture systems, and environmentalists concerned with stream restoration have led to contested cases that have been the subject of lengthy and complex court battles. Limited agriculture, the complete lack of streams in the north, and with Guam's abundant rain and typically steep watersheds in the south, should limit (but not necessarily eliminate) the focus on regulating stream diversions.

Institutions

Management of Guam water resources is accomplished through a networked program. There are several agencies within Guam with missions related to water resource management. Complementary Federal agencies also have interrelated charges. Each of the institutions makes decisions and assessments, ideally based on shared scientific data and collaboration. Data sharing and professionalism are key elements to keep the networked program functioning and effective. This section will note some of the key stakeholder organizations, provide their *mission statements*, and give a brief description of their current roles with respect to Guam water resources management.

Guam Environmental Protection Agency

> *Mission Statement: The Guam Environmental Protection Agency provides an integrated and comprehensive framework of environmental protection throughout the island and its waters. The Agency's framework is designed to facilitate the improvement and maintenance of a high quality environment at all times, to guarantee an enjoyable life for the people of Guam at present and in the future and to ensure that environmental degradation of the quality of land, water and air by any pollutants, including all physical, chemical and biological agents, should not be allowed.*

Guam EPA has a considerable charge in protecting and restoring Guam's water resources. Three chapters of the Health and Safety portion of the Guam Code are dedicated to the water resources stewardship responsibilities of the Guam EPA and its Administrator:

- Chapter 45, the Guam Environmental Protection Agency Act;
- Chapter 46, the Water Resources Conservation Act; and
- Chapter 47, Water Pollution Control Act.

These acts are included for reference as Appendices L, M, and N, respectively. The Guam EPA Act broadly defines the agency's purview and establishes a Guam Environmental Trust Fund for the agency. The agency also receives Federal funds in cooperation with the USEPA.

The Water Resources Conservation Act primarily defines the Administrator's authorities and responsibilities in administering groundwater well drilling and operating permits. It should be noted that the well drilling application also has a coordination requirement with the Guam Waterworks Authority (GWA). This Act also outlines cooperation with the US government, including establishing a Technical Advisory Committee to oversee a groundwater management program. The Act also establishes a Water Research and Development Fund and a committee to administer the fund to conduct water resources research on planning and management of surface and underground water resources.

The Water Pollution Control Act addresses the agency's role in areas such as developing and maintaining water quality standards in Guam's surface waters and regulation of sewage treatment and disposal systems. The Act encourages the Administrator to conduct water quality studies and enforce the recommendations of those studies. The Act also includes a provision related to Designation of a Groundwater Protection Zone, to be used in regulating surface activities that could pose a threat to underground drinking water reserves.

These Acts underscore the broad range of Guam EPA's responsibilities. In carrying out these responsibilities, GEPA coordinates with a wide array of water resources institutions and the public across the island. Several examples can be readily noted. GEPA has Federally-delegated primacy over the Safe Drinking Water Act areas, and thus regulates drinking water issues on island. As noted above, GEPA coordinates with GWA on permitting all new wells on Guam. Guam EPA works closely with US EPA, operating as an extension of their regulatory authority on all water resources issues. In issues of polluted stormwater runoff and surface water quality on Guam, GEPA coordinates with the Guam Coastal Management Program. The Water and Environmental Research Institute of the Western Pacific (WERI) is one of GEPA's closest partners, operating as the groundwater data clearinghouse and assisting with groundwater decisions. GEPA's regulatory authority extends to the military on Guam as well, where they review drinking water, wastewater, and stormwater utility construction plans.

Guam Waterworks Authority

> *Good Water Always*
>
> *Why We Exist*
> *Guam Waterworks Authority (GWA), a public corporation, provides good drinking water that meets the federal Safe Drinking Water Act (SDWA) to the island of Guam's civilian residents and collects about 60% of wastewater. GWA treats the wastewater and disposes of it in compliance with the federal Clean Water Act (CWA). Currently, 40% of GWA's customers continue to use cesspools and septic tanks that places the ground water that supplies our wells at risk of contamination. GWA provides the facility of water production and distribution system to the community.*
>
> *Strategic Goals*
> - *Institute sound asset management and capital planning*
> - *Develop a foundation for sound management operation and maintenance and financial planning*
> - *Engage GWA's customers to achieve the appropriate level of service*
> - *Achieve long-term resource sustainability*
> - *Establish the road map for full regulatory compliance*

GWA's range of water resource management authorities is laid out in the Guam Waterworks Authority Act in the Autonomous Agencies section of the Guam Code. This Act provides detailed descriptions of

GWA's roles and responsibilities. Excerpts from the Guam Waterworks Authority Act are presented for reference in Appendix O.

In particular, Articles 3 and 5 cover the Drought Management and Comprehensive Water Conservation Plan and Guam's Water Resources, respectively. Article 3 directed that a Guam Drought Management and Comprehensive Water Conservation Plan be developed by 1998. In the absence of such a plan, the Article directs coordination on drought condition evaluations with military via Water Conservation Levels established for operation of Fena reservoir, which supplies a considerable portion of the military and public demand on Guam. GWA is directed to have a set of rules and regulations related to instituting conservation measures, including interruption of water service during water shortages. The Act also directs GWA to evaluate water shortage and drought conditions through broad coordination with GEPA, WERI, the military, other Federal agencies as appropriate, and private well owners.

Article 5 sets definitions for Guam's Water Resources. The Article continues by defining prohibited uses of water and setting priorities for water use. The Priorities for Water Use section of the Article concisely sets out tenants that could be integrated into a full water code for Guam. The section also directs GWA to establish rules and regulations for water withdrawals from Guam's surface and groundwaters.

GWA also continually engages a wide range of stakeholders in water resource issues as part of Guam's networked program. Examples of the close working relationship with GEPA are given above. GWA is also deeply involved with the USEPA through a series of court actions pertaining to wide ranging deficiencies in their drinking water and wastewater systems. GWA relies on WERI for hydrologic data and consultation when planning for future groundwater well sources. GWA has also had regular detailed coordination and negotiations with the Navy related to the Military Buildup, formalized through a July 2010 Memorandum of Understanding (MOU) pledging mutual data sharing in drinking water and wastewater system development and cooperation in stewarding Guam's groundwater resources.

Guam Bureau of Statistics and Plans

> *The mission of the Bureau of Statistics and Plans is to ensure Guam's resources are effectively used for the benefit of present and future generations by ensuring consistency among various plans, policies and programs. In order to do this, the Bureau is committed to:*
>
> - *Serve as a catalyst for planned and balanced economic, social, environmental and physical growth*
> - *Advise the Governor during the formulation of policies and on the interrelationships among laws, plans, policies and programs*
> - *Provide insight during the formulation and integration of plans, policies and programs which further social, economic, environmental and physical development goals and priorities*

Statistics, projections, and forecasts from BSP are required to properly plan and program Guam's water resources infrastructure. In addition, a robust planning process will ultimately link and involve water resources planning in land use planning and vice versa.

Guam Coastal Management Program

> *To manage Guam's coastal resources in partnership with network agencies and the community to protect, conserve, restore and enhance the environment and resources of Guam by ensuring thebalance of economic development with environmentally prudent use of coastal resources for current and future generations.*

The Guam Coastal Management Program implements the Federal Coastal Zone Management Act on Guam. As such, they are involved in stormwater runoff and non-point source pollution issues that impact Guam's nearshore waters.

University of Guam

> *Mission Statement:*
>
> *Ina, Diskubre, Setbe*
> *To Enlighten, to Discover, to Serve*
>
> *The University of Guam is a U.S. accredited, regional Land-Grant institution. It is dedicated to the search for and dissemination of knowledge, wisdom and truth.*
>
> *The University exists to service its learners and the communities of Guam, Micronesia and the neighboring regions of the Pacific and Asia.*
>
> *The University prepares learners for life by providing the opportunity to acquire knowledge, skills, attitudes, and abilities through the core curriculum, degree programs, research and outreach.*
>
> *At the Pacific crosscurrents of the East and West, the University of Guam provides a unique opportunity to acquire indigenous and global knowledge.*

The University of Guam is the prime resource for developing local water resource professionals. As the Engineering School expands, the pool of water resource engineers will expand as well. It is important to note that although water resource issues are rooted in natural sciences, professionals from all disciplines are needed to ensure that the water resources community is diverse and strong.

Water and Environmental Research Institute of the Western Pacific

Water and Environmental Research Institute of the Western Pacific (WERI) at the University of Guam. We are currently six faculty and five staff and our 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 in Guam, the CNMI and the FSM.

Institutional History
The Water and Environmental Research Institute of the Western Pacific (WERI) was established at the University of Guam in May 1975. It is one of 55 institutes established by U.S. Congressional legislation at each Land Grant University in the United States and in several territories. Originally named Water and Energy Research Institute of the Western Pacific, WERI changed its name in 1998 in line with expanding research interests in water related areas of other disciplines, e.g., meteorology, geology, hydrology, geohydrology, engineering, environmental toxicology, environmental chemistry, mapping and modeling.

The role of the Institute is to facilitate and conduct high quality research that addresses water problems and water-related phenomena; train students, teachers and future water resource professionals, and disseminate research results to the community at large. Base support for WERI comes from the Water Resources Research Institute (WRRI) 104-B Program administered through the U.S. Geological Survey. The Institute also seeks funding for research projects from local and other federal sources.

Consistent with the regional role of the University, the Institute devotes part of its program effort to Western Pacific islands other than Guam. It is the only research center of its type in this geographic area and endeavors to respond to the unique conditions that exist here. WERI officially became the first Regional Water Resources Research Institute in the WRRI program by extending its mission to the Federated States of Micronesia (FSM) in 1991 and to the Commonwealth of the Northern Marianas (CNMI) in 1997. This designation has opened a broad new spectrum of research and service opportunities for the University of Guam.

WERI works closely with an Advisory Council established for each of its three regional entities. Each council is composed of representatives from various government departments that deal with water and water related issues, public and private sector engineers, environmentalists and planners as well as academics and interested members of the community. The Institute draws from the varied expertise of its research faculty members, University of Guam faculty, research affiliates from other universities, and local professionals.

In addition to conducting research and producing many technical reports on vital water resources issues, WERI serves as the clearinghouse for all hydrologic data on Guam. This is an invaluable service to all

water resource stakeholders on island. A WERI Hydrologic Data Collection Presentation is included as Appendix P. Guam law established WERI's role as the Guam Hydrologic Survey. Most of the data collection is done through a cooperative agreement with USGS and matches of local and Federal funding. The monitoring network of wells and gages is periodically reevaluated to determine data needs and technologies available for data collection. The WERI-USGS collaboration for the Groundwater Availability Study for Guam has provided an opportunity to greatly enhance the database capabilities for all existing groundwater data and provide a platform for easy distribution of data to all interested parties. In order to maintain and develop a responsive comprehensive monitoring program for hydrologic data, WERI requires close inter-agency teamwork to support their work and provide feedback on scientific analyses and analytical tools.

US Environmental Protection Agency

The mission of EPA is to protect human health and the environment.

EPA's purpose is to ensure that:

- *all Americans are protected from significant risks to human health and the environment where they live, learn and work;*
- *national efforts to reduce environmental risk are based on the best available scientific information;*
- *federal laws protecting human health and the environment are enforced fairly and effectively;*
- *environmental protection is an integral consideration in U.S. policies concerning natural resources, human health, economic growth, energy, transportation, agriculture, industry, and international trade, and these factors are similarly considered in establishing environmental policy;*
- *all parts of society -- communities, individuals, businesses, and state, local and tribal governments -- have access to accurate information sufficient to effectively participate in managing human health and environmental risks;*
- *environmental protection contributes to making our communities and ecosystems diverse, sustainable and economically productive; and*
- *the United States plays a leadership role in working with other nations to protect the global environment.*

Region 9 of the USEPA has jurisdiction over American Pacific island interests, and provides several services for Guam. USEPA coordinates with the Guam EPA and provides resources and reachback support as needed. An example of this support is the Groundwater Under Direct Influence of Surface Water (GWUDI) determination effort. Although GEPA has primacy over drinking water issues on Guam, the effort involved to set criteria and analyze large volumes of data to determine if surface water infiltration finds its way directly into drinking water wells in the Northern Guam Lens Aquifer required the assistance of Region 9. USEPA experts helped facilitate meetings to define the problem and develop solutions for a diverse group of affected stakeholders including GWA, the military, and private well owners. Another example of the depth and breadth of the USEPA's involvement in water resources

issues was the agencies active review process for the Guam Military Buildup Environmental Impact Statement. Naval Facilities Engineering Command (NAVFAC) developed the draft EIS for the action proponent, the Joint Guam Program Office. As part of the review, it was determined that cumulative impacts from induced growth and the construction workforce from the buildup would challenge the capacity and integrity of Guam's public drinking water and wastewater systems. Working with NAVFAC and GWA, USEPA was instrumental in brokering the "One-Guam" approach to utilities development on Guam. This approach advocates development of utility system capabilities and capacities that mutually benefit the military and public sector, vice development of separate parallel systems.

US Geological Survey

> *The USGS serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.*
>
> *Water Resources of the United States*
>
> *The U.S. Geological Survey (USGS) collects information needed to understand the Nation's water resources, and provides access to water data, publications, and maps, as well as to recent water projects and events.*

The USGS and WERI are involved cooperatively in collection and management of hydrologic data throughout Guam. USGS and WERI also collaborate on technical studies together, including the ongoing Groundwater Availability Study for Guam, which is funded by the US Marine Corps and managed through Naval Facilities Engineering Command, Pacific.

Federal Emergency Management Agency

> *FEMA's mission is to support our citizens and first responders to ensure that as a nation we work together to build, sustain, and improve our capability to prepare for, protect against, respond to, recover from, and mitigate all hazards.*

In addition to their disaster management role, FEMA is the agency that prepares the Flood Insurance Rate Maps (FIRMs, or "Flood Maps") for Guam.

Naval Facilities Engineering Command (NAVFAC)

> *NAVFAC is the Systems Command that delivers and maintains quality, sustainable facilities, acquires and manages capabilities for the Navy's expeditionary combat forces, provides contingency engineering response, and enables energy security and environmental stewardship.*
>
> *Sustainable Facilities: Preserve the environment and reduce total ownership costs.*

Environmental Stewardship: Responsible use, protection and conservation of natural and cultural resources.

NAVFAC is represented on Guam through the Facilities Engineering Command Marianas. The recent Joint Basing initiative has brought the Air Force's environmental and water resources expertise under the NAVFAC umbrella. As detailed above, NAVFAC maintains active water and natural resource protection relationships with all the Guam stakeholders as part of standard operations and is acting as the execution agent for the Guam Military Buildup.

Marine Relocation (Military Buildup)

As stated in the Guam Water Resources Management History section of Chapter 2, in May 2006 a Roadmap Agreement between the US and the Japan was prepared that covered the strategic realignment of United States forces in Japan. The initial planning for the realignment sought to relocate approximately 8,600 Marine Corps personnel and their 9,000 associated dependents from Okinawa to Guam. The assumption was that the Marines and their dependents would arrive Guam by 2014.

In response to this development, the Governor of Guam issued two Executive Orders, one in 2006 and another in 2008, respectively creating and restructuring a Civilian/Military Task Force (CMTF) to cooperatively maximize opportunities for the Guam community resulting from the Military Buildup. These Executive Orders are included for reference as Appendix Q. The 2006 EO envisioned the CMTF creating a Master Plan for the Military Buildup, defined the membership of the CMTF to be comprised of 20 GovGuam and DoD agency leaders, allowed for the formation of subcommittees, and detailed the coordination and information sharing functions of the CMTF between GovGuam, military, and private interests. The 2008 EO restructured the CMTF by adding an Executive Committee and establishing a Guam Buildup Office (GBO) within the Office of the Governor of Guam. The GBO was formed at the request of the DoD and the Joint Guam Program Office (JGPO) to provide a single point of contact within Gov Guam for the military expansion. JGPO is the Military Buildup proponent for the Environmental Impact Statement process. The GBO duties, as outlined in the EO, included serving as the clearinghouse for all buildup information and communications and monitoring all activities associated with the Buildup.

With respect to water resources, in 2008, the Natural Resources Subcommittee of the CMTF produced a "Natural Resources Strategy 2012." Chapter 13, Wetlands and Watersheds, of the document is included for reference as Appendix R. The chapter gives a detailed overview of the management context for water resources on Guam as planning for the Military Buildup was beginning. The document affirms that a watershed approach is the most effective framework to address water resource challenges since this approach addresses priority water resource goals by integrating multiple programs based on sound science, planning, and adaptive management techniques. An overview of the work performed by the Water/Watershed Planning Committee, including the Guam Clean Water Action Plan (see the Planning Documents section of this chapter), is also given, along with the observation that, "These initiatives are in place, although management activity has been very limited due to capacity challenges and funding constraints." The Community Interest section of the document describes several benefits of clean water and healthy watersheds that underscore the criticality of these resources. The chapter concludes with five goals and associated conservation actions related to wetlands and watersheds, including setting stormwater management standards and creating watershed and wetland management plans.

As EIS planning progressed for the Buildup, Guam agencies and the US EPA raised the need for a "One Guam" approach for water and wastewater utilities and other services that not only addressed on-base

demands but also the off-base demands associated with the Marine relocation. This became especially important as socio-economic plans calculated that the construction workforce and induced growth associated with the Buildup could add a peak of up to 80,000 more people to Guam's existing population of around 160,000. As part of the "One Guam" planning effort, a Memorandum of Understanding (MOU) between the US Navy and GWA was signed in July 2010. This MOU set a structure for information sharing and cooperative management of water resources on Guam. The MOU is included for reference as Appendix S. In the document, objectives are set for identifying costs and funding sources for cooperatively developed drinking water and wastewater utility solutions, protecting and enhancing water resources, planning infrastructure upgrades, and evaluating opportunities for integrating utility systems. In terms of developing solutions, the parties agree to cooperate in completing studies related to meeting the water needs of Guam including Northern Guam Lens Aquifer (NGLA) sustainability studies; to focus on upgrades to the Northern District Wastewater Treatment Plant to meet the wastewater treatment needs of the Buildup in northern Guam; to cooperate in selection of future well sites; and to share water resources as needed to address urgent needs. The MOU also sets about the organization of a NGLA management advisory team. The kickoff meeting for this group was held in January 2012 as detailed in Chapter 4.

In September 2010, the Record of Decision (ROD) was issued for the Guam Military Buildup Final EIS. As part of the ROD, an initial charter was developed to establish a Civil-Military Coordination Council (CMCC). This charter is included for reference as Appendix T. The charter defines the membership and functions of the CMCC, including the establishment of Council Working Groups (CWGs). The CMCC and the CWGs were formed to implement Adaptive Program Management (APM). APM is a mitigation measure implemented by adjusting the pace and/or sequencing of the Buildup and its construction activities to avoid or reduce environmental impacts or overstressing Guam's infrastructure. Water resources are addressed through the Utilities Working Group, which considers issues related to water and wastewater utilities (as well as power and solid waste disposal). Implementing APM involves monitoring key metrics related to each utility. For water, metric considered include supply/demand ratios, water pressure, well chloride levels (salinities), water quality monitoring results, service interruptions, and Safe Drinking Water Act compliance. For wastewater, metrics include Clean Water Act compliance, sanitary sewer overflows, sewage pump station capacities, and water quality monitoring results.

Since the ROD, June 2011 saw the "2 + 2 Meeting" between the US and Japan Secretaries of Defense and State. The meeting reaffirmed commitment to the buildup, and relaxed the 2014 completion date. Subsequent developments have changed the composition of the Buildup, warranting a Supplemental EIS, which is currently in production. The number of Marines to be relocated has been reduced from the originally planned 8,600 Marines and 9,000 family members, to a force of approximately 5,000 Marines and 1,300 family members on Guam. Approximately two-thirds of the Marines relocated to Guam will be rotational with the remaining one-third permanent. Approximately 1,300 family members will accompany the 5,000 Marines.

Chapter 4 Water Resources Issues and Actions

Water resource management issues continually arise and are addressed in Guam. This section will cover three recent efforts to define the issues and explore the most beneficial courses of action. Two of these efforts are a direct product of this review study; a Guam Water Resources Management Review Survey and a panel discussion on Guam Water Resources Management held at the 2011 conference titled "Water Resources Sustainability Issues on Tropical Islands."

The third effort is the kickoff meeting of the Northern Guam Lens Aquifer (NGLA) Advisory Group. This effort is an outgrowth of a Memorandum of Understanding between GWA and DoD, and can also be seen as a progression of the previous water resource planning committees that have operated on Guam.

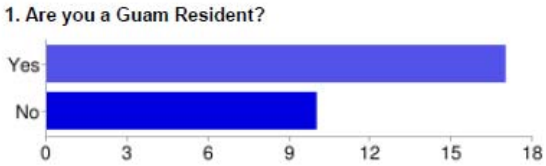
Guam Water Resources Management Review Survey

The Guam Water Resources Management Review Survey was developed to get a sense of what the Guam water resource management community considers to be priority issues in terms of the following six topic areas:

1. Water Resources Planning
2. Water Resources Policy
3. Water Resources Threats and Opportunities
4. Data Management
5. Water Resources Community
6. Collaboration

The survey was distributed electronically in September 2011 to approximately 50 water resource professionals with interest in water resource management on Guam. The survey was sent by email to professionals at the Guam EPA, the Consolidated Commission on Utilities, Guam Waterworks Authority, the University of Guam's Water and Environmental Research Institute, Guam Coastal Zone Management, the USEPA Region 9, NAVFAC Pacific and Marianas, the US Geological Survey, and various consultants familiar with Guam's water resources. The response rate was over 50%, with 28 responses received over the September – October timeframe. The survey should be considered informal, as its preparation was not subject to detailed scientific rigor and the sample size was somewhat limited. The survey began with two demographic questions, as shown below:

1. Are you a Guam Resident? (Yes / No)

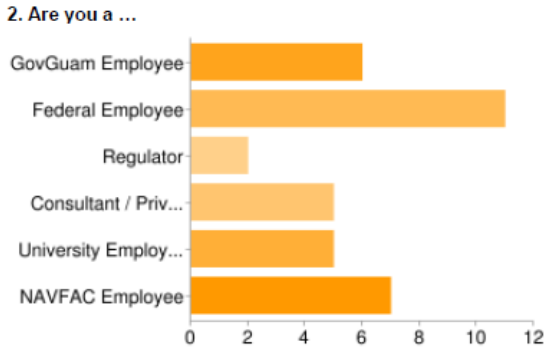


Yes	17
No	10

People may select more than one checkbox, so percentages may a more than 100%.

Of the 28 respondents, 27 responded to this question, with the majority (17) being Guam residents.

2. Are you a … (Check all that apply)
- **a. Guam Employee**
- **b. Federal Employee**
- **c. Regulator**
- **d. Consultant / Private Industry**
- **e. University Employee / Student**
- **f. NAVFAC Employee**



GovGuam Employee	6
Federal Employee	11
Regulator	2
Consultant / Private Industry	5
University Employee / Student	5
NAVFAC Employee	7

People may select more than one checkbox, so percentages may a more than 100%.

As noted in the above graphic, respondents could select more than one identifier. There were 36 responses from the 28 respondents, so some people did identify with more than one categorization. Fortunately there appears to be a good distribution between GovGuam employees, NAVFAC employees, University-affiliated respondents, and consultants. Only two people identified themselves as regulators.

Survey Questions:

Again, the survey addressed priority issues in terms of the following six topic areas:

1. Water Resources Planning
2. Water Resources Policy
3. Water Resources Threats and Opportunities
4. Data Management
5. Water Resources Community
6. Collaboration

The full graphical presentation of the results can be found in Appendix U.

Water Resources Planning

1. **What are the greatest water resource planning needs on Guam? (Rate on a 1-5 scale: 5=Essential unmet need, 4=Important need partially met by existing sources, 3=Important need fully met by existing sources, 2=Unessential but potentially beneficial, 1=Not necessary)**
    a. Comprehensive Water Resources Master Planning Document 4.27
    b. Water Quality Protection Planning 4.08
    c. Source Augmentation Planning (Impoundments, Desalination, Reuse, etc) 3.64
    d. Conservation Planning (Residential/Industrial Measures/Audits, Leak detection, etc.) 4.37
    e. Demand Forecasting 4.16
    f. Contingency Planning (Drought/Climate Change, Shortages, Emergencies, etc) 4.23
    g. Watershed Planning Islandwide 4.19
    h. Development of a Guam Water Code 3.59
    i. NGLA Sustainable Yield Updates 4.26
    j. Islandwide Water Balance Modeling 4.08
    k. Linking Land Use Planning to Water Resource Issues 4.42
    l. Water Efficient Design Standards 3.96
    m. Others? (Comment)

Rearranged in order of ranking by score, with higher scores corresponding to more imperative water resources planning needs:

1. 4.42 - Linking Land Use Planning to Water Resource Issues
2. 4.37 - Conservation Planning (Residential/Industrial Measures/Audits, Leak detection, etc.)
3. 4.27 - Comprehensive Water Resources Master Planning Document
4. 4.26 - NGLA Sustainable Yield Updates
5. 4.23 - Contingency Planning (Drought/Climate Change, Shortages, Emergencies, etc)
6. 4.19 - Watershed Planning Islandwide
7. 4.16 - Demand Forecasting
8. 4.08 - Islandwide Water Balance Modeling
9. 4.08 - Water Quality Protection Planning
10. 3.96 - Water Efficient Design Standards
11. 3.64 - Source Augmentation Planning (Impoundments, Desalination, Reuse, etc)
12. 3.59 - Development of a Guam Water Code

It should be noted that the overall average rating for items in this question was a 4.1 out of 5, which was generally characterized as an, “Important need partially met by existing sources.” There were several comments left in this section. The most prevalent comments were that all of these are important components of an overall water resource master planning strategy for Guam. It was also noted that a

Comprehensive Water Resources Master Plan update would benefit from being prepared with a 'One-Guam' perspective, jointly developed by DoD and GovGuam entities.

The top priority by ranking score was Linking Land Use Planning to Water Resource Issues. One respondent characterized this effort as rezoning areas, modify building code for areas, or restricting development in areas based on impact to water resources, especially the aquifer.

The water planning need that received the lowest ranking was Development of a Guam Water Code. With a score of 3.59, it fell between "Important need partially met by existing sources," and, "Important need fully met by existing sources." Many expressed uncertainty with this question, unsure of just water a water code would entail. As mentioned previously, an example of a water code that could have many elements applicable and adaptable for Guam is the Hawaii Water Code, which is included as Appendix J. Guam's water rules and laws, by contrast, are found in various sections of the Guam Code. Respondents often felt unsure if consolidating all water-related rules into one unified rule would yield significant beneficial results, especially in light of the amount of effort that would be required to coalesce the subject into one location.

Others noted that in addition to any comprehensive planning document, an inventory of water transmission and storage infrastructure and condition assessment would be useful to allow water resource planning. This effort could be accomplished through a thorough Sanitary Survey of drinking water systems which is an onsite review of the water source, and the facilities, equipment, operation, and maintenance of a public water system. At this time most of the Guam public water systems, run by both GWA and DoD, are overdue for regular sanitary surveys. One approach would be to have sanitary surveys conducted in a uniform manner for all public water systems on Guam at one time, so that "One-Guam" system planning could be conducted with common condition assessment criteria and operational review for all drinking water infrastructure, regardless of ownership.

2. **Guam currently has a "Networked Program" for water resources management, where roles and responsibilities are spread across several agencies and institutions.**
    a. **What are the best aspects of this arrangement? (Rate on a 1-5 scale: 5=Great advantage,3=Provides some benefits, 1=No benefits at all)**
        i. Flexibility in addressing water resource issues between agencies
        ii. Broad network of professionals with local knowledge
        iii. Collaboration leads to consensus and common understanding
        iv. Others? (Comment)

Rearranged in order of ranking by score, with higher scores corresponding to more beneficial aspects of a "Networked Program":

1. 3.85 - Broad network of professionals with local knowledge

2. 3.69 - Collaboration leads to consensus and common understanding
3. 3.19 - Flexibility in addressing water resource issues between agencies

Comments received in response to the question of benefits related to the Networked Program for Water Resources Management centered on the statement that, "Collaboration has the 'potential' to lead to consensus and common understanding, but does not always do so.
It was also expressed that at the macro level there is consensus and common understanding, but the implementation of such collaboration can be difficult. It was stated that subject matter experts are fully involved and can express their opinions without political pressures, since the working level deals with common science and engineering issues. The networked program was said to allow for testing multiple working hypotheses, problem solving, identification of additional data needs, and scenario planning that is difficult with narrow interests and partial information. It was also noted, though, that the networked approach does not always translate into education of the public on critical issues, creation of appropriate requirements, or enforcement of existing laws.

b. What are the most challenging aspects of this arrangement? (Rate on a 1-5 scale: 5=Severe disadvantage, 3=Creates occasional challenges, 1=Not a challenge at all)

i. Lack of manpower across agencies
ii. Lack of clear lines of authority
iii. Bureaucratic inefficiencies
iv. Interagency miscommunications
v. Incomplete information sharing
vi. Institutional knowledge loss through retirements across agencies
vii. Limited funding available between Guam agencies
viii. Others? (Comment)

Rearranged in order of ranking by score, with higher scores corresponding to more challenging aspects of a "Networked Program":

1. 4.56 - Limited funding available between Guam agencies
2. 4.15 - Lack of manpower across agencies
3. 4.12 - Bureaucratic inefficiencies
4. 4.12 - Interagency miscommunications
5. 4.00 - Incomplete information sharing
6. 3.83 - Institutional knowledge loss through retirements across agencies
7. 3.69 - Lack of clear lines of authority

It should be noted here that the challenging aspects of the Networked Program for Water Resources Management generally rated higher than the benefits of such a system, indicating significant room for improvement in organizational management of water resources. Noteworthy is the fact that limited funding for water resources management issues leads the list of challenges by a significant margin. It

was mentioned that this often threatens momentum on water resources management, as when one agency is underfunded or loses key personnel, the entire program is at risk of disappearing because pieces are in other areas. One comment was that funding is needed not just for staffing manpower and programs, but also for enforcement of existing laws, such as requirements for homeowners to connect to the sanitary sewer system. Generally, though comments centered on how to institutionalize and encourage collaboration, cooperation, and common grounds amongst the different agencies and entities. One respondent felt that there are too many organizations involved in this process given Guam's size, and that streamlining agencies will assist greatly in water industry functionality. Information sharing was cited as a distinct challenge as even when agency leadership makes a decision to share data, there is a lack of protocol and authority to facilitate the info sharing. More opportunities to come together for sharing information and consulting with one another were offered as solutions to collaboration challenges. Workshops and trainings on best management practices to protect water quality on Guam, or watershed and stormwater management offered to planners, engineers, and permitting agency staff were mentioned as prime opportunities to improve common understanding.

3. **Would Guam benefit from centralized water resource planning?**
   (Rate on a 1-5 Scale, 5= Yes, structure is sorely needed, 3=Centralization could provide some improvements over the Status Quo, 1=No, a flexible collaborative approach is best)

This question received and response score of 4.15, indicating a general opinion that centralized water resources planning would likely be of great benefit to Guam. No comments solicited for this question.

Water Resources Policy

4. **Does Guam need a formal Water Code?**
   (Rate on a 1-5 scale: 5=Yes, sorely needed to set priorities and define roles and responsibilities, 3=Some issues would benefit from setting rules and regulations, 1=No, a Water Code would just add to bureaucracy)

This question received and response score of 3.77, indicating a general opinion that a formal Water Code could benefit Guam, though many of the respondents were unsure of what would be involved in a water code, and how it would be implemented.

   a. **Why? What issues should and shouldn't be codified? (Comment)**

When asked, "Why? What issues should and shouldn't be put into a formal Water Code?" several respondents noted that they didn't know enough about goals and objectives, regulatory and implementation structures of other Water Codes to comment in detail. Some noted that the first step would be to clearly document the existing entities' roles, responsibilities and regulatory authorities, and then to see what gaps, overlaps, discrepancies, etc. exist, before determining whether a formal water codes is necessary. One respondent noted that any Water code for Guam would need to be based on an

appropriate doctrine that would address both surface water (in the south) and ground water (in the north). Some expressed the reservation that there is a risk that if a water code is developed on Guam, it may be largely ignored as has happened with other policies and regulations. It was noted that it could be a very powerful tool if all of the stakeholder involved signed on to it and had a way to be held accountable, and that the public would need to be informed that Guam's sole source aquifer serves almost the entire island and must be protected. The sentiment was also expressed that a water code for Guam should include strict enforcement with harsh penalties and fines on any type of pollution or any act adversely impacting water resources such as illegal dumping and burning, or property development not employing erosion and sedimentation practices.

Water Resources Threats and Opportunities

5. **What do you see as the greatest threat to water resources on Guam? (Rate on a 1-5 scale: 5=Severe unaddressed threat, 4=Significant threat partially addressed by existing programs, 3=Significant threat adequately addressed by existing programs, 2=Minimal threat, 1=Not a threat at all)**
    a. Saltwater Intrusion into the Northern Guam Lens Aquifer (NGLA)
    b. Septic Systems with Leachfields over the NGLA
    c. Drought
    d. Contamination of the NGLA through Direct Infiltration of Stormwater
    e. Polluted Runoff to Surface and Nearshore Waters
    f. Discharge of Inadequately Treated Wastewater to the Ocean
    g. Sanitary Sewer Overflows (Sewage Spills)
    h. Flooding
    i. Sanitary Issues in Drinking Water Systems
    j. Exfiltration of Sewage Collection Lines over NGLA
    k. Others? (Comment)

Rearranged in order of ranking by score, with higher scores corresponding to greater threats to water resources on Guam:

1. 4.11 - Septic Systems with Leachfields over the NGLA
2. 4.04 - Saltwater Intrusion into the Northern Guam Lens Aquifer (NGLA)
3. 3.96 - Sanitary Sewer Overflows (Sewage Spills)
4. 3.85 - Polluted Runoff to Surface and Nearshore Waters
5. 3.77 - Exfiltration of Sewage Collection Lines over NGLA
6. 3.74 - Discharge of Inadequately Treated Wastewater to the Ocean
7. 3.67 - Contamination of the NGLA through Direct Infiltration of Stormwater
8. 3.59 - Drought
9. 3.58 - Sanitary Issues in Drinking Water Systems
10. 3.46 - Flooding

Most of the scores hovered around 4, indicating a significant threat partially addressed by existing programs. The list presented presents a wide variety of water resources threats, but the comments gathered several more:

- Inadequately controlled solid waste disposal (legal and illegal dumps)
- Indiscriminate illegal dumping across the island
- Illegal burning exposing soils which leads to erosion
- Chemical/hazardous waste spills
- Underground storage tanks.
- Polluted runoff due erosion and discharge of sediments to coastal areas
- Lack of land use planning
- Uncontrolled development that outpaces availability of water and sewer capacity
- Poor development practices accelerating runoff and flooding
- Poor development practices in construction without proper erosion control devices.
- Invasive plant species such as hydrilla at Ugum water treatment plant.
- Recreational users tearing up soils with off-road vehicles
- Overuse due to excess demands on the NGLA.
- Unauthorized / unmetered water use
- Rising sea levels.

It is evident that there are many wide-reaching threats to water resources on Guam.

6. **What are the greatest opportunities for water resource supply augmentation on Guam? (Rate on a 1-5 scale: 5=Large potential opportunity, 3=May have some application/benefits, 1=Not feasible or desirable)**
    a. More/Larger Surface Impoundments
    b. Stormwater Reclamation/Recharge
    c. Wastewater Reuse
    d. Rainwater Harvesting
    e. Development of a Non-potable Water System
    f. Others? (Comment)

Rearranged in order of ranking by score, with higher scores corresponding to greater opportunities for water resource supply augmentation on Guam:

1. 4.00 - Rainwater Harvesting
2. 3.59 - Stormwater Reclamation/Recharge
3. 3.00 - More/Larger Surface Impoundments
4. 2.89 - Development of a Non-potable Water System

5. 2.85 - Wastewater Reuse

Rainwater harvesting and stormwater reclamation/recharge were viewed favorably, while other alternatives were relatively neutral or undesirable. Commenters noted that key on Guam is the fact that when rainwater/stormwater is most available it is least needed and vice versa, and that rainwater harvesting is already in use in some of the nearby islands. By far the most commented "supply augmentation" was reduction in domestic consumption by conservation practices, incentives, and rate structures, as well as reduction in transmission and distribution leakage. One person noted the potential for Ocean Thermal Energy Conversion (OTEC) to provide fresh water as a byproduct of its power production process.

Data Management

7. What are the greatest water resource data needs on Guam? (Rate on a 1-5 scale: 5=Essential unmet need, 4=Important need partially met by existing sources, 3=Important need fully met by existing sources, 2=Unessential but potentially beneficial, 1=Not necessary)

a. Well Production Monitoring Data
b. Well Water Quality Monitoring Data
c. Surface Water Inventory (Streams, diversions, impoundments)
d. Surface Water Monitoring (Flows, Water Quality)
e. Hydrologic Monitoring (Rainfall and Evaporation Patterns)
f. Hydrologic Monitoring (Runoff-Recharge relationships)
g. Nearshore Water Quality Monitoring
h. Others? (Comment)

Rearranged in order of ranking by score, with higher scores corresponding to greater water resource data needs on Guam:

1. 3.92 - Hydrologic Monitoring (Runoff-Recharge relationships)
2. 3.73 - Well Water Quality Monitoring Data
3. 3.72 - Surface Water Monitoring (Flows, Water Quality)
4. 3.72 - Hydrologic Monitoring (Rainfall and Evaporation Patterns)
5. 3.69 - Well Production Monitoring Data
6. 3.65 - Surface Water Inventory (Streams, diversions, impoundments)
7. 3.60 - Nearshore Water Quality Monitoring

Most of the scores hovered around 4, indicating an important need partially met by existing sources. Several of the respondents noted the need for an improved monitoring well network to yield a better understanding of the aquifer. Commenters noted a need for more deep groundwater monitoring wells to characterize the thickness and extent of the fresh water body, to monitor salt water intrusion, and to

give details on subbasin structures, capacities and water locations. This need was said to be vital to be able to locate wells in optimal spots with respect to sustainable yields and water quality.

Nearshore waters received a relatively low score, but commenters noted Guam has considerable data on bacteria, but very little on toxicity or other data that would enable development of Guam-specific water quality standards. It was also noted that nearshore water quality monitoring needs to be done in a sensible, objective manner using suitable organisms instead of the currently used "traditional" indicator organisms which live in tropical soils and do not indicate fecal contamination.

One respondent cautioned that more important than just collection of data is a collaboration to facilitate understanding of the data, through professionals with the training to review and understand the implications.

Water Resources Community

8. **How can the Guam Water Resources Community best be enhanced? (Rate on a 1-5 scale: 5=Large potential opportunity, 3=May have some application/benefits, 1=Not feasible or desirable)**
    a. Start/Expand Local Chapters of Professional Organizations (AWWA, WEF, etc.)
    b. Recruitment/retention incentives to attract and grow local water resources pool of expertise
    c. Graduate more water resources professionals locally
    d. Public outreach to expand citizen involvement
    e. Mentoring programs
    f. Others? (Comment)

Rearranged in order of ranking by score, with higher scores corresponding to greater opportunities for enhancement of the Guam Water Resources Community:

1. 4.11 - Recruitment/retention incentives to attract and grow local water resources pool of expertise
2. 4.04 - Graduate more water resources professionals locally
3. 4.00 - Mentoring programs
4. 3.96 - Public outreach to expand citizen involvement
5. 3.62 - Start/Expand Local Chapters of Professional Organizations (AWWA, WEF, etc.)

Most of the scores hovered around 4, indicating interest for enhancement of the Guam Water Resources Community. Though the interest is there, the comments represented wide variation in proposed approaches. Calls were made for more involvement for various Federal and GovGuam agencies, especially UOG/WERI and the Watershed Planning Committee. Support was given to both importing off-shore professionals and to “grow our own.” One specific comment suggested the Mayor's Council members need to be educated on the importance of actions they and their constituents can to

employ for the protection of water resources, particularly on the issues of pollution prevention and illegal dumping.

Collaboration

9. Where are the greatest opportunities for water resource stewardship collaboration? (Rate on a 1-5 scale: 5=Large potential opportunity, 3=May have some application/benefits, 1=Not feasible or desirable)

a. Public Outreach Efforts
b. Watershed Partnerships
c. Continuing Education Events (Workshops, Conferences, etc.)
d. (Re)Creation of a Water Resources Planning Committee
e. Formation of Professional Societies
f. CMCC Working Group Participation
g. Collaborative Hydrologic Modeling Teams
h. Others? (Comment)

Rearranged in order of ranking by score, with higher scores corresponding to greater opportunities for water resource stewardship collaboration:

1. 4.19 - (Re)Creation of a Water Resources Planning Committee
2. 4.13 - CMCC Working Group Participation
3. 4.07 - Watershed Partnerships
4. 3.96 - Public Outreach Efforts
5. 3.93 - Collaborative Hydrologic Modeling Teams
6. 3.85 - Continuing Education Events (Workshops, Conferences, etc.)
7. 3.50 - Formation of Professional Societies

Most of the scores hovered around 4, indicating interest for enhancement of water resource stewardship collaboration on Guam. Though the interest is there, the comments represented wide variation in proposed approaches. Some of the respondents felt that legislative mandates, accompanied by funding, could significantly help collaboration, particularly in the area mobilizing and authorizing a core group of entities with a charge to protect Guam's water resources. Examples given for the funding and authorities would be development and/or water/sewer fees to enforce zoning, sewer connection, and other water quality protection initiatives. Support was also mentioned for creation of a team focused on hydrologic modeling of the island with specialists from various agencies contributing.

Guam Water Resources Panel Discussion

As part of the Water Resource Sustainability Issues on Tropical Islands Conference held November 14-16, 2011 in Honolulu, Hawaii, the author was able to arrange and moderate a panel discussion on Guam Water Resources Management. The conference was co-sponsor by the University of Guam Water and Environmental Research Institute (UoG WERI), the University of Hawaii Water Resources Research Center (UH WRRC), and similar research institutes from Puerto Rico and the Virgin Islands. The conference and panel discussion were well attended with around 200 water resource professionals from a wide variety of backgrounds and homelands represented.

The panelists were well-known water resource experts from both Guam and Hawaii:

- Martin Roush, PE
  - General Manager, Guam Waterworks Authority (GWA), responsible for all civilian drinking water and wastewater systems on island
- John Jenson, Ph.D.
  - Professor of Environmental Geology, Water and Environmental Research Institute of the Western Pacific (University of Guam)
- William Tam
  - Deputy Director for Water, Hawaii State Department of Land and Natural Resources, Commission on Water Resource Management and chief author of the State Water Code
- Manabu Tagomori, PE, F.ASCE
  - Director of Water and Natural Resources, Oceanit, and Hawaii's first Deputy Director for Water at the Commission on Water Resources Management

Conference calls had been held between all of the panelists prior to the presentation, so that introductions could be made, and topics of interest could be discussed. The discussion began with the moderator giving a brief background and description of this Guam Water Resources Management Review study. Part of the background was a quick overview of the Military Buildup on Guam, and the pressures that this could put in the island's water resources. These pressures in Guam parallel the historical situation in Hawaii, when competing demands on the Pearl Harbor aquifer between the Navy, Honolulu Board of Water Supply, and the Sugar Cane industry brought about the development of the Hawaii State Water Code and the State Commission on Water Resources Management. The abstract for the panel discussion is provided in Appendix V.

Each of the panelists was then invited to give an opening statement, introducing himself and providing a few key insights to water resource management issues pertinent to Guam, Hawaii, and other tropical islands.

Mr. Tam began by explaining that his professional background lies in water law, and that he had worked extensively with Mr. Tagomori in the formative years of Hawaii's water resource management

organization, including on developing the Hawaii State Water Code and Commission on Water Resource Management (CWRM). He stated that the differences between island environments and that of the mainland are profound. On an island, the community is on its own and there is no opportunity for a backup plan should water resource management fail. Hawaiian cultural influences were taken into consideration in developing Hawaii's water policies. The cultural practice of sharing uses vice a first-come-first-served perspective was taken into account. Stewardship culture was also given precedence, especially taking into account what happens downstream and being conscious that the resource is a shared resource. He gave the metaphor of the Hawaiian sailing ship Hokulea. This ancient Polynesian voyaging canoe and its associated navigation techniques are enjoying a resurgence in recent times. On open ocean voyages, the ship effectively functions as an island with very limited resources, and fresh water is a very precious resource onboard. Stewardship of the resource is vital and it is also a fiduciary obligation of the Hawaii CWRM. He urged the audience to visit the CWRM website and view the "The Rain follows the Forest" video giving and overview of the State's Watershed Management Initiative. Over the years, CWRM has developed many resources in the form of laws, plans, and other materials. The State is now in the process of integrating water and land use planning to give shape to how these issues will interact in the long term. For example, transferring agricultural lands to urban uses should be well thought out with established criteria.

Mr. Tagomori offered further perspective from his involvement in forming the Hawaii State water resources management framework. He provided more detailed background on the State water code and the history of water management system in Hawaii, which attained Statehood in 1959. In 1961, a Groundwater Use Law was enacted, primarily to regulate the Pearl Harbor groundwater basin. The basin was under demand from the Navy, the Honolulu Board of Water Supply, and agricultural interests (sugar cane plantations). These demands steadily increased as estimates of the yield capacity of the aquifer were occasionally downgraded. These issues led to formation of the first State Water Commission in 1977, including designating the Pearl Harbor aquifer for water-use regulation. Initially this regulation was done through an independent water control board, representing the varied interests in the aquifer. In 1978, Hawaii had its Constitutional Convention, and created a new statewide water management system. Under this system, the Pearl Harbor, Waialua and Honolulu Basins were established. In 1982 water resource management was moved under the Department of Land and Natural Resources, for implementation as a single State agency. The Hawaii State Water Code was then adopted in 1987. The Water Code established the six-member Commission on Water Resource Management, adopted water basin designations, and required a hierarchy of plans and studies at the State level and from the four Counties (Kauai, Honolulu, Maui, and Hawaii). Establishing the CWRM did not instantly settle all water issues, and many persist until today. There has been a lasting debate as to how to regulate water resources. Initially, the Counties (and their drinking water departments) were against single state regulation, and argued that each County should manage its water individually. Most of the State has designated water basins, but some places still require independent water use permits. As the Water Code and CWRM, were being formed, there was also debate as to whether CWRM should regulate both water quantity and water quality. Ultimately, water quality issues fell under the purview of the State Department of Health as the USEPA's primacy agent in these areas. Centralizing water

regulation in Guam would also require addressing similar water quantity and quality issues with the established authorities of GWA and the Guam EPA.

Mr. Roush, then offered his perspective as the Manager of GWA. His background is in water issues associated with Arizona and the western US. Water scarcity in that region has created a complex system of water conservation and brokering. He has extensive experience in reclaimed water issues. His experience and lessons learned there have equipped him well to develop water management strategies. He has appreciated the chance to knowledge share with Hawaii colleagues for deeper perspective. In Guam, progress is being made and there are good resources to move forward. There are large-scale capital improvements to be made to the drinking water and wastewater systems in the coming years, on the order of $600 million. His primary focus is developing the institutional capacity of GWA to execute at this high level. His most immediate priority has to be to concentration on the GWA business model, and then water resource management issue can be addressed. In the meantime, GWA is working on developing the data management capabilities to support water resource management.

Dr. Jenson then volunteered that as a geologist and scientist, he has to consider the role of science in water resource management. He offered that his philosophy complements Mr. Roush's idea on business management in that good decisions, whether financial or scientific, need to be based on good data. In the arena of water resources, scientists' contribution must be defensible data. With critical resources, there is a critical need for reliable and accurate information and data. The data must have all the right attributes in terms of resolution, timescale, and precision. Science needs to give best data so the best decisions can be made. In this vein, the best data collection methods and programs need to be funded and implemented to provide a solid foundation for resource planning.

After the opening statements, the floor was opened to questions from the audience. Dr. Khosrowpanah from WERI recalled that in 1989, and Executive Order on Guam created a water planning committee under Guam EPA. He was part of the committee, and discussed the roles and responsibilities within the committee, and the cooperation regardless of physical resource ownership issues. Everything stopped when government support stopped. He stated that Guam EPA is still in charge of these requirements. He agreed with Mr. Roush that there is a need to place priority on fixing assets. But he thinks an entity such as a water commission should start up concurrently.

The moderator offered that water resource management planning has gained momentum with Guam Military Buildup. Several utility and groundwater studies have been funded in association with the Buildup, and an advisory group focused on Guam groundwater is being formed through an MOU between GWA and DoD. Mr. Tam also directed Dr. Khosrowpanah to Hawaii Chapter 174C, the State Water Code, to see how Hawaii CWRM was structured. Mr. Roush stated that WERI's role is a big one. Guam needs a good water resources community, with robust modeling capabilities. He also noted that some of the things that work for Hawaii and elsewhere may not work for Guam. Mr. Tagomori reiterated and Dr. Jenson concurred that water planning can only be done using good quality data, and that strong analysis relies on strong database capabilities. Discussion wrapped up shortly thereafter due to time constraints.

NGLA Advisory Group Kickoff

The third effort was the kickoff meeting of the Northern Guam Lens Aquifer (NGLA) Advisory Group. This effort is an outgrowth of the July 2010 Memorandum of Understanding (MOU) between GWA and the US Navy (see Appendix S). The effort can also be seen as a progression of the previous water resource planning committees that have operated on Guam, as the purpose and many of the participant institutions are similar to previous efforts. A driving motivation for restarting the effort based on the MOU was the US Marine Corps-funded Groundwater Availability Study on Guam being done by USGS and UoG WERI, including an NGLA water budget model. The model is expected to be a powerful tool for NGLA management, to be used cooperatively across agencies and institutions. The MOU describes the NGLA Advisory Group organization and agency membership, with an executive Senior Advisory Group, a managerial Working Group, and a pool of Technical Experts.

The Kickoff Meeting began with opening statements from the CCU Chair and NAVFAC Marianas Commanding Officer underlining the importance of cooperative protection of the aquifer for present and future uses. WERI then gave an overview presentation of the NGLA, characterizing it as the world's most interesting (and complicated / complex) aquifer. An update was also given on the Groundwater Availability Study on Guam, and its first anticipated deliverable, a "Water-Budget Model and Estimates of Groundwater Recharge for Guam." Meeting materials, including the agenda, NGLA presentation, Groundwater Availability Study Fact Sheet, sign-in sheet, and meeting minutes are included in Appendix W.

As the meeting progressed, the discussion included topics related to how the group would operate. Organizationally, the group rejected the notion that a detailed set of bylaws would be needed as the advisory group moved forward. There was a general consensus that the advisory group did not constitute an authority forum, and that things should be kept simple and informal to maintain a advisory forum based on collaboration. All agreed that periodic meetings should be held. Drawing on experience from past water resources committees, members recommended a meeting schedule more frequent than quarterly. Previous water and watershed planning committees started with great momentum on Guam but fizzled out for various reasons. It was agreed important that meetings be held on a regular basis to ensure continuity and successful outcomes.

The issue of roles and responsibilities going forward was also addressed. Funding will be needed to ensure ongoing data collection, analysis, operation and maintenance occurs continually for the utilization of the water budget model. The duties and responsibilities of maintaining the model in the future will need to be shared in some fashion among all of the advisory group stakeholders.

The group then discussed Goals and Objectives going forward. General recommendations included:

- All Parties will cooperate in all aspects of water resource management and development on Guam to ensure the long term, sustainable management of the NGLA.

- The goal of aquifer protection may encompass a wide range of water resource issues such as surface water and stormwater management due to their interactions and effects on the NGLA.
- There shall be joint management of the NGLA through the collaborative sharing of duties and responsibilities
- Protection of the aquifer is necessary, both short-term and long-term, for quantity, quality, and sustainable management
- Improvement of the overall quality, reliability and availability of water supply for all of Guam
- Construct a rolling five-year strategic management plan including funding
- Issues discussed that may become standard topics for the advisory group may include
    - Water Resource Planning,
    - Water Systems Operations,
    - Regulatory Updates,
    - CMCC Briefs,
    - Monitoring and Research Programs, and
    - Funding

Chapter 5 Organizational Structures

The organizational structures presented below represent different means to accomplish the common goal of protecting and enhancing Guam's water resources. Each of the structures is independent and none are mutually exclusive. For example, a water resources modeling organization could exist as a new and separate entity from the existing networked program of water-focused agencies, or it could be a component of a comprehensive water resources master plan committee. The organizational structures are presented in order of increasing complexity and level of effort required to establish the structures. In all scenarios, some degree of the existing networked program will remain, as no amount of centralizing and/or streamlining agencies and institutions to manage water resources could or should replace cooperation between engaged professionals in related fields.

Status Quo: Networked Program

The Status Quo for management of Guam water resources is the existing networked program. There are several agencies within Guam (GEPA, GWA, UoG/WERI, GCZM, etc.) that have parallel, if not overlapping, missions related to water resource management. Complementary Federal agencies (USEPA, DoD, USGS, etc) also have similar charges and there is a dynamic that exists between all the stakeholders. Each of the institutions makes decisions and assessments based on scientific data, often from common or complementary data sets that are of interest to multiple parties. Data sharing and professionalism are key elements to keep the networked program functioning and effective. As noted in the survey in Chapter 4, there are distinct benefits and challenges related to the networked program. The benefits center on the opportunity for broad-based collaboration across issues, while the challenges rest in funding, resourcing, and unclear lines of authority between decentralized agencies.

Water Resources Modeling Organization

The water resources modeling organization structure is a concerted step to optimize data utilization for the benefit of a variety of stakeholders. The modeling organization can exist with varying levels of formalized cooperation between agencies. Much of the recent push for this effort has been associated with the water budget model being prepared by the USGS and WERI. WERI has an established role as the repository of all groundwater data for Guam, and has continually received data from GEPA, GWA, DoD, USGS, and others. As modeling platforms have progressed, WERI staff and students have worked to leverage the models as a powerful visualization and analysis tool to advance common understanding of water resource issues. The current water budget modeling effort has provided WERI with an opportunity to develop and expand database capabilities that can be used in a variety of platforms for many purposes. As the water budget modeling project is of a fixed duration, commitments are being

formed to ensure that modeling capabilities continue to "live" and grow. GWA also has significant modeling expertise as a permanent part of the organization, primarily associated with ongoing water and wastewater hydraulic modeling and GIS asset management. As Guam water resources are of paramount importance and interest to all stakeholders, cooperative understandings of how each agency's expertise and resources can be leveraged to the benefit of all will determine the success of a water resource modeling organization.

Interagency Management Board

This water resources management construct adds to any existing structures the formalized acknowledged authority for cooperative decisions to be made. There have been historical efforts to establish such an association by Guam Executive Orders (Water Planning Committee, Watershed Planning Committee) with a set membership of stakeholders. The Military Buildup has accelerated some of these efforts with the Civilian Military Coordination Council (and its Utilities Working Group that works to keep the pulse on drinking water and wastewater issues) and the Northern Guam Lens Aquifer (NGLA) Advisory Group. These latter efforts reference Charters and MOU's as their basis documents. As the roles and responsibilities of these management boards mature, many of the details of execution may need to be further documented. Each functions under a loose adaptation of the Interagency Management Board working model as presented in Appendix X, with a structure of key executive decision makers supported by an interagency working group informed by a collaborative technical team.

Comprehensive Water Resources Master Plan Committee

A Comprehensive Water Resources Master Plan Committee would inherently be charged with developing and updating a Comprehensive Water Resources Master Plan for Guam. As mentioned in Chapter 3, GWA has a similarly titled document that focuses on planning for drinking water and wastewater systems. To make such a document comprehensive, utility aspects of water resource management will need to be coupled with assessments and strategies for addressing interrelated water quantity and quality issues for stormwater, groundwater, surface waters, nearshore waters, and wetlands. All of these resources should be considered in terms of their roles and impacts on environmental and ecological systems planning, water supply and conservation planning, as well as climatical and contingency (drought/flood) planning. Analysis and forecasts of populations and development trends should be considered, and the results should inform and guide land use planning and development policy.

Guam Commission on Water Resources Management

The most formalized and developed construct potentially available to Guam would be a legislatively created decision making entity charged with water resources management and planning. There are many examples of such agencies across the nation, primarily regional water quality and irrigation boards, though some authorities cross several regions or even States. The most accessible model of such an agency is the Hawaii State Commission on Water Resource Management (CWRM). This model would be accessible to Guam not just because of geography, but also because of similarities in water resources associated with tropical volcanic islands. Differences would need to be considered; primarily the overarching importance of the Karst NGLA, and the lack of any large scale agricultural industry on Guam. The Hawaii CWRM is based on the Hawaii State Water Code and is also governed by Hawaii Administrative Rules. Creation of an analogous entity on Guam would necessitate a comprehensive review and potential overhaul of Guam legislative policy. A new Guam code article would be needed to stand up such an agency, and creation of a formal Guam Water Code would further support and the institution. As the Hawaii CWRM was being created there was considerable discussion as to the roles and responsibilities between the new Commission and the established water utilities and water quality primacy agency (Hawaii Department of Health). Ultimately, planning responsibilities were distributed between the Commission and the Utilities, the Commission assumed authority over water quantity issues (well permits and stream diversions), and the Department of Health retained primacy over water quality issues (including developing and maintaining the State Water Quality Plan). In Guam, similar issues on roles, responsibilities, and authorities would need to be discussed and decided before a new agency could be created to address issues traditionally handled by GEPA and GWA.

Chapter 6 Potential Courses of Action

Presented in the table below are twelve potential courses of action (COAs) that the Guam water resources community could take to improve water resource management on the island. These are not recommendations. These potential COAs are simply presented for consideration, and may serve as a starter for discussion and action amongst Guam water resources stakeholders. The COAs are not presented in any particular order, and are not mutually exclusive. The table could be considered as a menu of opportunities to be pursued on an ala carte basis. Each COA is briefly described, and organizational considerations are provided to relate the actions to the organizational structures described in Chapter 5. No leads or action officers are identified as most of the COAs are collaborative efforts that will require broad based support across the Guam water resources community to be successfully implemented.

Potential Course of Action	Description	Organizational Considerations
Develop and Expand the Water Resources Community	Growth of the water resources community on Guam through graduation from local educational entities and/or worldwide recruitment can be pursued to ensure that the level of on-island expertise meets the challenges Guam faces.	This COA would support any organizational structure, as informed and educated professionals are needed in many water resource management disciplines. Early education on water issues and focus on science, technology, engineering, and math (STEM) subjects will help facilitate this COA. Continued development of UoG engineering curriculum will also help develop locally focused professionals.
Develop Water Resources Professional Associations	Establish chapters of professional societies such as the American Society of Civil Engineers, American Water Works Association, and the Water Environment Federation in order to build industry ties.	This COA would support any organizational structure, as informed and educated professionals are needed in all water resource technical disciplines. Some of these chapters are already in development, and guidance from industry leaders will help their institutional momentum.

Potential Course of Action	Description	Organizational Considerations
Conduct Water Resource Augmentation Studies	Assess and evaluate opportunities for augmenting water supplies through use of established (reservoir development) and alternative sources such as rainwater harvesting, stormwater reclamation, and wastewater reuse.	This COA would be a component of a Comprehensive Water Resources Master Plan, though the cross-disciplinary nature of the study would engage several areas of the current networked program. Efforts have been made to address this subject by GWA and through the Water Utility Study included in the Military Buildup EIS.
Assess Possible Climate Change Impacts to Water Resources	Consider possible climate change impacts to island hydrology aquifer health as part of long-term planning efforts.	This COA would be a component of a Comprehensive Water Resources Master Plan, though the cross-disciplinary nature of the study would engage several areas of the current networked program. WERI has several technical reports that address aspects of this subject, and the USGS/WERI Groundwater Availability Study may address this climate change implications as well.
Coordinate Monitoring and Data Sharing Activities	For all rainfall, groundwater, and surface water monitoring, coordinate on data acquisition, formatting, and database maintenance and accessibility issues.	This COA is foundational to any organizational structure, as sound scientific data should be the basis for all planning, modeling, and decision making processes. Continued diligence by all stakeholders will ensure sound data will be available to all.

Potential Course of Action	Description	Organizational Considerations
Produce and Maintain a Functional Water Balance Program	Assess surface and groundwater resources to produce a functional water balance program with ability to model the NGLA. Develop a plan for the model to be professionally maintained with continuous data updates, and a framework for critical water resource scenarios to be run through the model.	This COA primarily supports the Water Resources Modeling Organization construct, though a modeling body would support all other water resource management organizational structures. The ability of all stakeholders to effectively define and execute their roles and responsibilities on an ongoing basis after the USGS/WERI water balance model is created will determine its effectiveness as a planning tool.
Periodically Reassess Aquifer Sustainable Yields	Utilize the latest data sets and analysis techniques to routinely reevaluate sustainable yields for all NGLA subbasins.	This COA could be supported through the Water Resources Modeling Organization construct, though the effort could be undertaken through all other water resource management organizational structures. Sound data must be used to produce defensible sustainable yield estimates that can be used for planning and permitting purposes.
Foster Active Participation in the CMCC Utilities Working Group and the NGLA Advisory Group	The CMCC's Utilities Working Group has focus areas on drinking water and wastewater utilities, while the NGLA Advisory Group focuses on Guam groundwater. Both groups provide a forum for experts to discuss vital water resource challenges for Guam and develop timely solutions.	This COA primarily supports the Interagency Management Board construct, though their functions are being executed in the current networked program environment. Both groups rely on (often the same) technical experts to advise a stakeholder panel that provides assessments to executives from GovGuam and DoD. The ability of these groups to function effectively will set the basis for potential future water management organizational structures.

Potential Course of Action	Description	Organizational Considerations
Conduct Water Shortage Planning	Coordinate planning for water conservation, drought contingencies, water shortages, and emergency services across agencies.	This COA would be a component of a Comprehensive Water Resources Master Plan, though the cross-disciplinary nature of the study would engage several areas of the current networked program.
Expand Watershed Protection Planning	Develop Watershed Partnerships and produce watershed plans for all major watersheds on island.	This COA would be a component of a Comprehensive Water Resources Master Plan, though the cross-disciplinary nature of the study would engage several areas of the current networked program. Note that watershed planning would be fundamentally different in the volcanic southern portion of the island and the Karst northern area.
Produce and Periodically Update a "Comprehensive Water Resources Master Plan"	Cooperatively produce a master document that addresses water quantity and quality for Guam, considering surface water, groundwater, stormwater, drinking water, wastewater, and watershed health issues.	This COA would be addressed by a Comprehensive Water Resources Master Planning organization. The cross-disciplinary nature of the study would engage several areas of the current networked program. A water resources modeling body would be an excellence source to inform master plan updates. The Comprehensive Master Plan could be facilitated by an Interagency Management Board, though a Guam Commission on Water Resources Management would inherently have this charge as part of its governing mandate.

Potential Course of Action	Description	Organizational Considerations
Examine Water Resources Management Policies and Principles	As part of water resources management planning, evaluate and develop policies, such as a Guam Water Code, and organizational structures to implement policies.	This COA would support any organizational structure, as periodic review of policies and principles is beneficial in any institutional setting. This COA would be essential, though, to establishment of a Guam Commission on Water Resources Management, as a concerted review and redefinition of roles and responsibilities across Guam agencies would require such an examination.