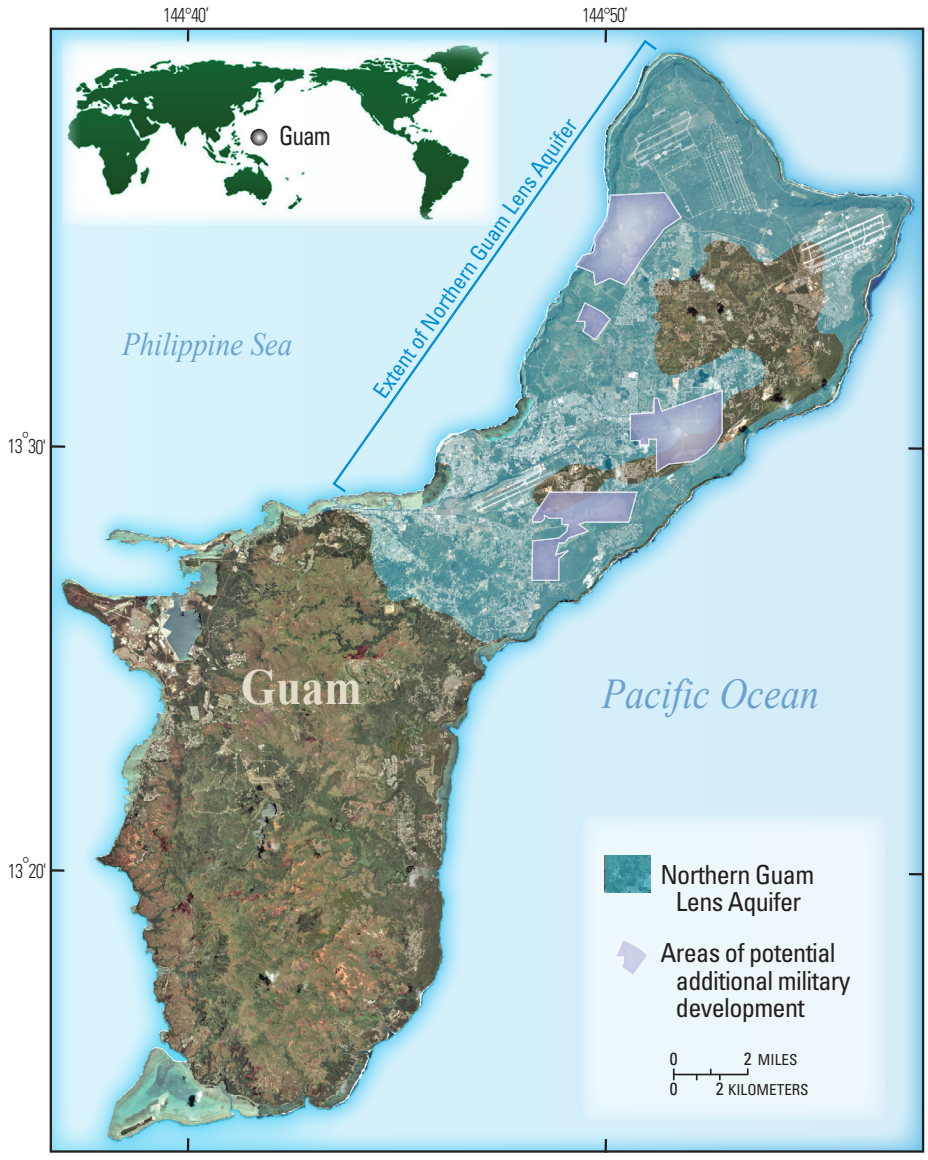
Groundwater Availability Study for Guam—Goals, Approach, Products, and Schedule of Activities

An expected significant population increase on Guam has raised concern about the sustainability of groundwater resources. In response, the U.S. Geological Survey (USGS), in collaboration with the University of Guam's Water and Environmental Research Institute of the Western Pacific (WERI) and with funding from the U.S. Marine Corps (USMC), is conducting a 3.5-year study to advance understanding of regional groundwater dynamics in the Northern Guam Lens Aquifer, provide a new estimate of groundwater recharge, and develop a numerical groundwater flow and transport model for northern Guam. Results of the study, including two USGS reports and a well database, will provide more reliable evaluations of the potential effects of groundwater production and help guide sustainable management of this critical resource.

Introduction

The population of Guam is expected to increase substantially over the next decade during a proposed military forces relocation, which includes a major realignment of U.S. Marine Corps (USMC) personnel and their families to northern Guam. Groundwater production from the Northern Guam Lens Aquifer, currently about 40 million gallons per day, could significantly increase as a result. This prospective increase has prompted concerns over the sustainability of additional groundwater development on the island. Recognizing these concerns, Headquarters, USMC, has provided $1.2 million for the U.S. Geological Survey (USGS) to conduct a 3.5-year groundwater availability study that will provide information and tools to more effectively manage Guam's groundwater resources. The USGS has in turn engaged the University of Guam's Water and Environmental Research Institute of the Western Pacific (WERI), with whom it has had a long-standing collaborative relationship, to provide local scientific expertise and coordinate with local cooperating agencies in developing a well database.



The island of Guam, in the western Pacific Ocean, has a freshwater-lens system in the productive limestone aquifer (Northern Guam Lens Aquifer) underlying the island's northern half, where most of the population resides and where population is expected to increase substantially as a result of military expansion. A groundwater-availability study will help guide sustainable management of this critical and increasingly used resource. The darker "window" in the middle of the aquifer is the extent of the volcanic basement rock above sea level, where groundwater pumping is precluded by the very low permeability of the rock. (Image from U.S. Department of Agriculture, Natural Resources Conservation Service, 20060714, Orthophoto Mosaic for Guam).

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Study Goals and Approach

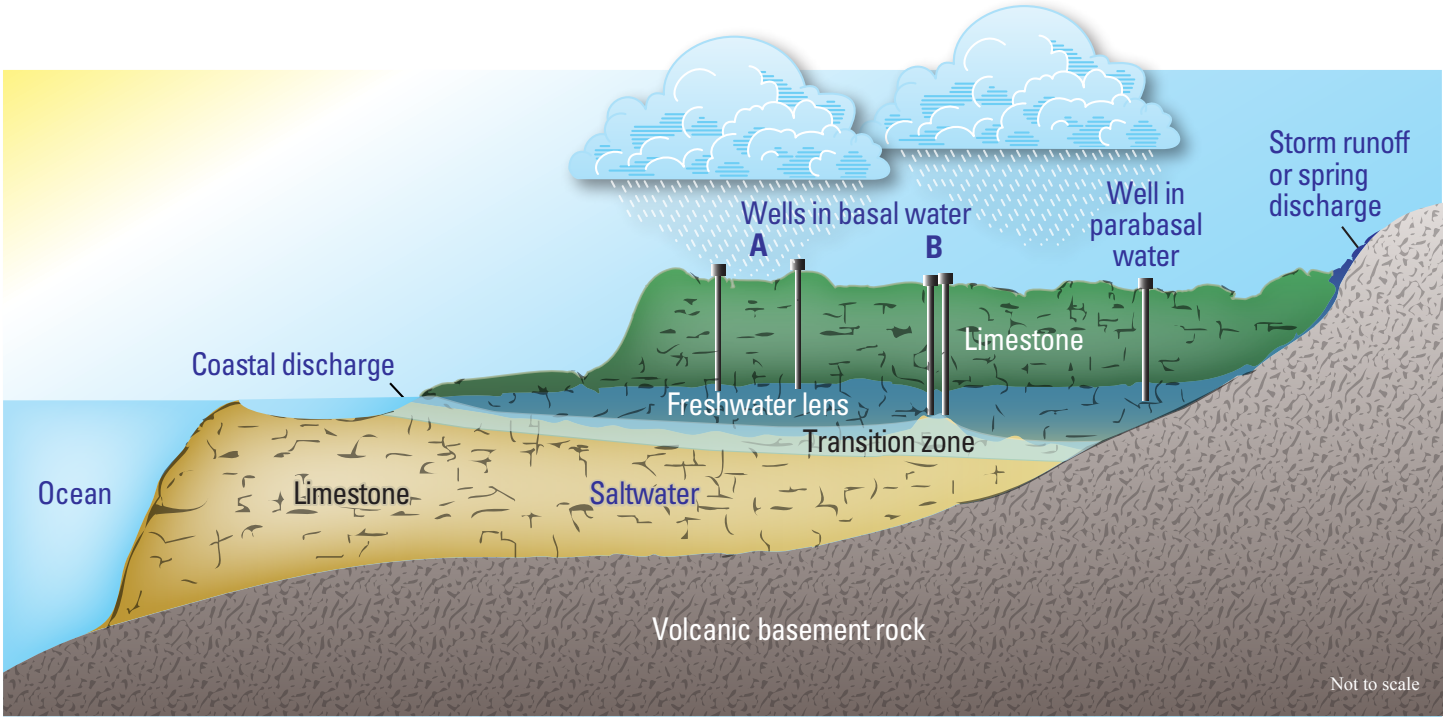
The goals of this study are to (1) advance the understanding of regional groundwater dynamics in the Northern Guam Lens Aquifer, (2) provide a new estimate of groundwater recharge for the entire island, and (3) develop a numerical groundwater flow and transport model for northern Guam that will serve as a tool to assist water-resource managers in estimating the effects of selected groundwater-pumping and climate scenarios on the water supply. Although the main area of interest is the Northern Guam Lens Aquifer, the study will also provide a new water-budget estimate of recharge for southern Guam. A four-phased approach will be used to meet the study goals: (1) compilation and review of existing hydrologic and geologic data; (2) collection of additional groundwater data; (3) water-budget calculations to estimate island-wide groundwater recharge rates; and (4) development of the groundwater flow model for northern Guam. Groundwater data will be collected and analyzed to determine regional groundwater-flow patterns and estimate aquifer hydraulic properties, and these data will be used to construct the groundwater flow model. The model will be used to estimate the regional effects of selected pumping and recharge scenarios on groundwater availability, and the results will assist water-resource managers to plan, design, and manage water systems that will produce a sustainable and reliable freshwater supply.

Collaboration with WERI

Throughout this study, USGS and WERI hydrologists will collaborate to incorporate the latest knowledge of the unique characteristics of the Northern Guam Lens Aquifer. The USGS and WERI have had a close collaborative relationship since 1998, when the 24th Guam Legislature first provided permanent funding to support the jointly funded Comprehensive Monitoring Program for collection and analysis of hydrologic data in Guam. For this study, WERI scientists will coordinate with other Guam agencies to develop a comprehensive geographic information system and spreadsheet-based database on well locations, depths, and construction, along with geologic and hydrologic data, including water-level and salinity histories and pumping rates for each well. This database is essential for building the groundwater flow model, and it will also constitute a separate valuable tool for water-resource management and future hydrologic studies on Guam. Development of the new water budget and the groundwater flow model will also take into consideration recent WERI studies of groundwater-recharge mechanisms in the Northern Guam Lens Aquifer.

Numerical Groundwater Flow Model of Northern Guam

Numerical groundwater modeling is the best available method for forecasting the effects of future pumping on groundwater availability. The groundwater flow model will be built to match historical water-level and salinity data on Guam, and it will then be used to estimate the effects of anticipated pumping and climatic conditions on water levels, salinity, and coastal groundwater discharge. Possible scenarios include: (1) continued pumping from existing wells at current rates, (2) increased pumping from existing wells, (3) pumping from proposed new well locations, and (4) reduced or increased recharge driven by drought or other climatic variations. The scenarios that will be simulated and tested with the groundwater flow model will be formulated in consultation with the stakeholder technical working group. (See box on right.)



Schematic cross-section of the Northern Guam Lens Aquifer. Wells tapping basal water (freshwater underlain by saltwater) must be designed and managed carefully to minimize the risk of saltwater contamination. Wells tapping parabasal water (freshwater underlain directly by the low-permeability volcanic basement) have the lowest risk of saltwater contamination. Schematic effects of pumping in the basal zone are depicted for (A) widely spaced wells that cause only slight rise in the transition zone and (B) closely spaced wells that are too deep and that cause brackish water from the transition zone to rise into the wells.

Stakeholder Technical Working Group

A stakeholder technical working group has been formed to foster local interagency communication and cooperation in support of the Guam groundwater-availability study. This group is essential to the success of the study and to the long-term use of the well database and groundwater flow model. In addition to U.S. Geological Survey (USGS) and Water and Environmental Research Institute (WERI) scientists, the working group comprises local technical experts from the Department of Defense and Guam government agencies, including the Guam Environmental Protection Agency and the Guam Waterworks Authority. Besides facilitating the progress and eventual application of the study products, the working group will help to ensure that ongoing and future water-management decisions will be based on shared scientific information and common understanding of Guam's hydrology. Working-group meetings will be held regularly throughout the study, and products of each phase will be shared through the working group and presented simultaneously to all stakeholders. Working group members will also be invited to observe or assist with fieldwork as practical, offer advice on the direction of the study, and suggest instructive and useful applications of the groundwater flow model. Study results, including the database and modeling tools, will be available to all stakeholders to help provide more reliable evaluations of the potential effects of groundwater production and preclude conflicts that can arise from insufficient information and differing interpretations of the data.

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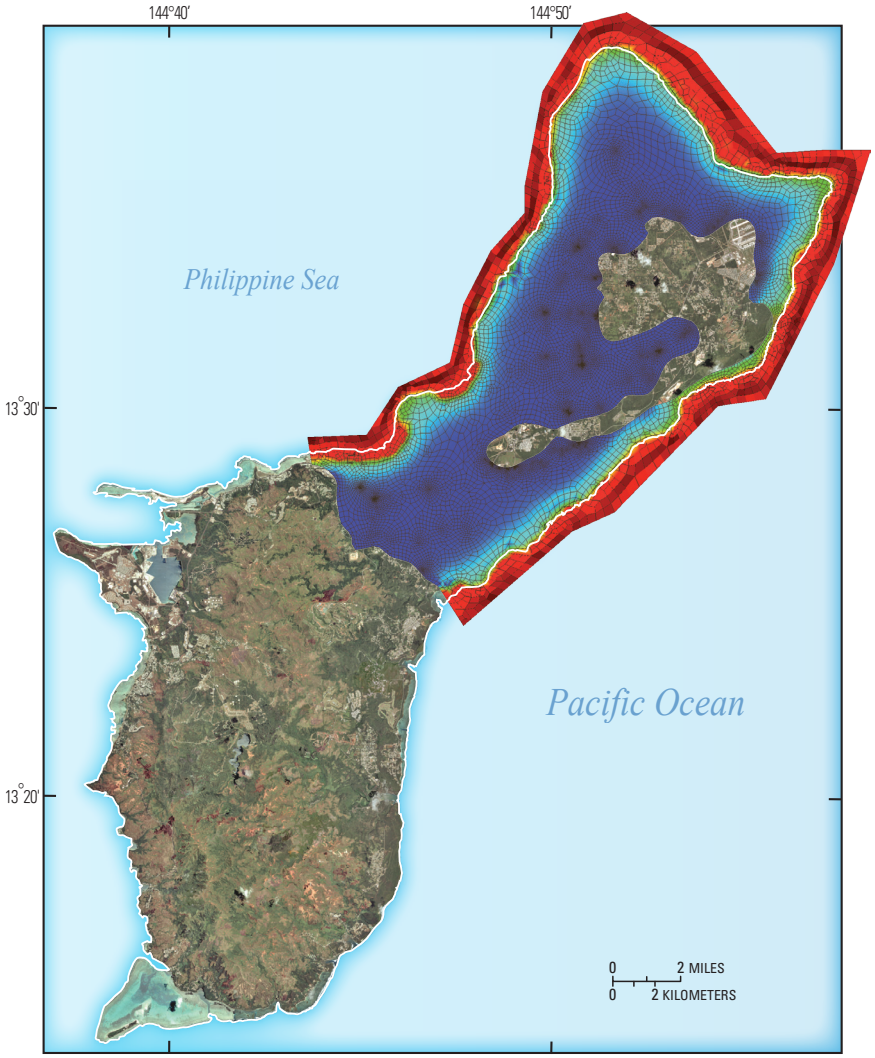
Numerical Model Limitations

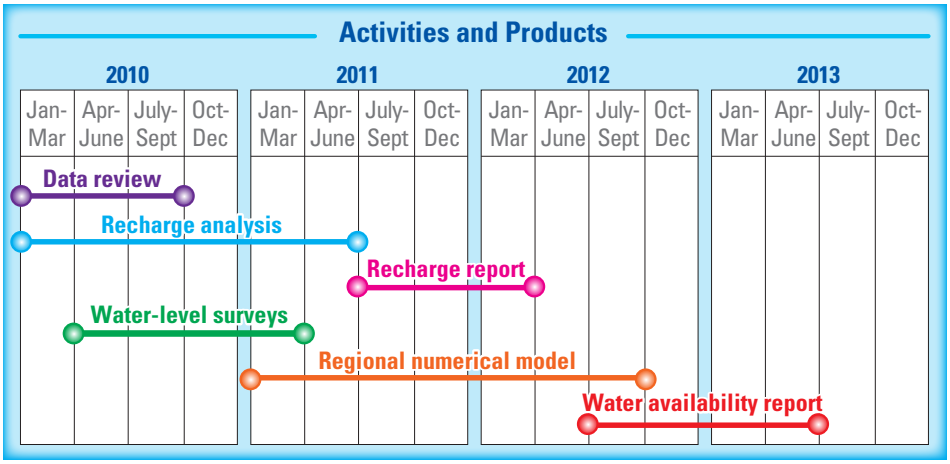
Although numerical models are today's state-of-the-art tools for managing groundwater resources, they have several limitations. They require specialized expertise to be used appropriately and effectively. In addition, current data on water-table elevations and salinity profiles from observation wells through the aquifer are needed to estimate model parameter values and to evaluate model accuracy. Therefore, a groundwater flow model must be supported by a robust and carefully managed long-term data-collection program. Lack of water-level and salinity data in parts of the study area may limit the model's predictive capability in those areas.

The Northern Guam Lens Aquifer is especially complex because of the widespread presence of fractures, voids, and caverns. Consequently, the



Example numerical groundwater flow model of the limestone aquifer of northern Guam. The colors, ranging from blue (freshwater) to red (saltwater), represent simulated groundwater salinity at the top of the freshwater lens. The "window" in the middle of the model is the extent of the volcanic basement rock above sea level, where groundwater pumping is precluded by the very low permeability of the rock.

model to be developed for northern Guam will simulate groundwater flow only below the water table, and it will not have sufficient resolution to capture and simulate some of the important local, small-scale conditions in the Northern Guam Lens Aquifer. For example, the model may not accurately predict site-specific changes in the salinity at a well. Besides the limitations imposed by the complexity of the aquifer, the temporal and spatial distributions of groundwater recharge, which are needed as input to the model, will be estimated using a water budget that also contains uncertainty. Nevertheless, a groundwater flow model will be useful for studying and predicting regional-scale responses to aquifer development or climatic changes.



Planned schedule for the various activities and products of the groundwater-availability study of northern Guam.

Study Products

Study products will include two USGS reports and the well database. The first report, documenting the results of the groundwater-recharge calculation, will be available after the second year of the study. The second report, discussing groundwater availability, the groundwater flow model, and results of selected pumping and recharge scenarios on water levels and salinity in the aquifer, will be published at the end of the 3.5-year study. Both reports will be made available through the Internet on the USGS website. The well database will be available through WERI and is designed to be updated in the future as knowledge of the aquifer improves.

Computer Modeling of Groundwater Flow

Computer models of groundwater systems simulate the flow of groundwater, including water levels, and the transport of chemical constituents and thermal energy. Numerical models synthesize all aspects of the conceptual model into an internally consistent mathematical representation of the groundwater flow system by incorporating available hydrologic, geologic, and withdrawal information. Groundwater models afford hydrologists a framework on which to organize their knowledge and understanding of groundwater systems, and they provide insights water-resources managers need to plan effectively for future water demands. Building on decades of experience, the U.S. Geological Survey continues to lead in the development and application of computer software that allows groundwater models to address scientific and management questions of increasing complexity.

For more information, see:

Provost, A.M., Reilly, T.E., Harbaugh, A.W., and Pollock, D.W., 2009, U.S. Geological Survey groundwater modeling software—making sense of a complex natural resource: U.S. Geological Survey Fact Sheet 2009–3105, 4 p.

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