Assessing Ground Water Sustainability of the Island of Tutuila, American Samoa

Introduction

The island of Tutuila in the territory of American Samoa is currently faced with two critical challenges that threaten the sustainability of domestic water supplies: water quantity and water quality. Groundwater sources provide nearly all drinking water to the island's ~57,000 residents, and a number of current sources are suspected to harbor contamination from pesticide residues, pollutants associated with automobiles, and pathogen and nutrient pollution from poorly constructed human and pig waste disposal systems (ASEPA 2006). The island can be divided into two main geographic regions, 1) the mountainous-forested interior, and 2) the geologically recent and thus, very hydrologically conductive Tafuna-Leone Plain (Fig. 1). In the Tafuna-Leone Plain, septic tanks, cesspools, and piggeries lie proximal to the drinking water wells in a highly permeable unconfined aquifer (Davis 1963). The negative impacts on groundwater quality are obvious and an understanding of the effects of human development on the sustainability of this resource is essential to water managers that are currently faced with hard decisions.

Problem and Research Objectives

There are currently no established aquifer boundaries or estimates of sustainable groundwater yields for the island of Tutuila. Definitions of aquifer zones based on geologic information and groundwater geochemistry can be used along with regional and local scale MODFLOW and SEAWWAT models to make estimates of sustainable yields. If high-level groundwater data is available for model calibration purposes, an assessment of the developability of the resource may also be possible.

To date, no assessments of the effects of land use on Tutuila's groundwater quality have been made. By comparing the density of potentially contaminating activities in well capture zones, a preliminary determination of the potential for domestic and agricultural contamination at current or future well sites can be made.

The effects of future climate uncertainty are inescapable and will have implications on water resource management throughout the Pacific. Using the data from the climate model predictions as input parameters for groundwater models will allow us to make recommendations to water managers that account for a variable climate.

Methodology

Groundwater modeling is invaluable for good management and proper planning of water resource development. New water level and climate data has been collected is currently being integrated into a MODFLOW model. Once calibrated, local and regional models will be applied to address a number of specific questions. Due to their degree of spatial and temporal dimensionality, numerical models have proven to be more effective in defining and estimating values of sustainable yield than in analytical models such as RAM2 (Liu and Dai 2012; El-Kadi 2013). Geochemical information from well sites can be used to assess the degree of anthropogenic effects on groundwater, as well as provide insight into the sources of both water and nitrate. Stable nitrogen isotopes of groundwater nitrate are widely used to differentiate between fertilizer versus animal/human and soil nitrate (Kendall and McDonnell 1998, and papers therein). On other tropical islands, stable isotopes of water have been used to assess recharge altitude (Scholl 1996) as well as the seasonality (Davis 1970) of precipitation contributing to groundwater. Coupled with other indicators, such as radon gas concentration and turbidity readings, timescales for precipitation, to surface water, to groundwater fluxes can be constructed (Le Gal et al. 2001).

Principal Findings and Significance

A field expedition to Tutuila for site reconnaissance and sampling was completed in summer 2013. Preliminary water samples from wells, springs, and streams were collected and the extent of available well data was determined. Nutrient concentrations were analyzed and the Tafuna-Leone Plain region was found to have a distinctive excess of nitrate and total nitrogen as compared to the small valley fill aquifers that are distributed around the coast (Fig. 2). Stable isotopes of N in nitrate were analyzed with the denitrifier method (Sigman 2001) and values from Tafuna-Leone Plain samples indicate groundwater nitrate inputs from septic or piggery waste sources (Fig. 3). Analysis of stable water isotopes were analyzed and the results indicated that enrichment in heavy isotope ratios is found in the eastern portion of Tutuila but not in the western portion of the island. Possible causes could be either 1) rain out as clouds move over Tutuila from east to west (the prevailing wind direction), or 2) seasonal variation in isotopic ratios coupled with a significant difference in hydrologic conductivities of the aquifers in each region. These findings are encouraging for continued sampling of precipitation and groundwater to help constrain the rate at which surface water becomes groundwater.

Future Work

A sampling campaign to Tutuila is planned in summer 2014. Objectives include gathering model calibration data, obtaining and analyzing water samples from coastal springs, defining high-level groundwater elevations, and gathering upland spring samples. In addition, student interns and research partners at American Samoa Community College will be trained to assist in sample collecting throughout 2015. Work is also continuing on the development of a recharge coverage for modeling purposes and data from new climate models is expected to be available by 2015.

A funding cut early in the project resulted in the removal of the following analyses that were stated in original proposal: 1) analysis of carbon isotopes, 2) a detailed examination of biogeochemical reactions along down gradient flow paths, and 3) the use of electrical resistivity techniques. The four primary objectives of the original proposal will remain attainable without the employment of these methods.

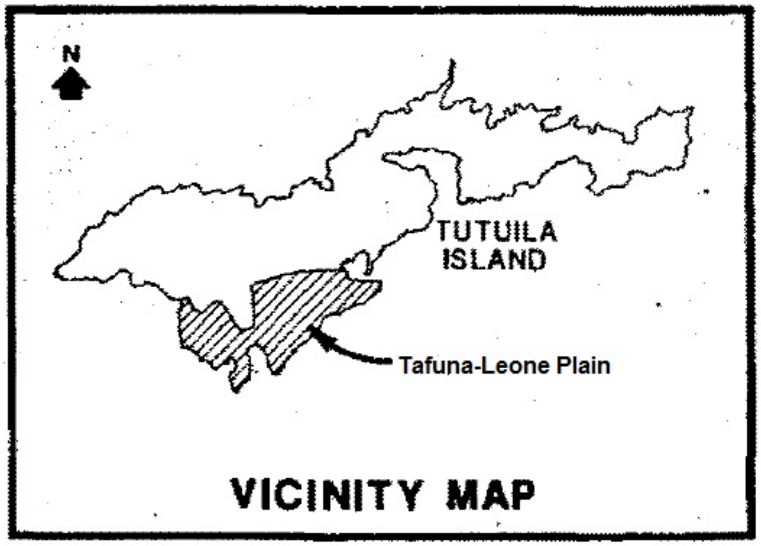

Figure 1. Map of Tutuila, American Samoa (modified from Kennedy et al. 1987).

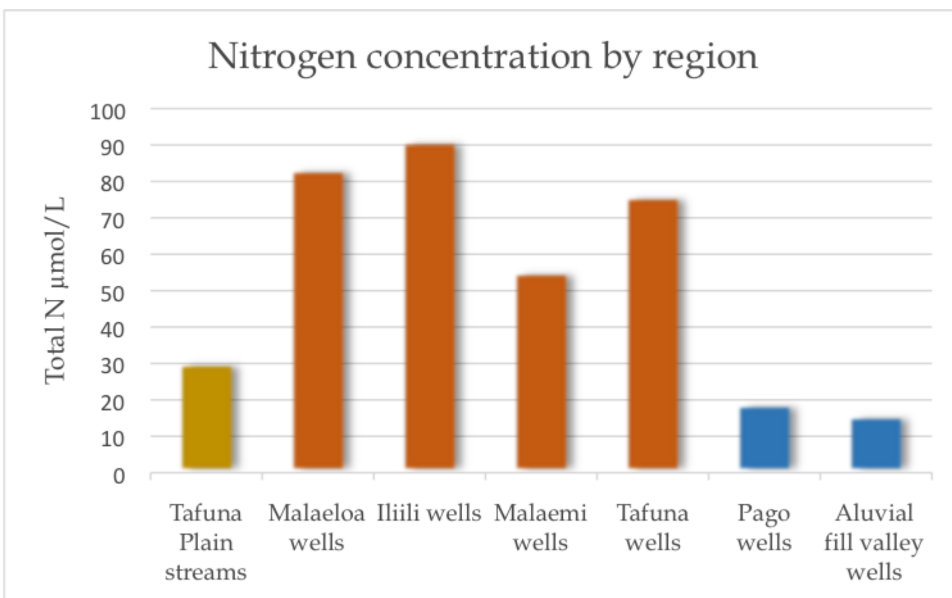

Figure 2. Average number of total N concentrations in discrete well fields and regions.

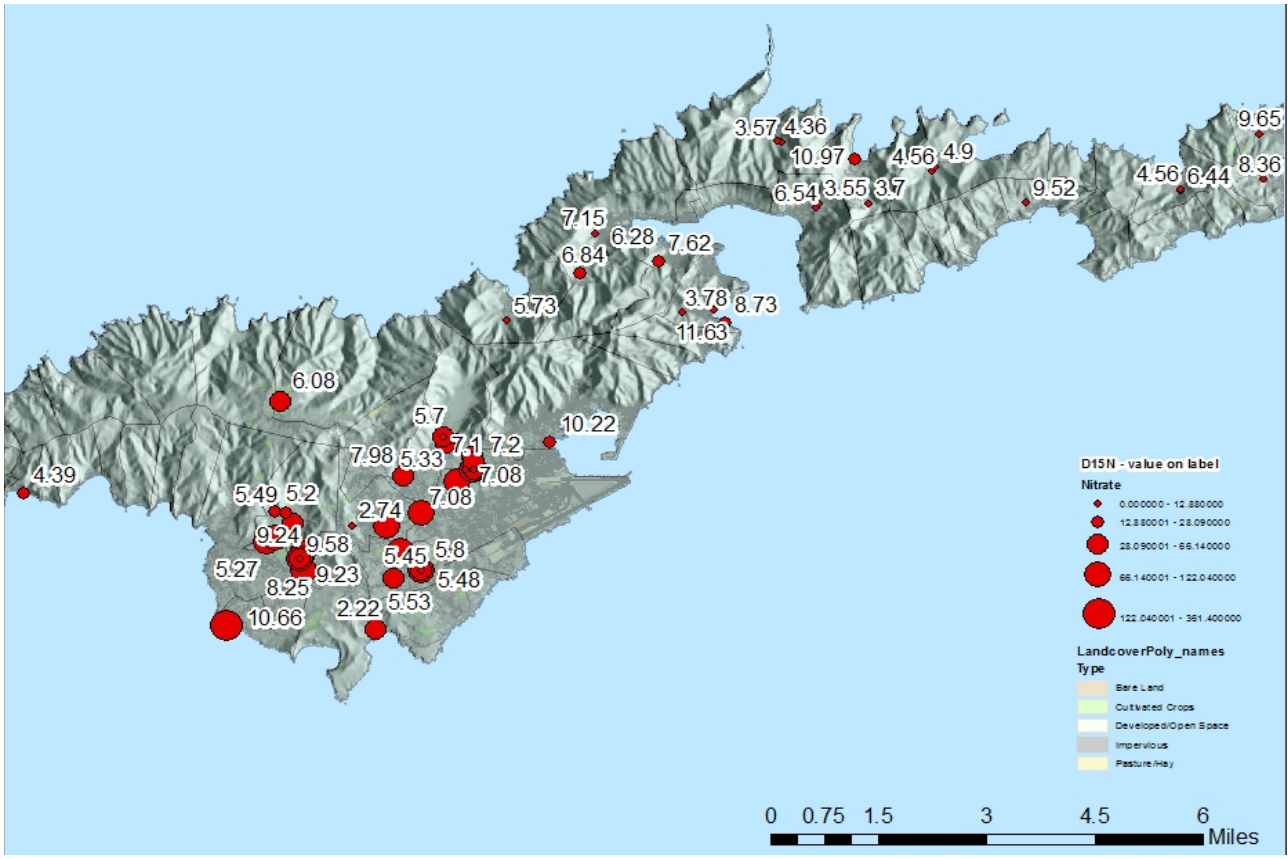

Figure 3. D15N data from water samples for wells, streams, and springs on Tutuila.

Publications Cited in Synopsis

ASEPA—American Samoa Environmental Protection Agency, 2006. *Territory of American Samoa Integrated water quality monitor and assessment report*. [305[b] report]. Pago Pago, AS 96799.

Davis, D.A., 1963. Ground-water reconnaissance of American Samoa: U.S. Geological Survey Water-Supply Paper 1608-C, 21 p.

Davis, G.H., C.K. Lee, E. Bradley, and B.R. Payne, 1970. Geohydrologic interpretations of a volcanic island from environmental isotopes. *Water Resources Research*, 6(1), 99–109.

El-Kadi, A.I., Validation of water budget analyses and numerical modeling of groundwater flow, Jeju Island, Korea: Phase II: Refining the sustainable groundwater yield. (in review)

Kendall, C., and J.J. McDonnell, (Eds.), 1989. Isotope tracers in catchment hydrology. Elsevier BV, Amsterdam.

Le Gal La Salle, C., C. Marlin, C. Leduc, J.D. Taupin, M. Massault, and G. Favreau, 2001. Renewal rate estimation of groundwater based on radioactive tracers (3H, 14C) in an unconfined aquifer in a semiarid area, Iullemeden Basin, Niger. *Journal of Hydrology*, 254, 145–156.

Liu, C.C., and J.J. Dai, 2012. Seawater intrusion and sustainable yield of basal aquifers. *Journal of the American Water Resources Association*, 48(5), 861–870.

Scholl, M.A., S.E. Ingebritsen, C.J. Janik, and J.P. Kauahikaua, 1996. Use of precipitation and groundwater isotopes to interpret regional hydrology on a tropical volcanic island: Kilauea volcano area, Hawaii. *Water Resources Research*, 32, 3525–3537.

Sigman D.M., K.L. Casciotti, M. Andreani, C. Barford, M. Galanter, and J.K. Bohulke, 2001. A bacterial method for the nitrogen isotopic analysis of nitrate in seawater and freshwater. *Analytical Chemistry*, 73, 4145–4153.