# Assessment of Groundwater Availablity in the Volcanic-Rock Aquifers of Oahu, Hawaii

## Basic Information

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## Publications


1. Rotzoll, K., D.S. Oki, and A.I. El-Kadi, 2014, “Up and Down: How can we assess hydraulic properties from tidal fluctuations in coastal aquifers?”, Abstract H53B-0845, presented at 2014 Fall Meeting, AGU, San Francisco, CA, Dec 15–19.
2. Rotzoll, K., D.S. Oki, and A.I. El-Kadi, 2014, “Development of a hydrogeologic framework from tidal analysis of coastal groundwater levels, Hawaii,” 40th American Water Works Association Conference, Honolulu, May 6–9
3. Rotzoll, K., D.S. Oki, and A.I. El-Kadi, 2013, “Development of a hydrogeologic framework using tidally influenced groundwater levels, Hawaii,” Abstract H11H–1248, presented at 2013 Fall Meeting, AGU, San Francisco, CA, Dec. 9–13.

## Problem and Research Objectives

The volcanic-rock aquifers of Oahu supply freshwater to 70 percent of Hawaii's population and most of other needs, including commerce, industry, and U.S. military. The resident population on the island has been increasing while freshwater resources are limited. Because the aquifers are small and are surrounded by saltwater, they have a restricted capacity to store groundwater and are thus particularly susceptible to impacts from human activity, through land-use changes or excessive withdrawals, and climate change (Izuka 2013). Availability of fresh groundwater is limited by the desire to avoid adverse effects on water resources, such as lowering water tables, saltwater intrusion, and depletion of streamflow and submarine groundwater discharge. Quantifying these effects is therefore critical for a successful groundwater management.

The last regional assessment of the water resources in the volcanic-rock aquifers of Oahu was completed during the 1990s (Hunt 1996, Nichols et al. 1996). Since then however, new technologies (computer power, modeling software) and new analysis techniques have been developed, recharge and hydrogeologic information have been updated, and the need to consider effects of climate change has increased. This warrants a revised assessment of the current groundwater availability, of the likely impacts of natural and anthropogenic factors on such availability, and of the effects of these factors on water resources in the future.

The study will utilize a numerical modeling approach of newly available recharge and hydrogeologic information to (1) improve understanding of the most developed regional groundwater-flow system in the main islands of Hawaii, (2) update knowledge of the availability and sustainability of Oahu's groundwater resources, and (3) provide insight into the impacts of human activity and climate change on groundwater resources.

## Methodology

For the assessment of Oahu's groundwater resources stored in volcanic rock, an island-wide numerical model that simulates groundwater flow and sharp interfaces between fresh- and saltwater was developed. Although sharp interface codes cannot completely simulate mixing and dispersion in the transition zone, the Saltwater-Intrusion package (SWI2) of MODFLOW 2005 (Bakker et al. 2013) allows simulating multiple sharp interfaces and density layers, and therefore offers a good representation of the transition zone between freshwater and saltwater.

Recent studies of the U.S. Geological Survey have generated new recharge estimates for Oahu for conditions prior to the onset of groundwater development and recent conditions from 2001 to 2010 (Engott et al. 2015). The study also predicted recharge estimates based on future climate conditions, climate models, and IPCC scenarios. Geologic and hydrogeologic data have also been updated through a number of USGS studies (e.g., Oki 2005). Although Hawaii aquifers are vastly heterogeneous, Oahu's hydrogeologic framework can be simplified to three hydrogeologic units: (1) dike-intruded volcanic rock, (2) dike-free volcanic rock, and (3) sediments together with rejuvenated Volcanics. The simplified hydrogeologic units are zones of similar hydraulic properties and hydrogeologic conditions. The altitude of the contact between volcanic rock and overlying sediments has been digitized for the entire island to 6,000 ft below sea level. The structural contours between basalt and sediments facilitate the model grid generation of the hydrogeologic units. Aquifer-property estimates are available from published model results (Oki 1998, Oki et al. 1998, Oki 2005, Rotzoll and El-Kadi 2007, Whittier et al. 2010), a comprehensive summary of parameter values (Hunt 1996), and a recent analysis of groundwater levels from wells with tidal influence (Rotzoll et al. 2013).

The study also examined the relationship between high-level dike-impounded aquifers and down-gradient Pearl Harbor freshwater-lens aquifers. The numerical model simulated three scenarios: (1) pre-development conditions, (2) average current conditions from 2001 to 2010, and (3) conditions under a future recharge scenario. Model calibration utilized available water levels and salinity profiles, if possible through an automated parameter-estimation routine. Model sensitivity will be implemented to address the influence of uncertainties in the model parameters on results. Part of the work focused on developing Python scripts to create model input files and to analyze results of the model output (Bakker 2014).

The calibrated numerical model will be used to evaluate historical anthropogenic effects (changes in land use and withdrawals) and future effects of climate change (changes in recharge and sea level). The historical anthropogenic effects are the difference between the simulated pre-development conditions and current conditions. The effects will be quantified by changes in water levels and in the freshwater/saltwater interface position, and differences in groundwater fluxes across hydrologic boundaries. Comparison of the results of these scenarios will be the basis for assessing the human impact on groundwater resources of Oahu's volcanic-rock aquifers. Climate change affects groundwater resources in Hawaii by causing changes in recharge and sea level. Changes in recharge alter the groundwater budget, causing changes in groundwater storage and availability. Sea-level rise causes a rise of the freshwater/saltwater interface by displacing the freshwater lens upward and coastal inundation (Rotzoll and Fletcher 2013). The numerical model will be used to simulate these impacts for Oahu expressed in the contrast between the simulated current conditions and future conditions.

## Principal Findings and Significance

Efforts to develop an island-wide model for the Island of Oahu are progressing towards achieving the study objectives. The islands' geology is complex and aquifers are vastly heterogeneous. To simply the development, the geology has been reduced to three hydrogeologic units: (1) dike-intruded volcanic rock, (2) dike-free volcanic rock, and (3) sediments and rejuvenated Volcanics. The altitude of the contact between overlying sediments and volcanic rock has been digitized for the entire island to 6,000 ft below sea level, which facilitated the model grid generation of the hydrogeologic units. The SWI2 model code was successfully applied to one-dimensional cross sections to test the suitability to simulate density-dependent groundwater flow in freshwater-lens aquifer systems. A one-layer island-wide model simulating dike-intruded and dike-free volcanic rock with a uniform grid-cell size of 500 ft was developed. Model calibration, currently in progress, is utilizing measured water levels, midpoint of the transition zone between fresh- and saltwater depth data, baseflow, and Pearl Harbor spring-discharge data.

This project has been merged with Project 2012HI412S: Determination of groundwater fluxes and evaluation of the effectiveness of low-permeability valley-fills in the Pearl Harbor Aquifer area, Oahu.

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