Development of a Hydrogeologic Framework Using Tidally Influenced Groundwater Levels, Hawaii

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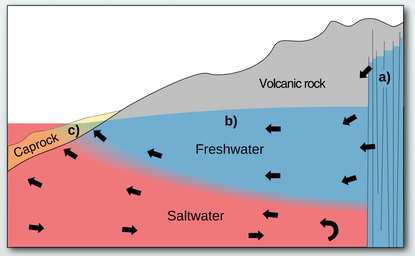
1. Abstract

Accurate estimates of regional hydraulic properties are essential for models that are used to manage groundwater availability and quality. Aquifer hydraulic properties can be derived from tidally influenced groundwater levels that are recorded in wells and coastal pools. This is possible because the attenuation of tidal signals with distance inland from the coast reflects the aquifer's regional hydraulic properties. Localized studies of tidal attenuation in Hawaii have been published, but no regional synthesis of tidal attenuation information in Hawaii exists. Aquifer properties were estimated from tidal attenuation for Hawaii using groundwater-level records from more than 250 wells in volcanic rock and more than 200 wells in coastal sediments. Results are combined in a regional context with respect to the hydrogeologic framework of each island in Hawaii. A general trend of decreasing hydraulic conductivity with age was detected from the Island of Hawaii (youngest) to Kauai (oldest). The analysis can improve conceptual models of groundwater flow in Hawaii aquifers and facilitate the development of regional numerical groundwater-flow and transport models needed for sustainable water-resource management.

2. Hydrogeologic Framework



Hawaii aquifers can be categorized into

a) dike-intruded volcanic rock

b) dike-free volcanic rock

c) caprock.

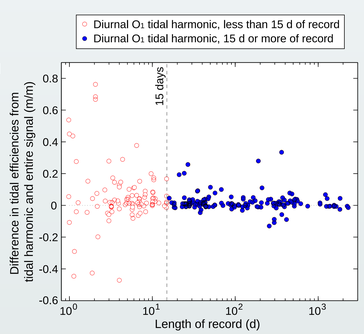
Coastal sedimentary deposits form a caprock that confines, attenuates tidal propagation into, and creates a thick fresh-water lens within the volcanic-rock aquifer.

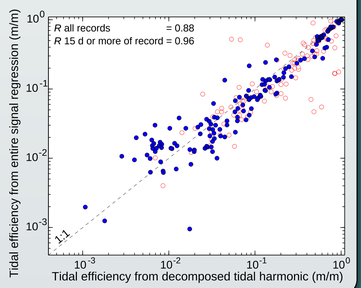
3. Data Analysis

Tidal signals are preferably analyzed by isolating known tidal harmonics to find the tidal efficiency (ratio of groundwater level tidal amplitude to ocean-tide amplitude). However, short records do not resolve all tidal frequencies. For example, to resolve O_1 and K_1 for hourly time series, the minimum record length is 13.7 d.

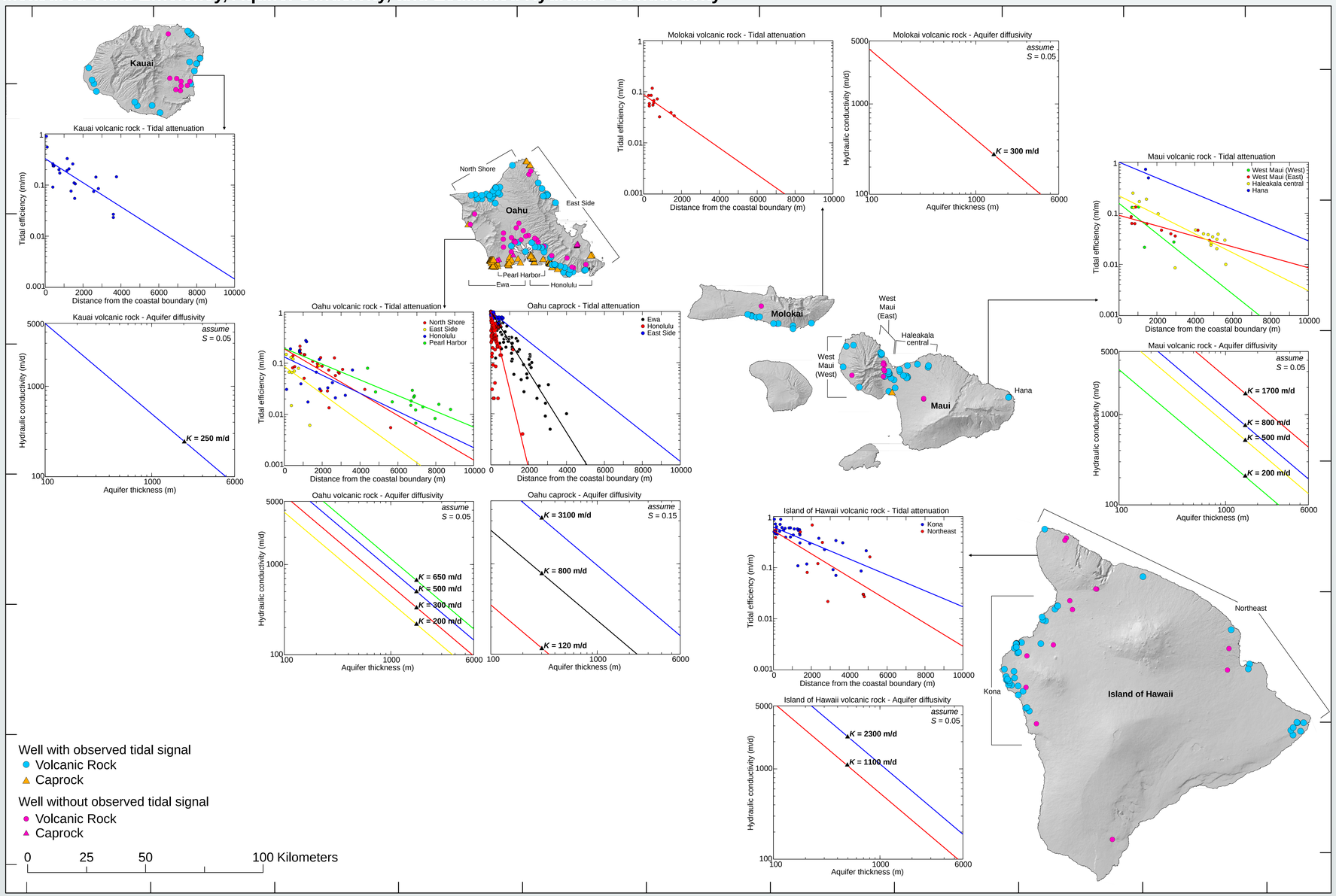
The difference between tidal efficiencies from harmonics and the entire signal may be substantial for records shorter than 15 d, because the amplitude estimated from tidal harmonics is inaccurate for short records.

Because of an excellent correlation between tidal efficiencies from tidal harmonics and the whole signal, the entire signal was used to estimate tidal efficiencies for records shorter than 15 d. For records of 15 d or more, the O_1 tidal efficiency was used.





4. Measured Tidal Efficiency, Aquifer Diffusivity, and Estimated Hydraulic Conductivity



Wells in which groundwater levels are unaffected by ocean tides are located inland or in low-permeability rocks. The slope of logarithmic tidal efficiency with distance from the coastal boundary is directly related to aquifer diffusivity (Jacob 1950; Ferris 1951). Assuming typical values of specific yield (*S*) and aquifer thickness allows estimating hydraulic conductivity (*K*).

Regional estimates of hydraulic conductivity for caprock and dike-free volcanic rock fall in the ranges of previously estimated values. A general trend of decreasing hydraulic conductivity with age from the Island of Hawaii (youngest) to Kauai (oldest) is noticeable. The analysis is part of an ongoing USGS regional volcanic-rock aquifer study: *http://hi.water.usgs.gov/studies/GWRP/*

5. Conclusions

- Tidal efficiency can be estimated from records shorter than 15 days.
- Hydraulic-conductivity estimates depend on assumed specific yield and aquifer thickness, yet results are consistent with published values for volcanic-rock and caprock aquifers.
- Hydraulic conductivity decreases with island age from the Island of Hawaii to Kauai.