Management Summary

Groundwater Development Potential and Conceptual Hydrogeologic Model for Tutuila, American Samoa

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Scope

THIS MANAGEMENT SUMMARY SUPPLIMENTS A WRRC SPECIAL REPORT OF THE SAME TITLE, PRODUCED MAY 2019. THE FULL REPORT PRESENTS COMPREHENSIVE REVIEW OF ALL HYDROLOGIC INFORMATION AVAILABLE FOR TUTUILA, AMERICAN SAMOA. THESE DATA ARE APPLIED TO INFORM UPDATES TO THE ISLAND'S CONCEPTUAL HYDROGEOLOGIC MODEL.

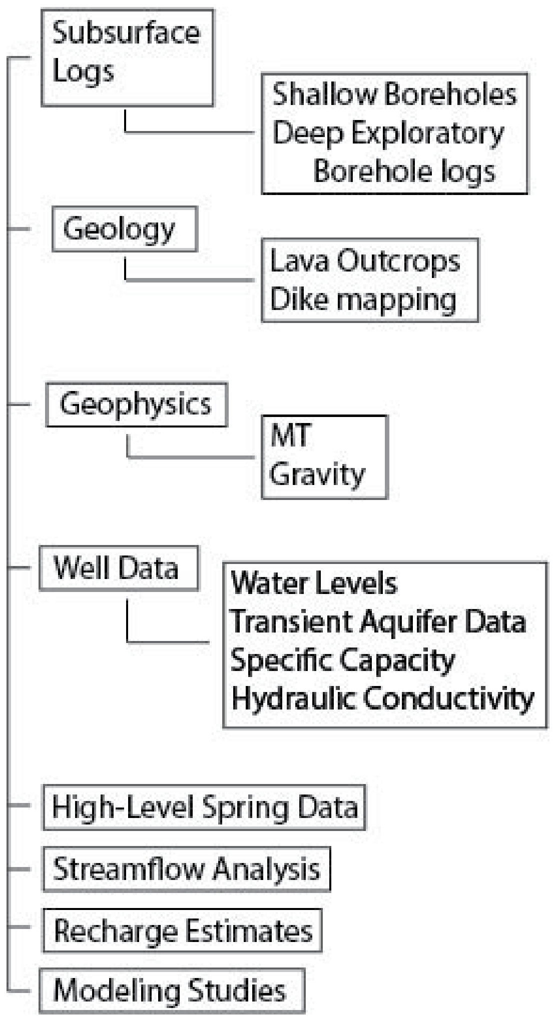

Figure 1: List of Hydrologic and geologic datasets currently available for Tutuila and reviewed within the full report.

On Tutuila, the main island in the Territory of American Samoa, groundwater resources provide drinking water to over 90% of the island's approximately 60,000 residents. Tutuila's primary groundwater resource is contained in a basal freshwater lens residing near sea level and supported by underlying seawater within saturated rock.

The Importance of Groundwater

Developing a well-informed and data-driven understanding of groundwater quality and quantity in island settings is a prerequisite for sustainably managing water resources. Surface water supplies are commonly limited on small tropical islands, often making groundwater the primary water resource available for human needs, as well as being essential to maintain numerous ecosystem services. On the island of Tutuila in the Territory of American Samoa, developing a sustainable water resources management strategy will require continued study of the island's subsurface structure, and ongoing updates to the conceptual hydrogeologic model. In this report, currently available hydrological information was compiled with recently acquired subsurface datasets (Fig. 1) to inform an updated conceptual hydrogeological model of Tutuila's groundwater and surface water resources. Published reports, recently collected data, and studies from similar basaltic islands were integrated to explain groundwater behavior in Tutuila's already developed basal aquifers, and to inform hypotheses of high-level groundwater occurrence where data limitations exist. Datasets presented include borehole, geophysical, water level, aquifer test, geomorphologic, and surface water data.

Geology and Hydrogeology

What remains today of Tutuila's older shield phase, after much subsidence below sea level, is the deeply eroded and weathered summit of the original island.

Geology: Tutuila can be divided into two primary geographic regions, each having erupted during different phases of volcanism. The east-west trending series of Pleistocene age shield volcanoes, named Pago, Taputapu, Olomoana, and Alofau, erupted about 1.5 MYA and have since eroded into a sharp 32 km long ridgeline (Fig 2). These eruptions produced a complicated and heterogeneous assemblage of alkalic igneous rocks, in the form of thick lava flows, pyroclastic deposits, and cross-cutting intrusive dikes and plugs. The Tafuna-Leone Plain region erupted between 10,000 and 4,000 years ago, according to carbon-14 dates and anthropological evidence, and created a geologically young (Holocene) series of lava and ash flows on the island's southwestern flank.

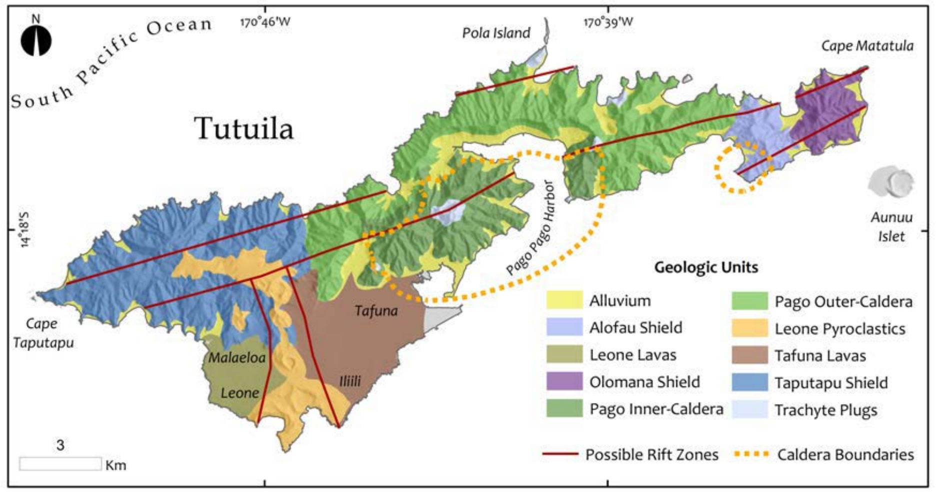

Figure 2: Simplified geology of Tutuila showing volcanic shields, relevant geologic units, and inferred volcanic structures such as rift zones and caldera boundaries.

Hydrogeology: Generally, on basaltic oceanic islands, the primary freshwater resource is contained in a lens-shaped body near sea level within saturated rocks (Fig. 3). This basal freshwater lens is supported by the underlying seawater due to the contrasting densities between fresh water and salt water. An extreme range of hydraulic conductivities in Tutuila's rocks causes production rate limitations in extremely low-conductivity areas, and issues with surface water contamination of groundwater in highly conductive zones. Groundwater under the direct influence of surface water in the Tafuna-Leone Plain region has afflicted portions of Tutuila with one of the longest-standing boil-water advisories in U.S. history. Compounding these issues is the fact that the island's landmass is quite small and the total volume of freshwater storage is limited.

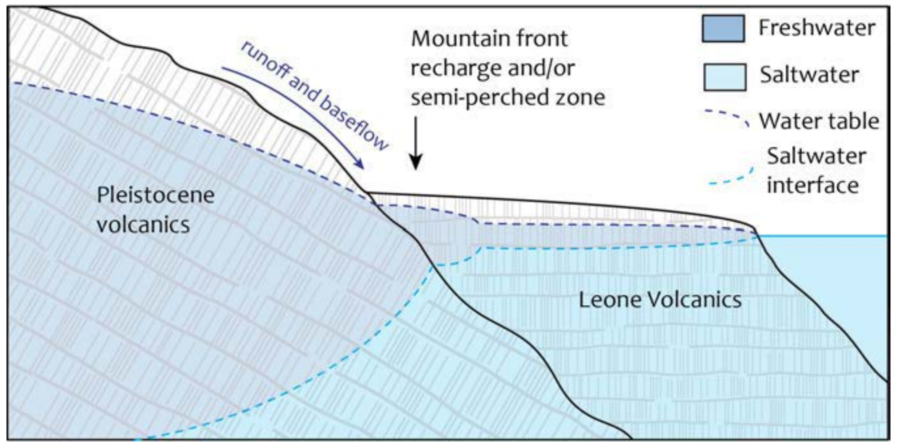

Figure 3: Basic conceptual model of the basal lens aquifers on Tutuila, with emphasis placed on hydrologic interaction between less (Pleistocene) and more (Leone) permeable geologic units.

Borehole Logs and Geologic Mapping

Geology controls subsurface hydrology: boreholes and rock outcrops provide the best clues for understanding the subsurface, which in turn, is a prerequisite for informed management of water resources.

There are existing borehole logs from over 40 shallow wells throughout Tutuila and from 2 deep boreholes (Fig. 5) located on the Tafuna-Leone Plain. While the shallow borehole logs are limited in their detail and clarity, the deep borehole logs are very informative for showing the subsurface composition in the area of each well. Rock outcrops can also provide valuable clues for understanding the island's geology, but are only accessible in locations where erosion or other processes have cleared Tutuila's prolific vegetation, such as the coastline (Fig. 4). Only three studies (Stearns 1944; Walker and Eyre, 1995; Eyre and Walker, 1991) have examined the whole island's surface geology. In general, what both surface and subsurface geological investigations reveal is that the island is constructed of a complex arrangement of lava flows, associated clinker zones, a limited amount of marine and terrestrial sedimentary units, and pyroclastic materials—including pockets of cinder and ash layers. These units are generally limited in thickness and extent making the island's construction extremely heterogeneous. It is likely that the small scale of these heterogeneities may be so localized as to not have much control over regional aquifer properties.

Surface Geologic Mapping

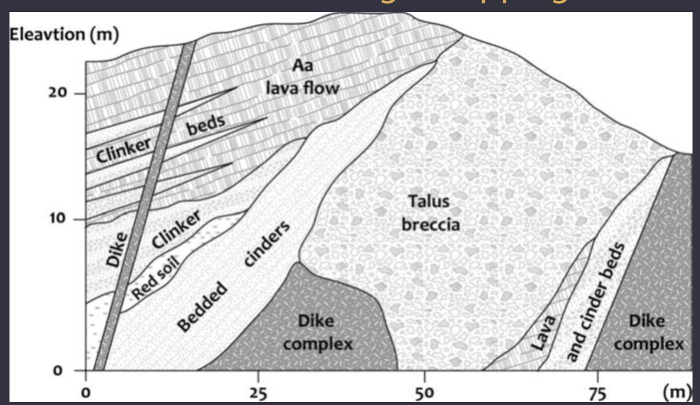

Figure 4: Diagram of the geologic components of the Pleistocene volcanics in an outcrop at Masefau Bay. Note major heterogeneity throughout the cross section. Modified from Stearns (1944) with permission.

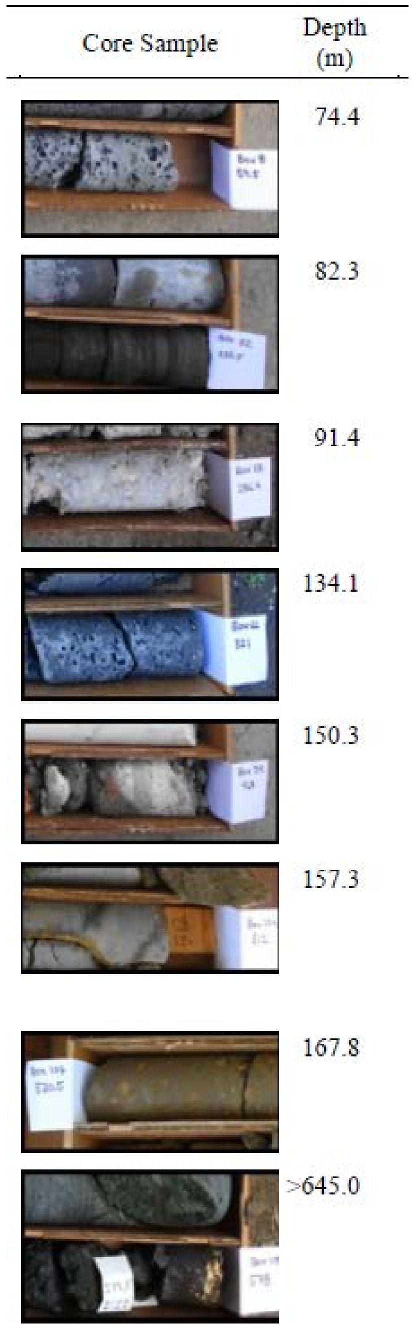

Figure 5: Simplified compilation of drilling logs and core sample photos for one of the deep-boreholes, TGH-3, Iliili site. Note large range in different rock types.

Aquifer Tests and Geophysical Data

Aquifer test and water level data can be used to assess groundwater flow, infer aquifer properties, and estimate hydraulic connectivity in different areas. These data are typically generated by performing well measurements or pump tests. There have been at least 130 wells drilled on Tutuila, and approximately fifty (50) of these are currently operational ASPA production wells. To develop the most comprehensive estimates of aquifer parameters on Tutuila, the full report presents all available water level, pump test, step-drawdown, and recovery test data compiled from USGS records, archived ASPA records, and recent WRRC aquifer tests.

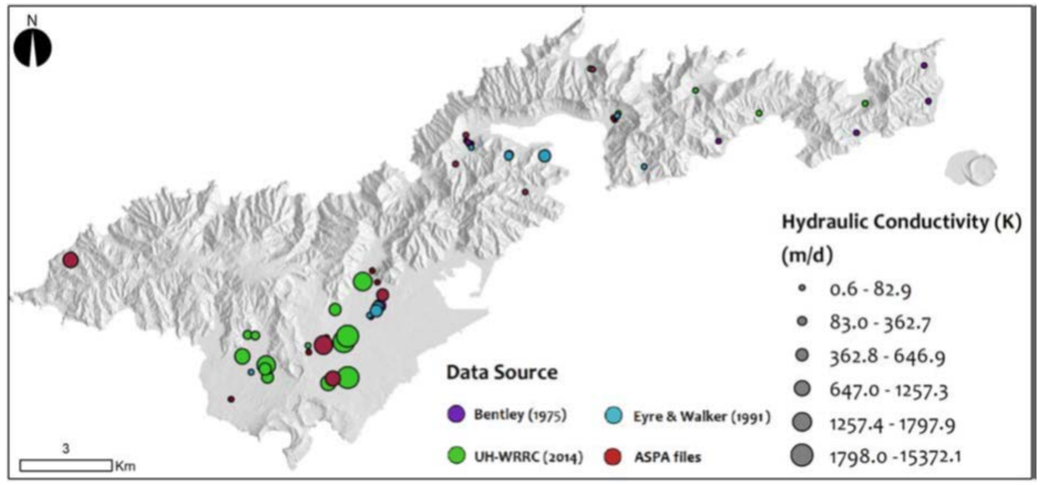

Figure 6: Values of hydraulic conductivity calculated from all known well tests on Tutuila

Geophysics: Only two geophysical studies have been conducted on Tutuila, a Bouguer gravity anomaly survey (Machesky, 1965), and a magnetotelluric (MT) survey of subsurface electrical resistivity beneath the Tafuna-Leone Plain and the Taputapu Volcano for the purpose of exploration for a geothermal resource (Geologica Geothermal Group, Inc., 2014). The data is generally informative for understanding where dike complexes may be more prevalent, where there are zones that could be inferred to be saturated with seawater, and where highly-resistive areas may indicate the unsaturated zones. However, as with all geophysical measurements, hydrological features are difficult to discern from the geophysical profiles.

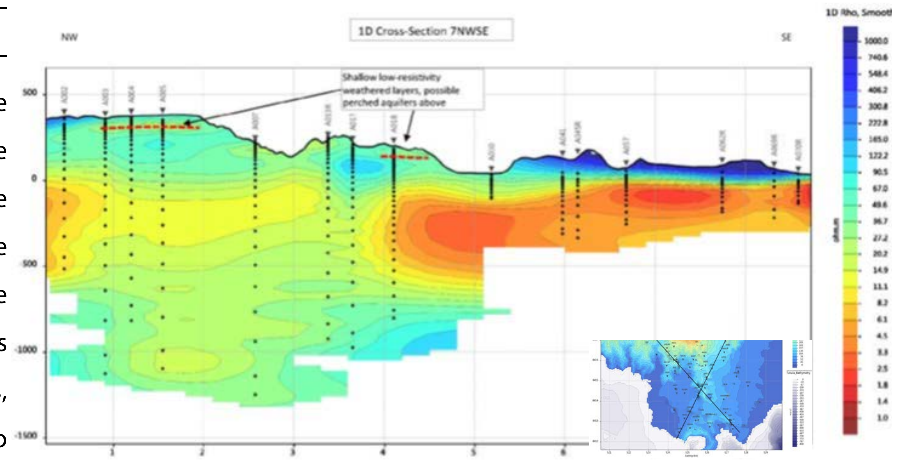

Figure 7: Cross section of western Tutuila (Tafuna-Leone Plain and the Taputapu Volcano) showing MT survey of subsurface resistivity. Warmer colors indicate less resistive materials to show conductivity from seawater saturation in the subsurface.

Conceptual Hydrogeologic Model

Geologic and hydrologic observations, as well as experience with existing well performance suggest that Tutuila's hydrogeology is very complex.

Conceptual Model

A two-stage eruptive history, (the shield-building and rejuvenated phases) compounded with high erosion rates, has increased the heterogeneity of Tutuila's subsurface. Observations of Tutuila's geologic structure from outcrops and borehole logs show a heterogeneous distribution of lavas, breccia, debris flows, cinders, and intrusive bodies yielding a complex and difficult to predict subsurface geology. This has manifested as an extreme range in observed hydraulic conductivities throughout the island. Some low-hydraulic conductivity areas, such as the Pago Shield, display significant production rate limitations, and other areas, such as the Tafuna Plain, are so highly conductive they cause issues with surface water contamination of groundwater. While it is likely that no single conceptual hydrogeologic model best represents the entire island, separate models can likely be applied to different hydrogeologic units where sufficient data is available.

High-Level Groundwater

The existence of high-level water in the island's older shields is irrefutable, but its nature is poorly understood. A significant perched aquifer exists at Aoloau Village, and numerous persistent springs are reported throughout the island. Existing geologic evidence suggests high-level waters are likely to be impounded by different types of geologic structures in different locations. However, it remains unclear what exactly those sctructures are.

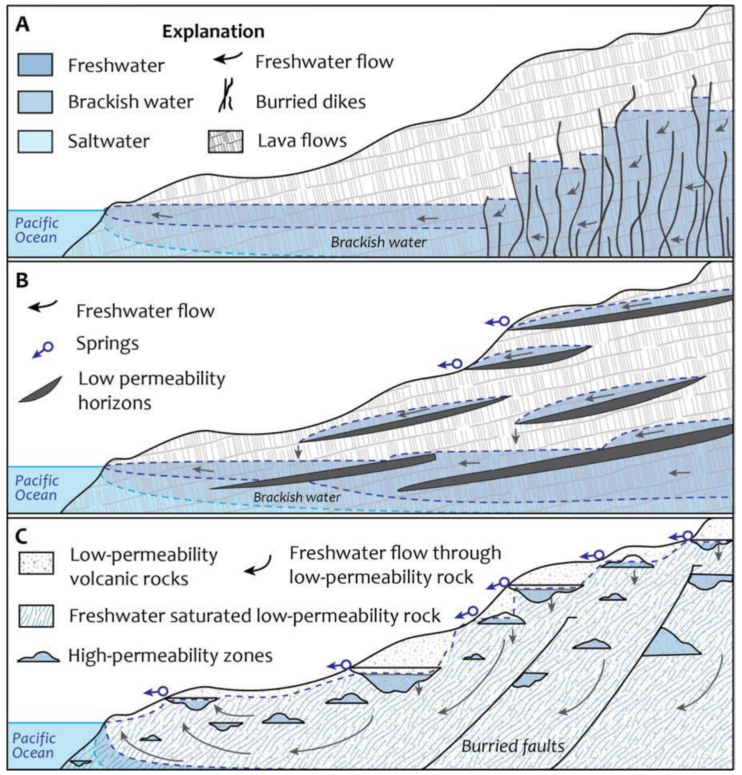

Figure 6: Three hypotheses for the occurence of high-level groundwater each controlled by different types of water impounding geologic structures. A) Dike-impounded groundwater based on the Hawaiian Conceptual model, B) Small perched aquifers within lava flows, C) Complex geologic system as in the Canary Islands Model including buried cinder cones, faults or paleovalleys.

Take-Aways and Recommendations

1. Wells in the Pleistocene Volcanics can be expected to yield only low quantities of water. However, Geologic and hydrologic evidence suggests the Taputapu Shield is more likely to display more favorable producing conditions than the Pago Shield. Nonetheless, the Taputapu region is large and heterogeneous, and the productivity of wells is predicted to vary greatly with site-specific conditions.

2. Conditions found during well drilling are likely to be site specific, in which case it will be difficult to predict the regional connectivity of any given location without long-term pump tests after drilling. Continued collection of high-resolution water level data during production would be useful to assess the degree of connectivity between more permeable portions of the aquifers.

3. Careful assessment of aquifer parameters during and/or after drilling with step-draw-down, constant-rate , and recovery tests will help to set appropriate pumping rates and better understand the aquifer.

4. Developing high-level reservoirs on Tutuila will almost certainly require geophysical exploration and multiple test wells to find high-yielding zones, However, the magnatude of available resources may not offset the cost of exploration and development.

Conclusions and Directions for Future Study

The collection of hydrologic data presented in this report is foundational for developing numerical groundwater models, which are generally considered to be the most reliable tools for quantifying groundwater availability. While a large amount of data has been consolodated here, there remain a number of significant data gaps needing to be filled. These gaps include: 1) an updated, high-temporal, and spatial resolution recharge distribution, 2) an assessment of mountain front recharge (MFR) runoff to infiltration ratio, 3) conceptual model testing and validation, 4) higher resolution Cl- information from production wells, 5) aquifer testing for existing wells with no existing test records, 6) improved assessment of aquifer boundaries, and 7) development of sustainable yield criteria. Filling these gaps should be a key goal for water managers and researchers seeking to continue making progress in developing data-driven management strategies that ensure the sustainability of Tutuila's water resources for future generations.

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