

Annual Report of the Hydrology Study

of the Geothermal Project

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Published literature review and data compilation

The first step of the project involved compiling a collection of over 50 documents and reports concerning the hydrology and relevant geology of Kilauea and the Kilauea East Rift Zone (KERZ). The report authors include the Department of Land and Natural Resources (DLNR), University of Hawaii, Hawaii Institute of Geophysics (HIG) and the Hawaii Natural Energy Institute (HNEI) researchers, the U.S. Geological Survey (USGS), Puna Geothermal Venture (PGV) and private consultants (Geothermex and ENEL).

The information gathered from these reports allows a conceptual model of the near-surface flow system to be formulated. This information includes details of: aquifer geometry (from SOH and PGV drilling reports), recharge (from USGS reports and PGV rainfall data), fluid properties (from past modeling studies in Hawaii and other geothermal sites), rock matrix properties (from drill reports, past models in Hawaii and other geothermal sites), aquifer flow characteristics (from drilling reports, numerical models in Hawaii, and USGS reports), fluid, energy and solute sources and sinks (USGS and HIG reports), and current groundwater parameters (USGS files, HIG reports, State of Hawaii Files).

Water levels, groundwater temperatures and groundwater chloride or salinity measurements are considered the most important data

for understanding the aquifer flow system. This data was obtained from several sources including USGS files, DLNR files, PGV reports, published literature and on-going monitoring projects being conducted by UH researchers. Getting accurate water levels has turned out to be the most troublesome aspect of the project. The ideal situation would provide a water level measured at each well in the study area on a single day. Currently, we lack current water levels for several of the critical wells in the study area. For example, the most current water level from the Pahoia wells is from 1987. Unreliable water levels are also a problem. The water level measurements from PGV monitoring wells MW1 and MW3 differ by over 8 feet and the wells are only about 100 yards apart. Although such changes in head over a short distance are possible in a rift zone, we have not been able to confirm this with same day measurements of both wells.

Tidal analysis of continuous monitoring data

Continuous hourly water level, temperature and conductivity data have been collected from Kapoho Airstrip, PGV MW2, GTW3, Malama Ki and Hawaiian Paradise wells by Elizabeth Novak and Don Thomas. In addition, continuous pressure measurements have been recorded in SOH1, SOH2 and SOH4 by the HNEI. These continuous records show daily fluctuations caused by ocean and earth tide loading. By comparing well water level data with ocean tide data one can determine tidal efficiency and tidal lag. This information was

then used with a numerical simulation to determine transmissive and storage properties for the aquifer. Also, by removing the tidal signal from the aquifer, it allows us to determine what effect recharge has on water level.

Numerical simulation of the aquifer

An extensive search for an acceptable numerical simulation code involved contacting USGS, Battelle and Lawrence Berkeley Lab personnel to evaluate numerical models capable of handling heat and solute transport in an unconfined aquifer. Models considered included SUTRA, TOUGH, HST3D and CFEST. We acquired a copy of the Coupled Fluid, Energy, and Solute Transport (CFEST) code and documentation from Battelle. With this model, it is possible to simulate a cross-section of the shallow aquifer perpendicular to the ERZ. This cross-section passes through public water-supply wells, PGV monitoring wells and geothermal wells, Malama Ki well and a thermal spring discharge at the ocean (see Figures of ERZ, mesh, and conceptual cross-section of the aquifer).

There has not been any published attempts to numerically simulate a geothermal convection system superimposed on an oceanic-island freshwater lens. This type of numerical simulation is quite complicated due to the non-linear nature of the mathematical equations needed to solve the problem. For each point or node in the cross-sectional mesh, the program must solve a groundwater

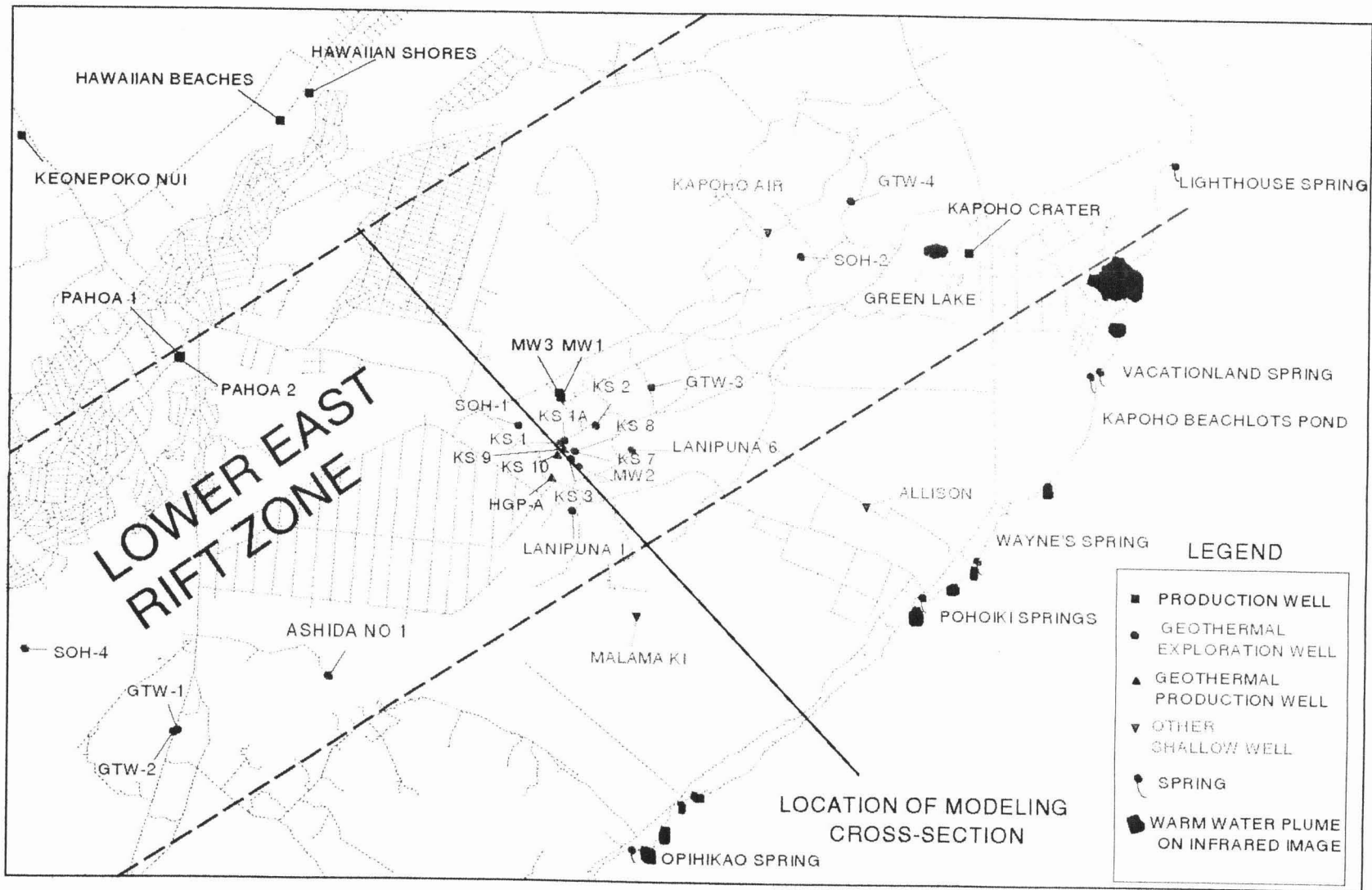
flow equation, a solute transport equation and a heat transport equation. The difficulty arises because all three equations depend on each other; when the result of one equation changes the others must be solved again with the new values. The computer program solves the equations thousands of times iteratively until the changes in the head, concentration and heat values are below a preset tolerance. A single solution sequence takes several hours to complete, and when changes are made in the model input parameters, the whole sequence must start over again. Currently, we are concentrating on investigating the solute transport characteristics of the aquifer. Once we establish a steady-state freshwater lens we will begin to incorporate heat transport in the system.

Once the computer model is calibrated to known head, concentrations and temperatures, it will be used to make predictions about future scenarios. It will allow us to make estimates of the volume of hot fluid leaking into the shallow aquifer and what may happen if the volume increases or decreases. The model will also allow us to track the flow velocities of contaminants in the aquifer. We will be able to predict the length of time it will take a contaminant, such as a pulse of brine, to travel from the geothermal site downgradient towards a discharge point at the ocean.

Project needs

1. We have not been updated by GeothermEx as to the progress of their geothermal system modeling. The amount of heated fluid escaping upwards from the geothermal system is a critical factor in developing the shallow model. We will need to get this information from the results of the GeothermEX modeling work.
2. We need a cooperative effort between the State and PGV to obtain water level measurements in the Pahoa wells, the PGV monitoring wells and Malama Ki well in a single day. It is especially critical to get water level values from MW1 and MW3 due to the large difference in previous known water levels. An accurate conceptual model of the rift zone flow system is impossible without this information.
3. We need to keep receiving as much data as possible from the on-going continuous monitoring project headed by Don Thomas although we recognize the difficulty encountered in collecting this data due to the harsh environment in the monitoring wells. The information is critical for determining aquifer response to recharge events.
4. We are waiting for a copy of the final version of the geologic map of the KERZ on arc-info GIS format to be submitted to the state by the HVO. We can incorporate

this into our map-info program which lists well
locations, etc.



HAWAIIAN BEACHES

HAWAIIAN SHORES

KĒONEPOKO NUI

KAPOHO AIR

GTW-4

LANTHOUSE SPRING

PAHOA 1

KAPOHO CRATER

PAHOA 2

GREEN LAKE

MW3 MW1

VACATIONLAND SPRING

SOH-1

KS 2

GTW-3

KAPOHO BEACHLOTS POND

KS 1

KS 1A

KS 8

LANIPUNA 6

KS 9

KS 10

KS 7

MW2

HGP-A

KS 3

ALLISON

LANIPUNA 1

WAYNE'S SPRING

ASHIDA NO 1

MALAMA KI

POHOIKI SPRINGS

SOH-4

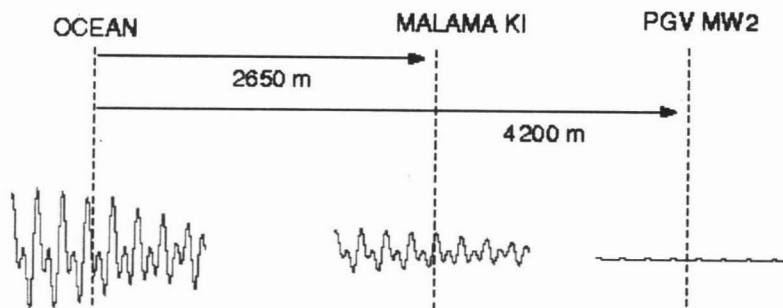
GTW-1

GTW-2

LOCATION OF MODELING CROSS-SECTION

OPIHIKAO SPRING

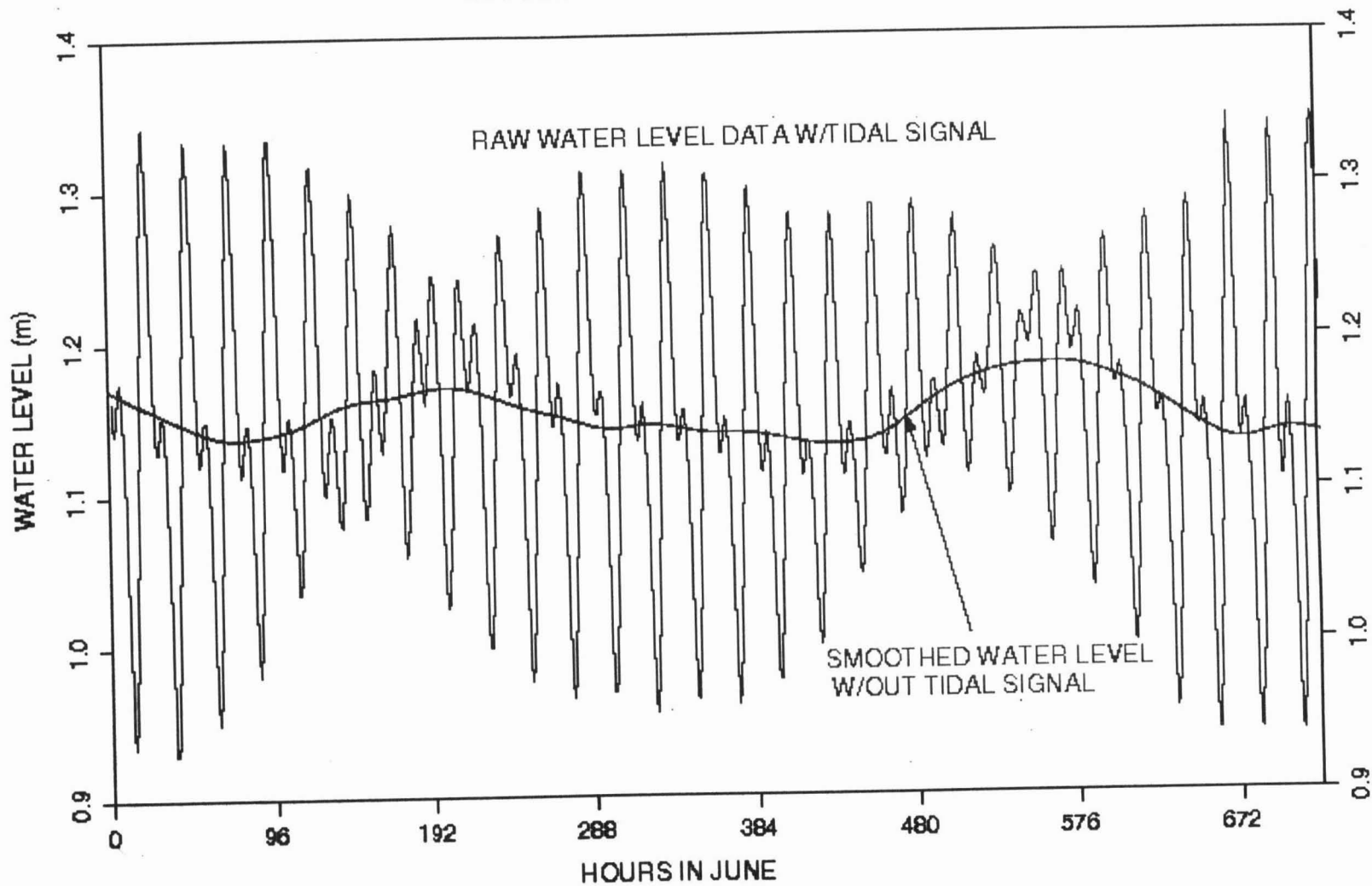
THE OCEAN TIDAL SIGNAL TRAVELS AS A PRESSURE RESPONSE THROUGH THE AQUIFER AND CAN BE MEASURED IN MONITORING WELLS AWAY FROM THE COAST



RELATIVE AMPLITUDE:	1.0 m	0.34 m	0.014 m	EXPONENTIAL DECAY
RELATIVE TIME LAG:	0 hr	2.5 hr	3.5 hr	LINEAR DECAY

FROM THESE RELATIONSHIPS, THE AQUIFER'S TRANSMISSIVE AND STORAGE PROPERTIES ARE ESTIMATED BY USING A NUMERICAL SIMULATION OF TIDAL SIGNAL PROPAGATION THROUGH THE AQUIFER

MALAMA KI WATER LEVEL DATA



SMOOTHED WATER LEVEL MEASUREMENTS

