Numerical Groundwater Flow Simulation of Red Hill Ridge, Oahu

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Summary

- Objective: Red Hill Fuel Storage Tanks
- Regional model, SWAP
  - Source area delineations
  - Source water susceptibility to contamination
- Updated SWAP model
- Conversion to Red Hill model
  - Conceptualization
  - Calibration
  - Capture Zones
PROJECT SITE LOCATION
Determine groundwater flow around Red Hill Fuel Storage Facility:

- Develop 3-D groundwater flow model (MODFLOW)
- Determine capture zones of drinking-water wells
- Provide a flow model that can be used to simulate solute transport of dissolved hydrocarbons (RT3D)
Source Area Delineations
- Identify all public drinking water sources
- Island-wide groundwater flow models
- Source water capture zone delineation
  • Delineate Zone A (50-ft around well)
  • Delineate Zone B (2-year capture zone)
  • Delineate Zone C (10-year capture zone)

Source water susceptibility to contamination
- Potential contaminating activities assessment
- Assessing the susceptibility of water sources to contamination
SOURCE WATER AREA DELINEATION

Zone through which contaminants, if present, are likely to migrate and reach a drinking water source (well or surface water intake)
MODFLOW Grid in Cross-section View
Simulated Groundwater Levels, Oahu (in m)
Delineate Well Capture Zones using computer generated particles traveling backwards

- Trace the 2 and 10-year capture zones
- Export as area shapefiles
- Import to GIS
Potential Contaminating Activities
SWAP MODEL

PCA Score
- 0 – 100
- 101 – 400
- 401 – 1000
- 1001 – 2200

Capture Zone
- Zone B (2-year)
- Zone C (10-year)
METHODOLOGY

Develop 3-D groundwater flow model:

• Calibrate steady-state flow model with island-wide SWAP model
  • Recharge 1996-2005
  • Boundary conditions (specified head on sides, Ghyben-Herzberg interface as bottom boundary)
  • 10-year average withdrawal

• Calibrate transient flow model with a 18-day aquifer test
GROUNDWATER FLOW SYSTEM

Legend
- Freshwater Lens System
- Dike-Impounded System
- Schofield Plateau
- Boundary of Ground-Water Area
- Boundary of Ground-Water Subarea
- Topographic Divide
- Flow Direction

Base modified from U.S. Geological Survey National Hydrography Dataset, Albers equal area projection, standard parallels 21°18'40" and 21°38'20", central meridian 157°56', datum NAD83.
HYDRAULIC FLOW BARRIERS
10-YEAR AVERAGE PUMPAGE
HYDRAULIC CONDUCTIVITY

Legend

Hydraulic Conductivity [ft/day]

- 0.3 - 1.6
- 2.6 - 5
- 13 - 26
- 39 - 66
- 99 - 131
- 147 - 197
- 262 - 394
- 492 - 656
- 1640 - 1969
- 2297 - 2625
REGIONAL SWAP MODEL – BOUNDARY CONDITIONS

Basal-Water Calibration - South Oahu

- Computed Head [ft]
- Observed Head [ft]

- Ewa-Kunia
- Pearl Harbor
- Waimalu
- Moanalua
- Kalihi
- Beretania
- Kaimuki
- Waialae
- Hawaii Kai

Map showing contours and locations with head values.
LOCAL MODEL - BOUNDARY CONDITIONS

Recharge = 36.6 mgd
7-LAYER MODFLOW Model Grid

128,125 cells

Red Hill Ridge

Caprock
Valley Fill
Basalt

Vertical exaggeration factor 5
7-LAYER MODFLOW MODEL GRID

Legend
- Caprock
- Valley Fill
- Basalt

Vertical exaggeration factor is 5

North Halawa Valley

Red Hill Ridge

0.1 mile
1 mile
CALCULATED WATER LEVELS
WATER BUDGET

Underflow
Recharge = 36.6
Boundary Flux = 6.2
Wells = -42.8
All numbers in mgd

Legend:
- Background indicates water flow direction.
- Numbers indicate water volume in mgd.
- Positive values indicate inflow, negative values indicate outflow.

Scale:
0 0.5 1 2 Miles
Observation Wells

Legend:
- Red Hill Property Boundary
- Observation Wells
- Infiltration Gallery
- Fuel Tanks
- Pipeline

Salt Lake Crater

North Halawa Valley

South Halawa Valley

Moanalua Valley

Halawa Deep Obs
Halawa Shallow Obs
Oily Waste Disposal Facility 8
RH MW-04
RH MW-03
RH MW 02
TAMC 2
Manaiki
RED HILL SHAFT PUMPS ON/OFF
Specific Yield = 0.03
RED HILL SHAFT PUMPS ON/OFF
CAPTURE ZONE DELINEATION, all wells pumping
CAPTURE ZONE DELINEATION, Red Hill Shaft off

Legend
- Well
- Fuel Tanks
- Ten-Year Capture Zone (Ten-year average pump rate)
- Ten-Year Capture Zone (Maximum pump rate)
CAPTURE ZONE DELINEATION, both
CONCLUSIONS

• Incorporate geometries of low-permeability valley-fill barriers

• Successful regional to local model conversion

• Effectiveness of the North Halawa valley-fill barrier is underestimated

• Simulated aquifer test allows estimation of storage parameters \( (S_Y = 0.03) \)

• Capture zones of Red Hill Shaft only intersect Red Hill tanks

• Developed a groundwater flow around Red Hill Fuel Storage Facility that can be used to simulate solute transport (RT3D)
DATA GAPS & UNCERTAINTIES

Recharge
Engott, et al., 2015, USGS SIR 2015-5010

Water level elevation
GPS survey of well measuring points

Geology
Updated structural basalt contours
Include weathered basalt underneath valley fill
Consider rejuvenated volcanism around Salt Lake Crater

Aquifer Test
Pump on/off at Halawa Shaft
Recent 2010 Recharge

2010 Land cover
1978-2007 Rainfall

Areas where mean annual recharge is between 465 and 528 inches – includes taro fields and reservoirs, which are difficult to see at this scale.
Oahu Recharge Report

Engott, J.A., Johnson, A.G., Bassiouni, M., and Izuka, S.K., 2015,
Spatially distributed groundwater recharge for 2010 land cover estimated using a water-budget model for the Island of O‘ahu, Hawai‘i:
http://dx.doi.org/10.3133/sir20155010
Volcanic Structural Contours

Altitude, in feet relative to sea level.
Contour intervals:
Black line, 1,000 feet
Gray line, 200 feet

4,025
Peak altitude, in feet relative to sea level

Yellow tint shows island’s current extent
Izuka, S.K., Engott, J.A., Bassiouni, M., Johnson, A.G., Miller, L.D., Rotzoll, K., and Mair, A.,
in press,
Volcanic aquifers of Hawai‘i — hydrogeology, water budgets, and conceptual models: