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DEPUTY DIRECTOR

STATE OF HAWAIʻI | KA MOKUʻĀINA ʻO HAWAIʻI
DEPARTMENT OF LAND AND NATURAL RESOURCES | KA ʻOIHANA KUMUWAIWAI ʻĀINA
COMMISSION ON WATER RESOURCE MANAGEMENT | KE KAHUWAI PONO
P.O. BOX 621
HONOLULU, HAWAII 96809

December 10, 2025

The Honorable Ronald D. Kouchi, President
and Members of the Senate
Thirty-Third State Legislature
State Capitol, Room 409
Honolulu, Hawaii 96813

The Honorable Nadine Nakamura, Speaker
and Members of the House of Representatives
Thirty-Third State Legislature
State Capitol, Room 431
Honolulu, Hawaii 96813

Dear President Kouchi, Speaker Nakamura, and Members of the Legislature:

For your information and consideration, I am transmitting a copy of a report titled "Groundwater Conditions in the Keauhou Aquifer System, Island of Hawaii", as required by Act 189, Session Laws of Hawaii 2025. In accordance with Section 93-16, Hawaii Revised Statutes, a copy of this report has been transmitted to the Legislative Reference Bureau and the report may be viewed electronically at https://files.hawaii.gov/dlnr/reports-to-the-legislature/2026/CW26-Act-189-Rpt-FY25.pdf

Ola I Ka Wai,

DAWN N.S. CHANG
Chairperson

Enclosure

Report to the Thirty-Third Legislature

2026 Regular Session

GROUNDWATER CONDITIONS IN THE KEAUHOU AQUIFER SYSTEM
ISLAND OF HAWAII

Prepared by the

Commission on Water Resource Management
Department of Land and Natural Resources
State of Hawaiʻi

Act 189 SLH 2025

November 2025

REPORT TO THE THIRTY-THIRD LEGISLATURE

2026 Regular Session

GROUNDWATER CONDITIONS IN THE KEAUHOU AQUIFER SYSTEM, ISLAND OF HAWAII

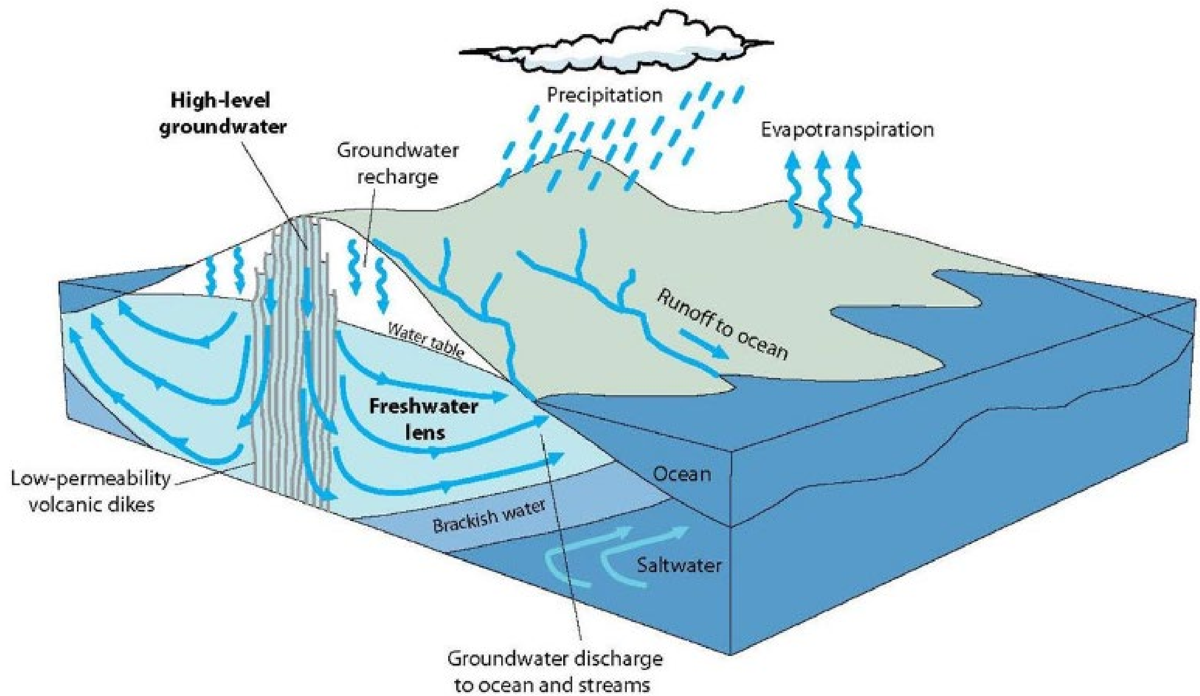
I. Introduction

Pursuant to Act 189, the Department of Land and Natural Resources is required to submit an interim report to the Legislature every six months, detailing, at minimum, groundwater levels and water quality analysis in the Keauhou Aquifer System.

II. Background

<u>The Hydrologic Cycle</u>

The hydrologic cycle refers to the constant movement of water between the ocean, the atmosphere, and the earth, and includes precipitation, infiltration and recharge, runoff, and evapotranspiration. Evapotranspiration is the loss of water from soils, canopy, and open water bodies through evaporation and the transfer of water from plants to the air through transpiration. Moisture in the air is carried by trade winds up mountain sides, where it cools and condenses, and finally falls to the land surface as precipitation (i.e., rain or fog drip). Plants immediately absorb and use some of the rain and fog drip, but the remaining volume of water infiltrates through the ground surface, runs off to the ocean or streams, evaporates into the atmosphere, or ends up recharging the ground water aquifers. Refer to Figure 1 on the next page.



Source: USGS Pacific Islands Water Science Center (http://hi.water.usgs.gov/studies/GWRP/islhydro.html)

Figure 1 – The Hydrologic Cycle

Ground Water Occurrence in Hawai‘i

Ground water in Hawai‘i is stored in several different types of aquifers: basal, dike impounded, perched, caprock, brackish, and deep confined freshwater. Basal aquifers are the primary source for municipal water in Hawai‘i. There is a brackish transition zone where the freshwater basal lens meets seawater, with salinity gradually increasing with depth. The upward movement of this transition zone presents a constant potential danger of saline contamination to the freshwater aquifer. Interestingly, previous conceptual ground water models are being modified in response to recent discoveries of freshwater aquifers beneath the saltwater underlying basal aquifers on Hawai‘i Island.

The Commission on Water Resource Management (CWRM) established ground water hydrologic units, or aquifers, and assigned each one a unique code to provide a standard method by which to reference and describe ground water resources, facilitate consistent collection and sharing of information amongst diverse governmental and non-governmental entities, optimize ground water development, and implement resource protection measures. Aquifer boundary lines should be recognized as management lines and not strict hydrologic boundaries where ground water flow does not cross. There are 114 aquifers delineated across the islands of Kaua‘i, O‘ahu, Moloka‘i, Lāna‘i, Maui, and Hawai‘i. These are shown in Figure 2 below.

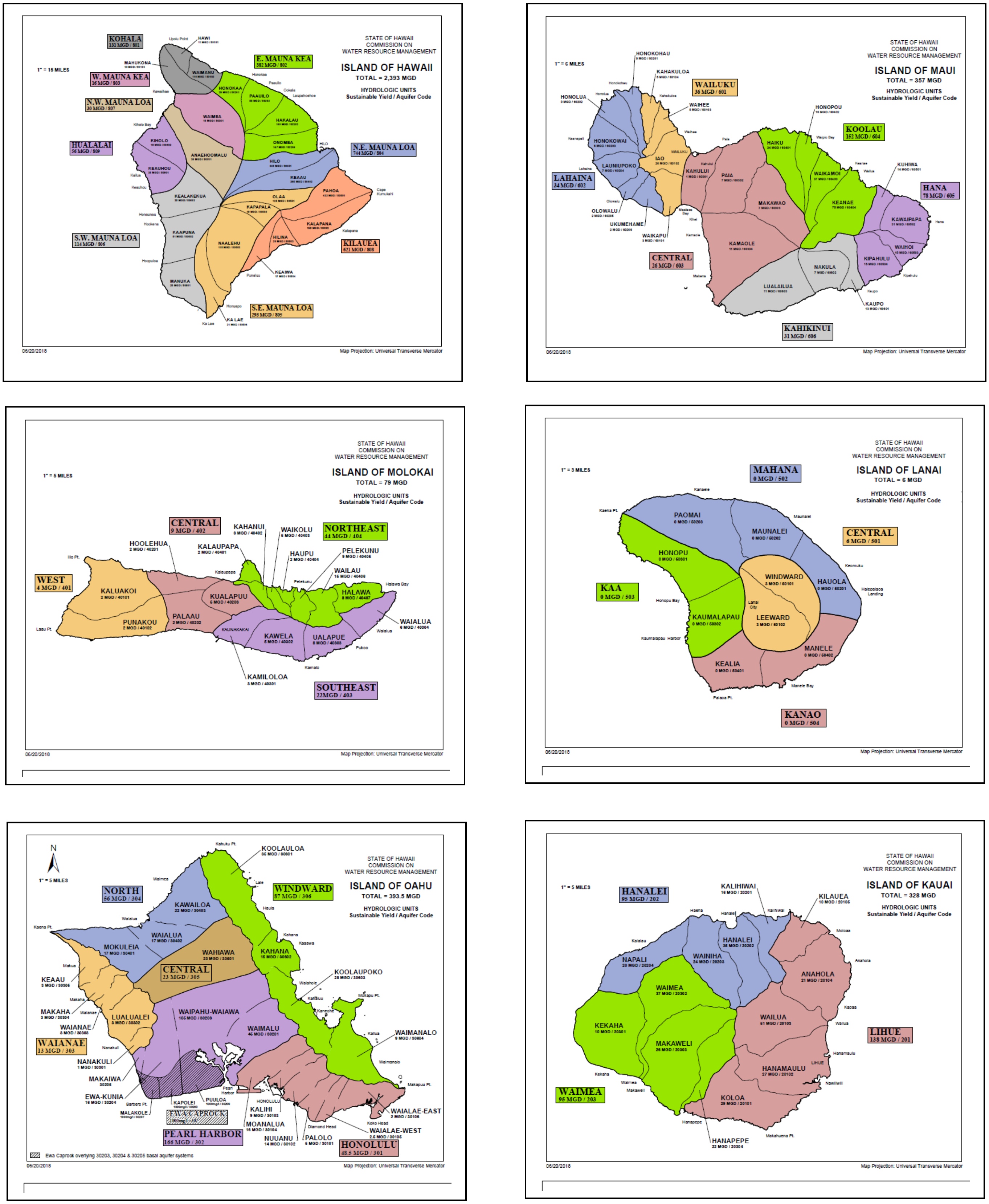


Figure 2 – Hydrologic Unit Maps

The availability of ground water resources is dependent upon recharge, or the replenishment of fresh ground water, and ground and surface water interactions. However, ground water flow can be difficult to understand and predict because scientists must infer and interpolate its status and characteristics from limited data and modeling tools. CWRM, researchers, and others are constantly working to improve the understanding of ground water flow and the ability to assess the availability of ground water for human consumption.

The amount of ground water that can be developed in any aquifer is limited by the amount of natural recharge and aquifer outflow that must be maintained to prevent seawater intrusion, to maintain perennial streamflow, and to sustain the ecosystems dependent upon ground water discharge. CWRM first adopted sustainable yield estimates in the Water Resource Protection Plan (WRPP) in 1990 and has revised them based on management approaches, new information and modeling techniques, and the identification of errors in previous models or studies.

Basal Lenses

The freshwater lenses in basal aquifers occur in dike-free volcanic rocks and in sedimentary deposits and are the most important sources of freshwater supply in Hawaiʻi. Basal waters can be either confined or unconfined. Unconfined aquifers are where the upper surface of the saturated aquifer is the water table itself. Confined aquifers are where the aquifer is overlain by low or poorly permeable formation boundaries that cause the ground water under the formation to be pressurized. Water levels in a confined aquifer will rise above the confining formation through breaches in the formation such as wells or natural flowing springs. In some coastal areas there is a sediment sequence of low permeability commonly called "caprock." This caprock barrier tends to confine and restrict the seaward flow of freshwater and causes the thickness of the freshwater lens to be greater than it would if the caprock was absent. Depending upon the effectiveness of the caprock, the resulting lens could range from local thickening of a relatively thin lens of a hundred feet to over 1800 feet. Therefore, the amount of water stored in a basal lens bounded by caprock is significant. Water is withdrawn from the basal aquifer for various uses; basal aquifers provide the primary source for municipal water in Hawaiʻi.

The thickness of the freshwater basal lens can be estimated using the Ghyben-Herzberg formula, which assumes a hypothetical sharp interface between freshwater and seawater, and states that every foot of freshwater above mean sea level indicates 40 feet of freshwater below mean sea level. For example, if freshwater is known to occur at an elevation 20 feet above mean sea level, it can be reasonably estimated that the hypothetical sharp interface would be approximately 800 feet below sea level. The Ghyben-Herzberg formula provides a reasonable estimate of the freshwater basal lens thickness; however, in actuality, the interface between freshwater and seawater occurs as a brackish transition zone, rather than a sharp interface, with salinity gradually increasing with depth. Therefore, the Ghyben-Herzberg formula is used to estimate the midpoint of the transition zone, which is 50% seawater and 50% freshwater. The thickness of transition zone depends on various chemical and physical parameters including, but not limited to geology, advection and dispersion, mechanical mixing, physical properties of the aquifer, tidal fluctuation, and atmospheric pressure variation. The movement of the brackish transition zone, both horizontally inland from the seacoast and vertically upward, presents a constant potential danger of saline contamination to the freshwater portion of the system. Surface water and ground water interactions in these areas predominantly occur near coastal areas in streams, wetlands, and anchialine ponds.

Dike Water

Ground water impounded behind dikes in the mountains is often called "dike-impounded water," or "high-level water." Dikes are low permeability magmatic intrusions, usually within rift zones or calderas, that typically consist of nearly vertical slabs of dense, massive rock, generally a few feet thick, which can extend for considerable distances and cut across existing older lava flows. High-level water impounded in permeable lavas occurring between dikes in the interior portions of the islands is usually of excellent quality due to the elevation of dike impounded aquifers, the low permeability of dike structures, and the distance from the ocean, which prevents sea water intrusion. Tunnels and shafts have been drilled through multiple dike compartments to develop this water source. Dike water can occur in low elevation rift or caldera zones such as Windward Oahu.

Some water leakage occurs across dike boundaries, and this water flows to down-gradient dike compartments or to the basal aquifer. However, the interaction between these dike-confined and basal aquifers is not well understood and is difficult to quantify. In fact, recent discoveries of deep freshwater aquifers beneath saltwater underlying basal aquifers on Hawaiʻi Island are modifying the conceptual models of ground water, at least on the Hawaiʻi Island. These may be related to dike water impounded geology. Also, additional discoveries of very high-level water on Hawaiʻi Island may also modify the current conceptual models for ground water. Dike-impounded water may overflow directly to a stream at the ground surface where stream erosion has breached dike compartments. Once breached to the water table, the percentage of overall contribution to total stream flow depends on the head of the stored water, how deep the stream has cut into the high-level reservoir, the permeability of the lavas between dikes, the size of the compartments as well as connections to other compartments, and the amount of recharge into the breached compartment. Surface water and ground water interactions in these aquifers are assumed to have a one-to-one relationship for management purposes.

Perched Water

Water in perched aquifers is also classified as high-level water. In this type of system, water is "perched" on top of layers of low permeability material such as dense volcanic rock, weathered and solidified ash, or clay-bearing sediments that may overlie basal or dike aquifers. Discharge of perched water sometimes occurs as springs where the water table breaches the land surface by erosion. Perched water supplies can be developed by tunnels or by constructing masonry chambers around spring orifices to collect flow and to prevent surface contamination. This type of water is of excellent mineral quality, and like most dike water, is free from seawater encroachment. Perched water can also be found in alluvial deposits. Alluvial water is found in the more recent alluvial layers in valley fills and remains perched because of older compacted alluvial layers below. Sometimes small wells can be productive in this area but generally the alluvium provides small amounts of water.

Related to dike water, recent discoveries of very high-level water on Hawaiʻi Island may also modify the current conceptual models for ground water if they are shown to effectively be perched water. Surface water and ground water interactions in these aquifers depend on the local conditions and physical construction of wells.

<u>Deep Confined Freshwater</u>

On Hawaiʻi Island, there are at least four deep monitor wells that have penetrated through basal aquifers and underlying saltwater and have encountered freshwater in confined artesian aquifers. Two such wells are in each of the Hilo and Keauhou Aquifer System Areas. These discoveries have altered the traditional island conceptual model of freshwater completely floating on top of higher density saltwater. More study is necessary to better understand the extent and nature of this ground water occurrence.

III. The Keauhou Aquifer System area

The Keauhou Aquifer System area of Hawaiʻi Island is located within the Hualalai Aquifer System. The hydrogeology is generally known to consist of at least three bodies, a basal lens, a high-level aquifer body (either dike-confined or perched), and a deep confined body.

The dashed line in Figure 3 below indicates the approximate boundary of the high-level aquifer body. The wells in red are wells that draw water from the basal lens, while the wells in blue draw water from the high level. There are no wells currently that withdraw water from the deep confined aquifer body.

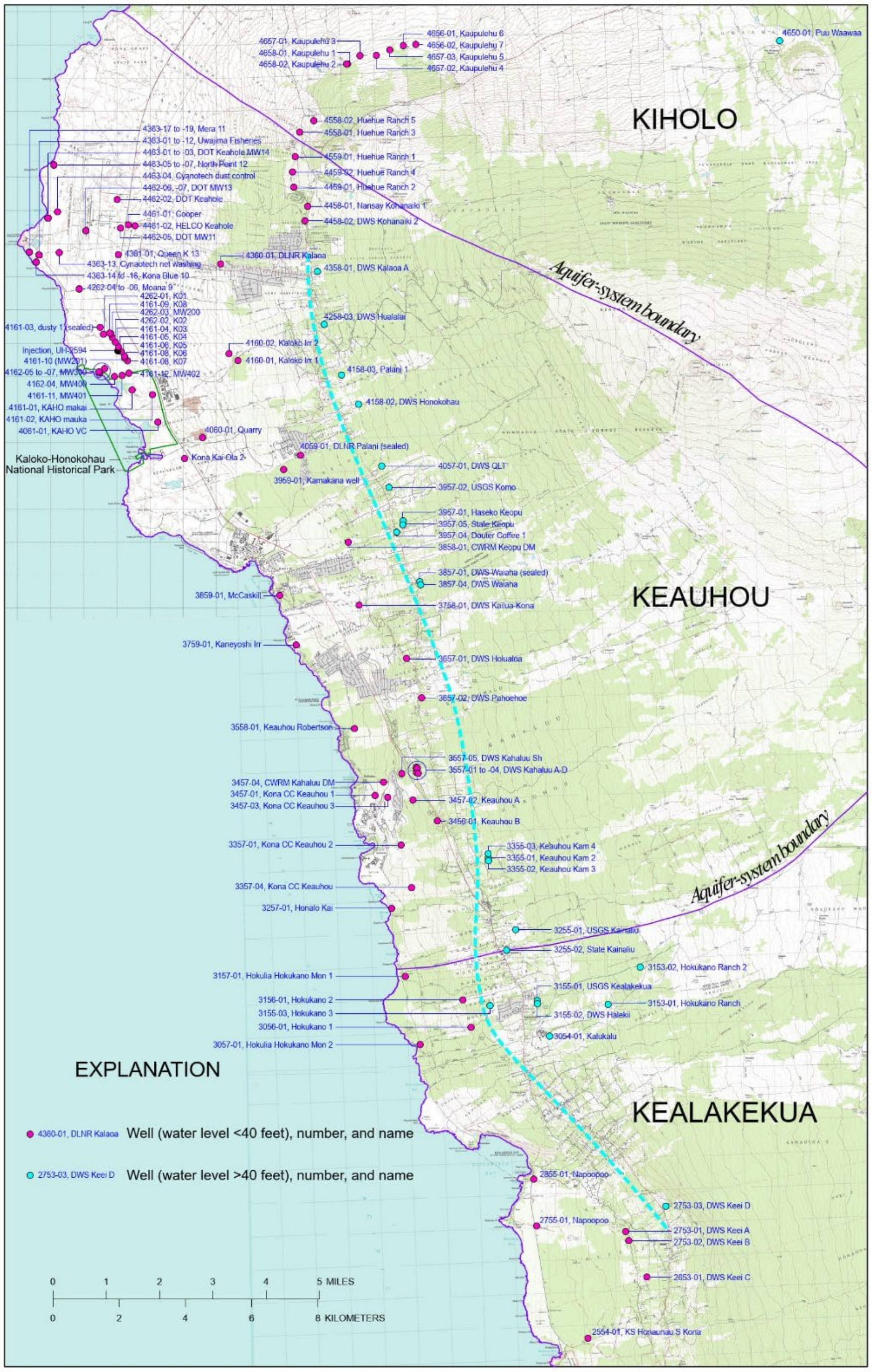


Figure 3 – Wells in Keauhou

Not much is known about the interaction between the three bodies of water, but efforts are being made to learn more about this potential interaction.

Withdrawal of ground water from each of these bodies has the potential to impact cultural and ecological resources such as groundwater dependent ecosystems, as well as other wells and aquifer bodies.

Groundwater monitoring is critical in this area as it is statewide, as it helps CWRM assess the health of the aquifer.

Through groundwater monitoring, CWRM can assess trends or changes in the aquifer via two key data collection types - water levels and salinity profiles.

A. Groundwater Level Data

Groundwater levels are observed via either CWRM staff regular observations or well owners self-reporting their water levels.

Groundwater Level Data Recorded by CWRM Staff
Between the monitoring period of 2015-2025, monitoring wells such as the Keopu 1 well (state well number 8-3857-001) have shown a 0.34' increase in the water table and a stable trend in the transition zone since 2022 (refer to Figure 4). The transition zone is the zone where water transitions from fresh to salt.

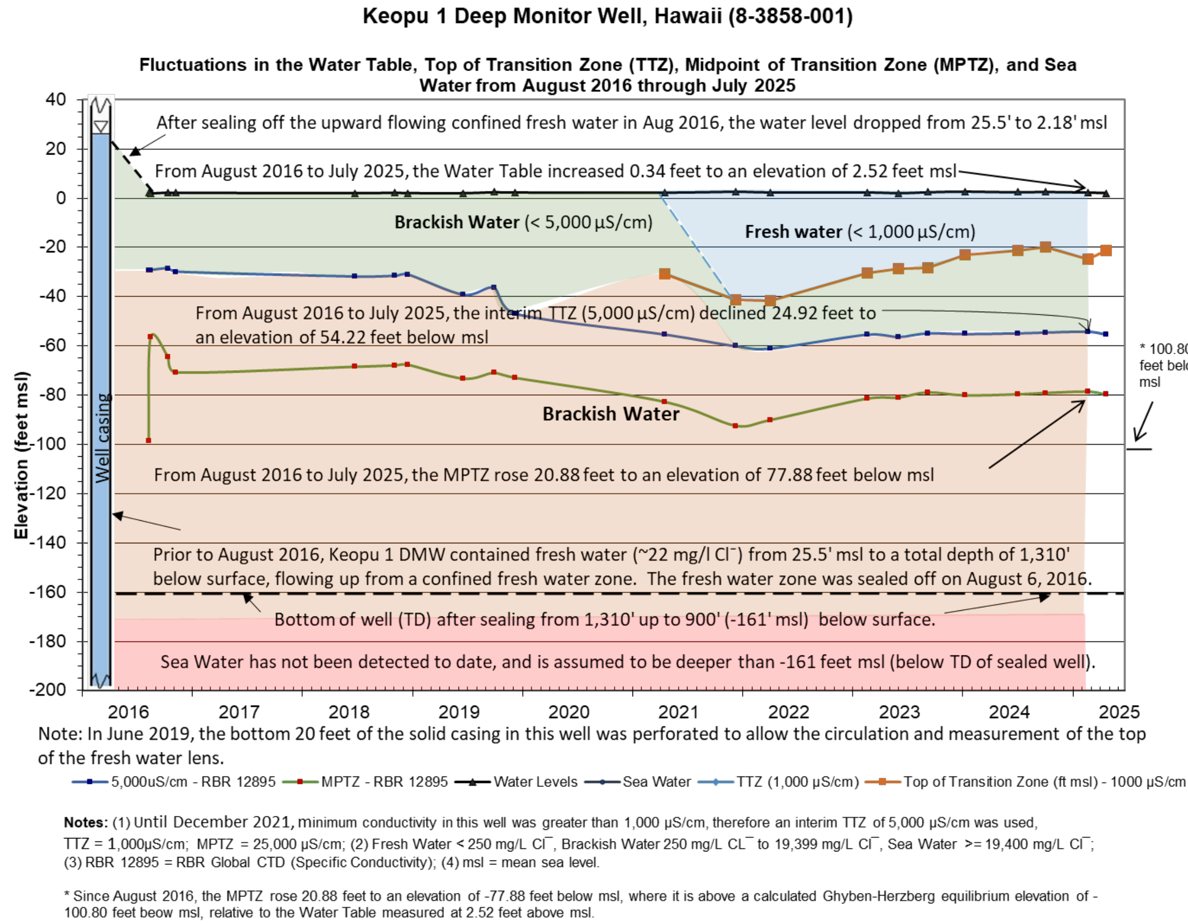
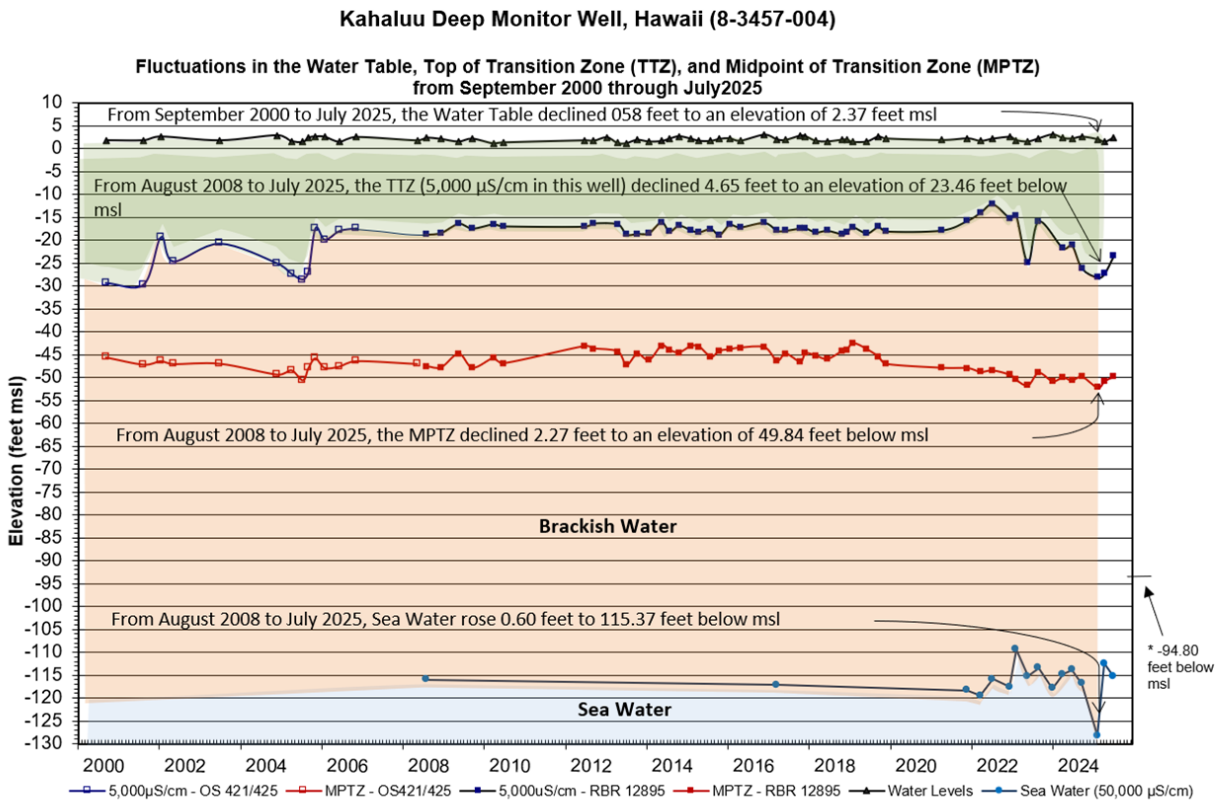


Figure 4 - Groundwater profile for the Keopu 1 deep monitor well (state well number 8-3857-001)

Similarly, from 2008 to July 2025, the Kahaluu deep monitor well (state well number 8-3457-004) has shown only a 0.50’ decline in the water level and 2.27’ of decline in the mid-point of the transition zone (MPTZ). For the period between 2016-2025, a decrease in the MPTZ indicates that the freshwater lens is thickening in the vicinity of the well. The MPTZ trends for the monitoring period between 2023-2025 indicate that the aquifer is relatively stable. Refer to Figure 5 below.



Notes: (1) Minimum conductivity in this well is greater than 1,000 µS/cm Therefore, TTZ = 5,000µS/cm; MPTZ = 25,000 µS/cm; (2) Fresh Water < 250 mg/L Cl⁻, Brackish Water 250 mg/L CL⁻ to 19,399 mg/L Cl⁻, Sea Water >= 19,400 mg/L Cl⁻; (3) OS 421/425 = Ocean Sensors CTD (absolute conductivity); (4) RBR 12895 = RBR Global CTD (Specific Conductivity); (5) msl = mean sea level.

* Since the year 2008, the MPTZ declined 2.27 feet to an elevation of 49.84 feet below msl, where it is above a calculated Ghyben-Herzberg equilibrium elevation of 94.80 feet beow msl, relative to the Water Table measured at 2.37 feet above msl.

Figure 5 - Groundwater profile for the Kahaluu deep monitor well (state well number 8-3457-004)

<u>Reported Groundwater Level Data:</u>

Well owners have not consistently reported groundwater level data. Therefore, wells with inconsistent data reporting (reported data less than five data points) are omitted from the following analysis.

As groundwater levels are subject to natural seasonal changes, in addition to linear trend analysis, seasonal decomposition (variance) analysis provides the following trends for the subject wells' reported data. Refer to Figure 6 below.

Well Name	Aquifer type	Data Points	Start Date	**End Date	Slope (ft/monitoring period)	*Trend (Water level)	Seasonal Amplitude (ft)
Keahuolū #1 Deepwell A	High Level	149	2010-01-01	2022-05-01	-0.01684	Decreasing	0.57
Keōpū #1 Deepwell A	High Level	101	2014-01-01	2022-05-01	-0.22685	Decreasing	0.51
Huehue Ranch 1	Basal	355	1993-04-01	2022-10-01	0.21076	Increasing	0.337
Honokōhau Deepwell A	High Level	355	1992-11-01	2022-05-01	0.11045	Increasing	0.05
Huehue Ranch 4	Basal	66	2009-10-01	2015-03-01	0	Stable	0
Kahaluʻu A Deepwell	Basal	55	2010-01-01	2014-07-01	0	Stable	0.003
Kahaluʻu B Deepwell	Basal	55	2010-01-01	2014-07-01	0	Stable	0
Kahaluʻu C Deepwell	Basal	55	2010-01-01	2014-07-01	0	Stable	0
Kahaluʻu D Deepwell	Basal	55	2010-01-01	2014-07-01	0	Stable	0
Kahaluu Shaft	Basal	55	2010-01-01	2014-07-01	0	Stable	0
Hōlualoa Deepwell A	Basal	55	2010-01-01	2014-07-01	0	Stable	0
Waiʻaha Deepwell A	High Level	55	2010-01-01	2014-07-01	0	Stable	0
Kalaoa #1 Deepwell A	High level	55	2010-01-01	2014-07-01	0	Stable	0
Huehue Ranch 2	Basal	157	2009-10-01	2022-10-01	-0.00082	Stable	0.154
Makalei #1 Deepwell A	Basal	267	1991-09-01	2013-11-01	-0.00125	Stable	0.017
Hualālai Deepwell A	High Level	346	1993-08-01	2022-05-01	-0.0032	Stable	0.613

Figure 6: Groundwater level trends from production wells with seasonality

* Trends are classified based on following matrix : **Increasing** (slope > +0.01 ft/ monitoring period), **Decreasing** (slope < -0.01 ft/ monitoring period); **Stable** (slope between -0.01 and +0.01 ft/ monitoring period)

** Reported data belong to various production and monitoring period for individual wells.

B. Groundwater Quality Data (Chlorides/Salinity): Based on the reported chloride results, chlorides are very responsive to changes in pumpage in the basal aquifer. On the other hand, the high-level aquifer has consistently shown no significant increase in chloride concentrations with respect to historic and current natural (e.g., precipitation) and anthropogenic (e.g., pumpage) stresses on the aquifer.

According to the United States Environmental Protection Agency's *National Secondary Drinking Water Regulations (NSDWRs)*, chloride concentration equal to or less than 250 parts per million (also milligrams per liter) is considered as a fresh. Further, based on widely accepted standards provided for Hawaiʻi Island (page 8-9, *AQUIFER IDENTIFICATION AND CLASSIFICATION FOR THE ISLAND OF HAWAI'I: Groundwater Protection Strategy for Hawai'i by Mink & Lau, May 1993*) following classification of groundwater bodies is provided,

Chloride concentration (Mg/L)	Groundwater Status
<250	Fresh
250-1000	Low
1000-5000	Moderate
5000-1500	High
>18,980	Seawater*

Figure 7 – Chloride concentrations

(* The Commission uses a chloride concentration of 19,400 mg/L to delineate salt water. This standard is based on its strong association with seawater salinity of approximately 35 parts per thousand, or 3.5% salt by weight).

C. Current Pumpage from the Keauhou Aquifer System Area

The sustainable yield for the Keauhou Aquifer System Area is 38 million gallons per day (mgd). Current pumpage out of the aquifer is 14.150 mgd on a 12-month moving average through July 2025.

Figures 8 and 9 show the pumpage in the Keauhou aquifer system area broken down by ahupuaʻa.

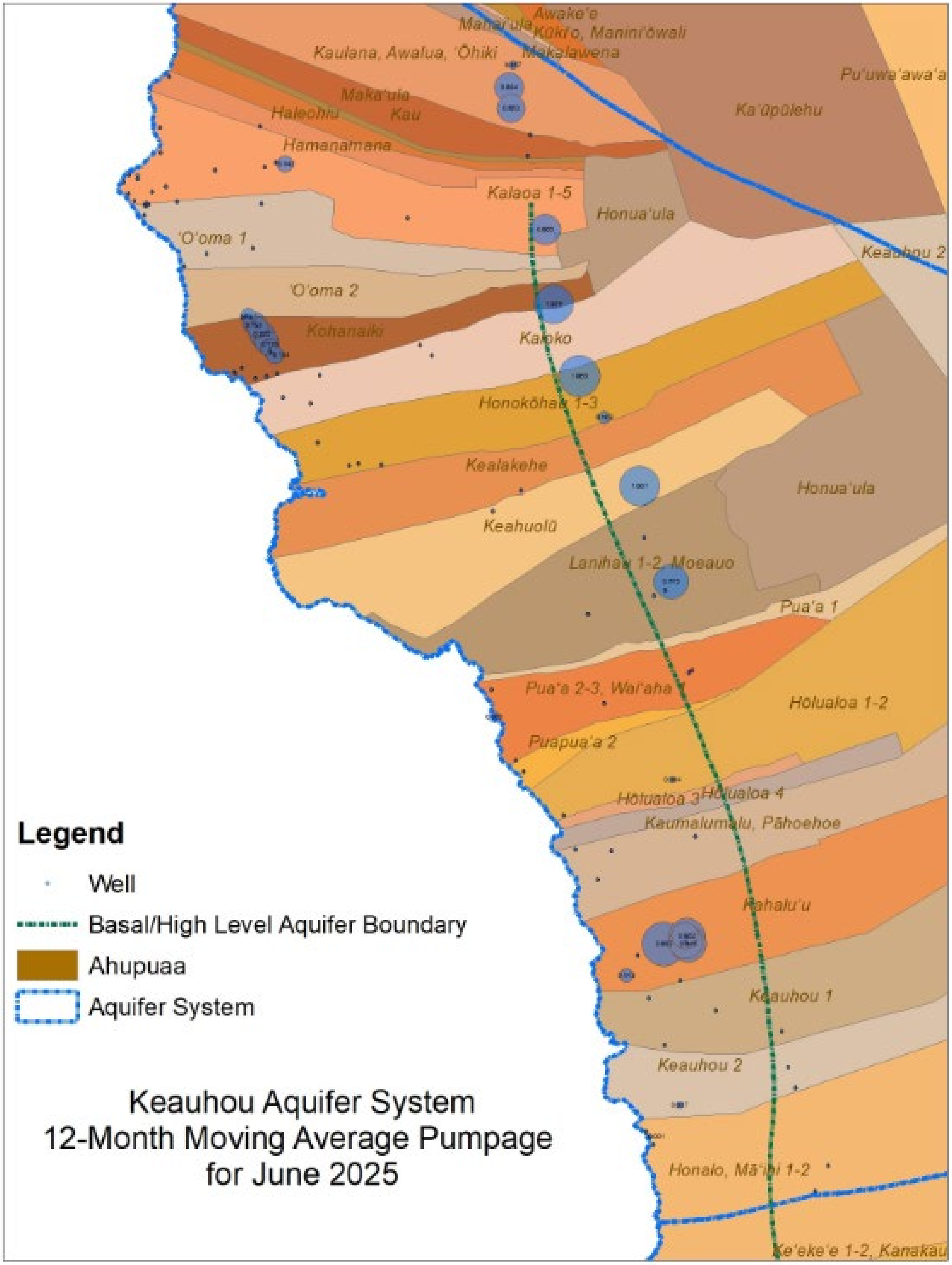


Figure 9 – Keauhou pumpage by ahupua'a

AHUPUA‘A	12-MAV (8/25)
Honalo, Maihi 1-2	0.001
Honokohou 1-3	1.263
Kahaluu	6.597
Kalaoa 1-30	0.138
Kalaoa 1-5	0.736
Kau	0.000
Kaulana, Awalua, Ohiki	1.322
Kaumalumalu, Pahoehoe	0.008
Keahuolu	1.032
Keauhou 1	0.000
Keauhou 2	0.007
Kohanaiki	2.250
Lanihau 1-2, Moeauo	0.773
Ooma 23	0.000
Ooma 24	0.000
Puaa Waiaha 1	0.063

Figure 9 – Pumpage quantities by ahupua‘a

As the Keauhou Aquifer System can be further divided into basal and high-level aquifer types, Figure 10 provides the pumpage of the aquifer over time.

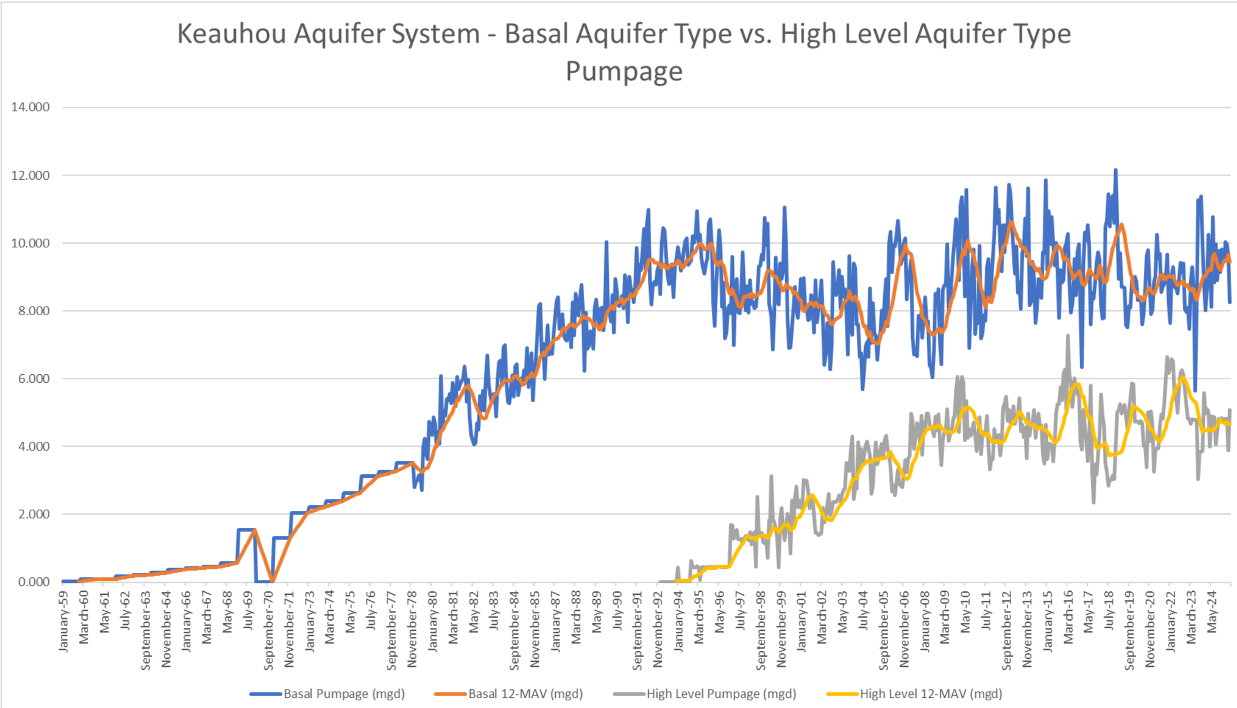


Figure 10 – Pumpage of Keauhou Aquifer System in basal vs. high level aquifers

IV. Pilot Adaptive Management Plan Project for Keauhou

CWRM staff commenced a pilot Adaptive Management Plan for the Keauhou aquifer system area in the beginning of 2025. The framework for the plan included goal setting and objectives, modeling, monitoring and data collection, management actions and triggers, assessment and feedback, and stakeholder involvement.

Data collected and knowledge gained will be used to refine subsequent iterations of the plan, and lessons learned from this process may help CWRM to develop adaptive management plans in other areas around the state.

An advisory committee was assembled, and three expert groups were established that focused on Hydrology, Indicator Species, and Contamination & Pollution.

Each group held and completed a series of meetings. These individual meetings resulted in preliminary reports from each group. Each group report will be posted publicly on CWRM's website. These reports have been distributed to the other expert groups and will be distributed to the Commissioners for review. CWRM staff will convene a meeting to discuss the reports with the expert group members, as well as traditional and customary practitioners from the Keauhou area. Further adjustments may be made based on the discussion before the reports are used to prepare an initial monitoring and management plan for the Keauhou Aquifer System.