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HANNAH KIHALANI SPRINGER

CIARA W.K. KAHAHANE
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

STAFF SUBMITTAL

COMMISSION ON WATER RESOURCE MANAGEMENT

May 19, 2026
Honolulu, Hawaiʻi

Request for Delegation of Authority to Chairperson to Enter into a Joint Funding Agreement with the U.S. Geological Survey for the Project "Analysis of Groundwater Flow in the Central Aquifer Sector, Maui, Hawaiʻi" for Federal Fiscal Year (FFY) 2027; and Declare that the Project is Exempt from the Preparation of an Environmental Assessment under Hawaiʻi Revised Statutes Chapter 343, and Hawaiʻi Administrative Rules Chapter 11-200.1

I. SUMMARY OF REQUEST

Staff requests that the Commission enter into a Joint Funding Agreement (Agreement) with the U.S. Geological Survey (USGS) to study groundwater in Maui's Central aquifer sector to address uncertainties in groundwater flow and provide information needed to evaluate the validity of existing aquifer-system boundaries and potentially revise existing boundaries. Although developing new boundaries is beyond the scope of this project, the information generated by this study is expected to be useful for this purpose.

II. BACKGROUND

Demand for water from Maui's Central aquifer sector, which contains the Kahului, Pāʻia, Makawao, and Kamaʻole aquifer systems, is expected to increase in the future. However, the hydrogeology and limits of groundwater development in the Central aquifer sector is poorly understood.

Decisions about ground water availability and water allocations are intrinsically linked to hydrologic boundaries. The hydrologic and aquifer system boundary lines within the Central aquifer sector were delineated using selected topographic, geographic, political, surface-ditch, and geologic features. Because many of the aquifer-system lines do not correspond to features that control groundwater flow, withdrawal from one aquifer system will affect groundwater flow in other aquifer systems. This interconnectedness is important to understand and directly affects groundwater management decisions.

Therefore, a better understanding of groundwater flow in the Central aquifer sector is necessary for:

1) Management of coastal, groundwater-dependent habitat for endangered native waterbirds
2) Evaluation of sustainable groundwater development, and
3) Balancing of beneficial uses of groundwater.

A summary of the project, including the anticipated approach and work plan, is attached as Exhibit 2.

III. LOCATION

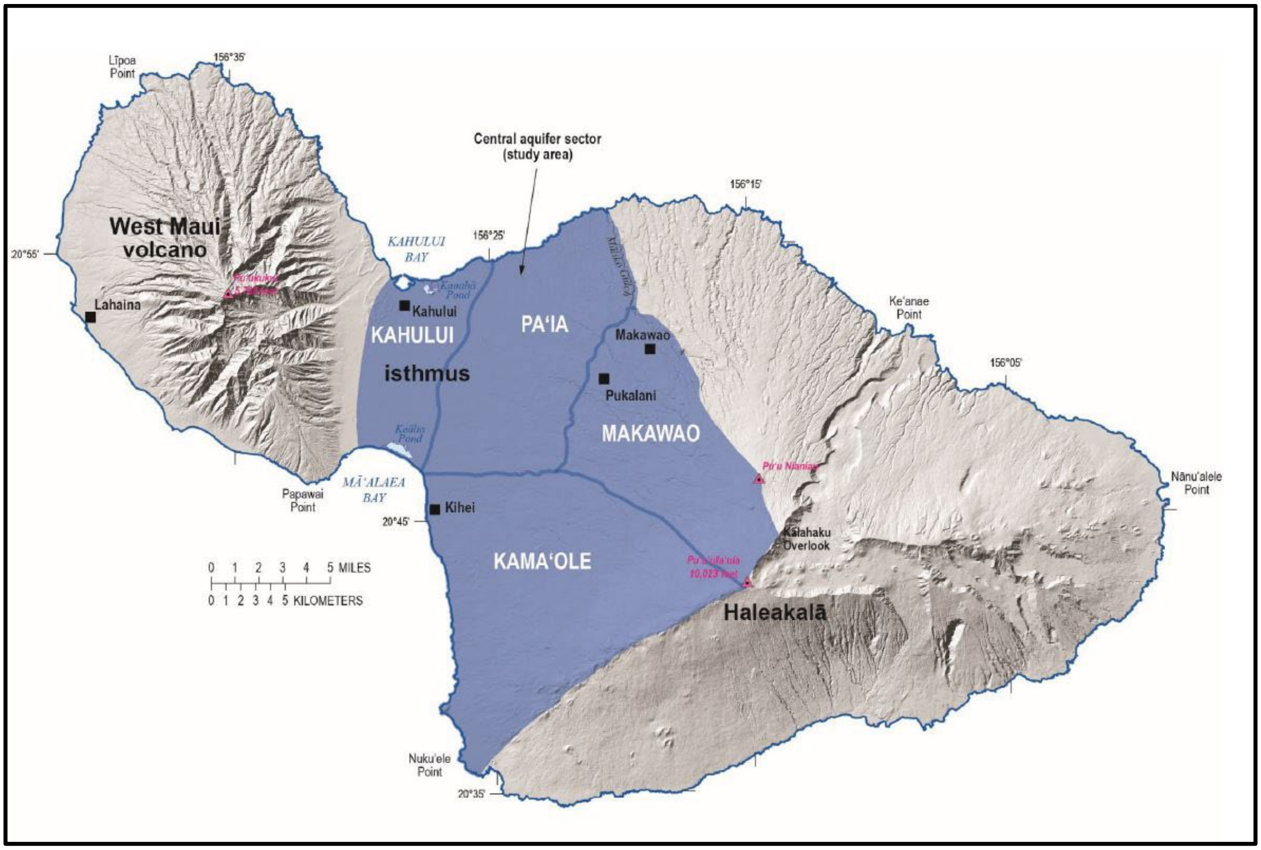

Figure 1. Map of the island of Maui showing the Kahului, Pāʻia, Makawao, and Kamaʻole aquifer systems in blue.

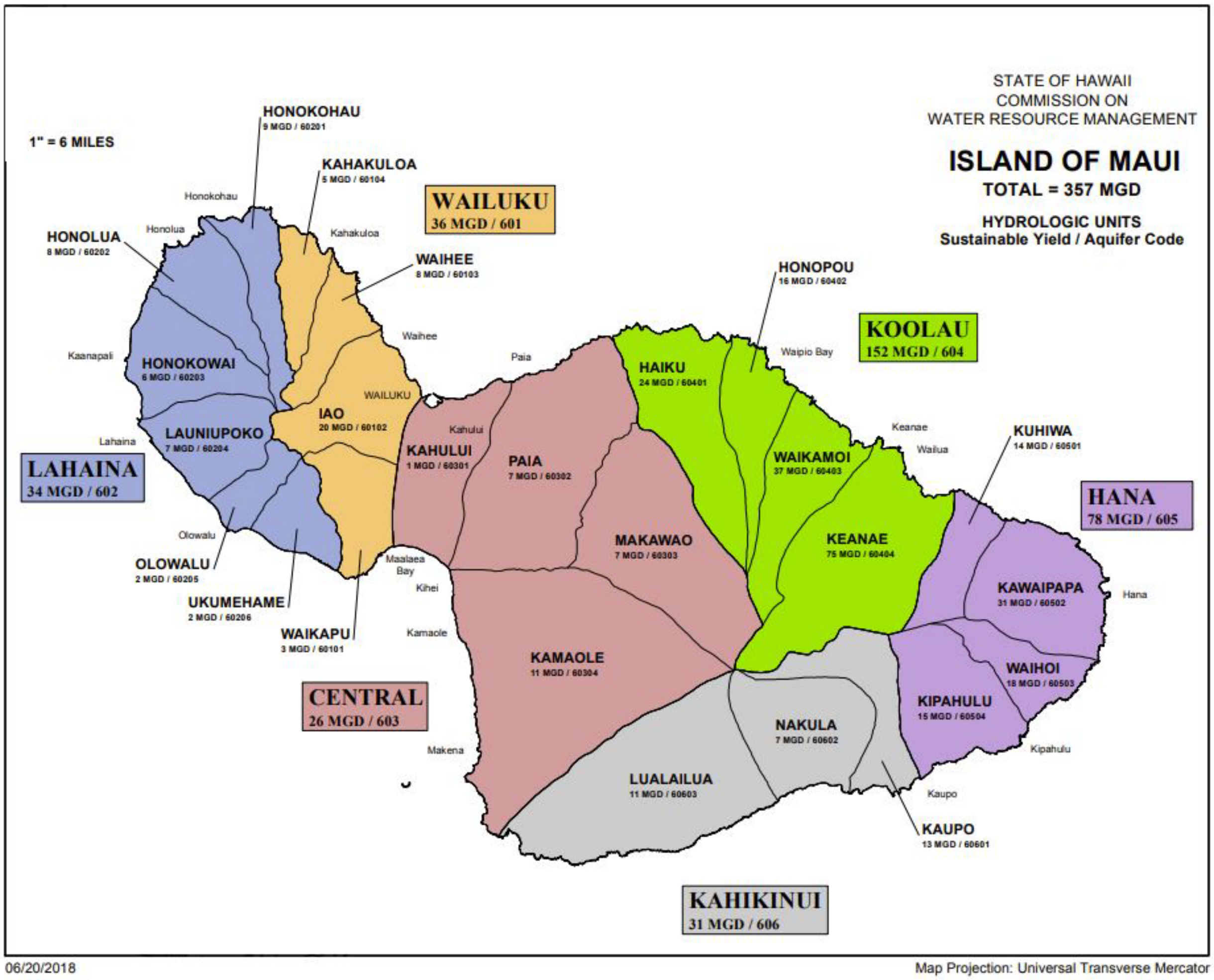

Figure 2. Map of the island of Maui's hydrologic units and the sustainable yields for each aquifer sector, including the Central aquifer sector shown in red.

IV. COSTS AND DELIVERABLES

The total cost for this 3-year study is estimated to be $442,000. The Commission will contribute $399,000 and the USGS will contribute $43,000 in matching funds. The cost includes salary and overhead. No supply or equipment purchases are anticipated for this study. The Commission's portion will be paid using Fiscal Year 26 and 27 General Funds.

	Year 1	Year 2	Year 3	TOTAL
USGS	$25,000	$18,000		$43,000
Commission	$229,000	$160,000	$10,000	$399,000
TOTAL				**$442,000**

The anticipated deliverables of this study are:

1) A published USGS report in the Scientific Investigations Report series.
2) A data release documenting groundwater-flow model files.
3) Meetings (virtual and in person) to discuss model scenarios, study progress, and results.

V. ENVIRONMENTAL COMPLIANCE

Under Hawai‘i Revised Statutes §343-5(a), the use of state funds triggers the need for an environmental assessment (EA). However, the proposed action is exempt from an EA based on Hawai‘i Administrative Rule §11-200.1-15(c)(5) and the Exemption List for the Commission on Water Resource Management approved by the Environmental Council on January 5, 2021, and falls under Exemption Class 5, Part 1, No. 2, which provides for “Non-destructive data collection and inventory, including field, aerial and satellite surveying and mapping” and No. 5, which provides for conduction of “topographic and location surveys.” No exemption notice is required.

VI. AUTHORITY

The Commission has the legal authority pursuant to Hawai‘i Revised Statues (HRS) §174C-5(4) to contract and cooperate with various agencies of the federal government.

VII. CONSISTENCY WITH THE HAWAI‘I WATER PLAN

The Water Code, HRS §174C-2(b), requires that the Commission implement and utilize comprehensive, long-range water resources planning in its regulation and management of the State’s water resources. To accomplish this mandate, the Hawai‘i Water Plan (HWP) is intended to serve as the long-range guide for managing water resources in Hawai‘i by providing direction and general guidance for making water use decisions, including the issuance of permits as set forth in the Water Code. [1]

The HWP currently consists of five major component plans identified as the: 1) Water Resource Protection Plan, 2) Water Quality Plan, 3) State Water Projects Plan, 4) Agricultural Water Use and Development Plan, and 5) County Water Use and Development Plans. This Agreement is consistent with the HWP and other plans as follows:

- Water Resource Protection Plan (WRPP) - the 2019 update to the WRPP recognizes that aquifer-system boundaries were established with limited subsurface information and do not necessarily constitute hydrologic boundaries.[2] It identified a need for up-to-date data on Hawai‘i water resources, water use, and water dynamics to make water resource management decisions. Chapter 3

[1] https://dlnr.hawaii.gov/cwrm/planning/hiwaterplan/
[2] https://dlnr.hawaii.gov/cwrm/planning/hiwaterplan/wrpp/

of the WRPP includes an Action Plan that recommends the Commission improve recharge estimates and update aquifer sustainable yields with new and best information (Task 1.3.1).

- Maui Water Use and Development Plan (MWUDP) – the 2019 update to the MWUDP encourages hydrologic investigations in the Central aquifer sector to better understand groundwater supply to meet projected demand and allow for proper regulation of groundwater.[3]

- Furthermore, the 2020 USGS Hydrological Monitoring Needs Assessment for the State of Hawaiʻi identified the Kahului, Pāʻia, Makawao, and Kamaʻole aquifer systems, among others, as "high" groundwater monitoring priority areas.[4] The result of this study is a first step to more accurately monitoring groundwater resources in the Central aquifer sector.

VIII. RECOMMENDATION

Staff recommend that the Commission:

1) Authorize the Chairperson to enter into a Joint Funding Agreement with the U.S. Geological Survey for FFY 2027 to study groundwater in Maui's Central aquifer sector to address uncertainties in groundwater flow and provide information needed to evaluate the validity of existing aquifer-system boundaries.

2) Delegate authority to the Chairperson to modify the Agreement, provided that there is no increase in cost to the Commission.

3) Find that this Joint Funding Agreement is exempt from the preparation of an environmental assessment under Hawaiʻi Revised Statutes chapter 343 based on Hawaiʻi Administrative Rules §11-200-8(a)(5) and the Exemption List for the Commission on Water Resource Management approved by the Environmental Council on January 5, 2021.

The terms of this Agreement are subject to the approval of the Department of the Attorney General. This type of agreement with a federal agency is exempt from the procurement code under HRS §103D-102(b)(3).[5]

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[3] https://files.hawaii.gov/dlnr/cwrm/planning/wudpma2019ma.pdf
[4] https://pubs.usgs.gov/sir/2020/5115/sir20205115.pdf
[5] HRS §103D-102(b)(3): Notwithstanding subsection (a), this chapter shall not apply to contracts by governmental bodies: To procure goods, services, or construction from a governmental body other than the university of Hawaii bookstores, from the federal government, or from another state or its political subdivision.

Ola i ka wai,

CIARA W.K. KAHAHANE
Deputy Director

EXHIBITS

1. Joint Funding Agreement for the “Analysis of Groundwater Flow in the Central Aquifer Sector, Maui, Hawai‘i”

2. Project Summary

APPROVED FOR SUBMITTAL:

RYAN K.P. KANAKA‘OLE
Acting Chairperson

United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Pacific Islands Water Science Center
1845 Wasp Blvd, Bld 176
Honolulu, HI 96818

April 9, 2026

Ciara Kahahane
Deputy director
State of Hawaii Commission on Water Resource Management
Department of Land and Natural Resources
State of Hawai'i
1151 Punchbowl St. Rm 227
Honolulu, HI 96813

Dear Ciara Kahahane:

Enclosed is our standard joint-funding agreement 27ZHJFA00017 between the U.S. Geological Survey Pacific Islands Water Science Center and State of Hawaii Commission on Water Resource Management for project **"Analysis of Groundwater Flow in the Central Aquifer Sector, Maui, Hawai'i"** (see attached full statement of work), during the period October 1, 2026 through September 30, 2029 in the amount of $399,000 from your agency. U.S. Geological Survey contributions for this agreement are $43,000 for a combined total of $442,000. Please sign and return one fully-executed version to gs-w-hi-piwsc_agreements@usgs.gov.

Federal law requires that we have a signed agreement before we start work. Please return the signed agreement by **October 1, 2026**. If, for any reason, the agreement cannot be signed and returned by the date shown above, please contact Kolja Rotzoll (email kolja@usgs.gov) to make alternative arrangements.

This is a fixed cost agreement to be billed quarterly via Down Payment Request (automated Form DI-1040). Please allow 30-days from the end of the billing period for issuance of the bill. If you experience any problems with your invoice(s), please contact Sharbra Gordon-Scott at phone number (253) 552-1698 or sgordon-scott@usgs.gov.

The results of all work performed under this agreement will be available for publication by the U.S. Geological Survey. We look forward to continuing this and future cooperative efforts in these mutually beneficial water resources studies.

Sincerely,

Scott VanderKooi
Acting Center Director

Enclosure
27ZHJFA00017

Exhibit 1

Form 9-1366
(May 2018)

U.S. Department of the Interior
U.S. Geological Survey
Joint Funding Agreement
FOR
Water Resource Investigations

Customer #: 6000001189
Agreement #: 27ZHJFA00017
Project #: ZH00URA
TIN #: 99-0266119

Fixed Cost Agreement YES[X] NO[ ]

THIS AGREEMENT is entered into as of October 1, 2026, by the U.S. GEOLOGICAL SURVEY, Pacific Islands Water Science Center, UNITED STATES DEPARTMENT OF THE INTERIOR, party of the first part, and the State of Hawaii Commission on Water Resource Management party of the second part.

1. The parties hereto agree that subject to the availability of appropriations and in accordance with their respective authorities there shall be maintained in cooperation a project "**Analysis of Groundwater Flow in the Central Aquifer Sector, Maui, Hawai'i**", herein called the program. The USGS legal authority is 43 USC 36C; 43 USC 50, and 43 USC 50b.

2. The following amounts shall be contributed to cover all of the cost of the necessary field and analytical work directly related to this program. 2(b) include In-Kind-Services in the amount of $0.00

(a) $43,000 by the party of the first part during the period October 1, 2026 to September 30, 2029

(b) $399,000 by the party of the second part during the period October 1, 2026 to September 30, 2029

(c) Contributions are provided by the party of the first part through other USGS regional or national programs, in the amount of: $0

Description of the USGS regional/national program:

(d) Additional or reduced amounts by each party during the above period or succeeding periods as may be determined by mutual agreement and set forth in an exchange of letters between the parties.

(e) The performance period may be changed by mutual agreement and set forth in an exchange of letters between the parties.

3. The costs of this program may be paid by either party in conformity with the laws and regulations respectively governing each party.

4. The field and analytical work pertaining to this program shall be under the direction of or subject to periodic review by an authorized representative of the party of the first part.

5. The areas to be included in the program shall be determined by mutual agreement between the parties hereto or their authorized representatives. The methods employed in the field and office shall be those adopted by the party of the first part to insure the required standards of accuracy subject to modification by mutual agreement.

6. During the course of this program, all field and analytical work of either party pertaining to this program shall be open to the inspection of the other party, and if the work is not being carried on in a mutually satisfactory manner, either party may terminate this agreement upon 60 days written notice to the other party.

7. The original records resulting from this program will be deposited in the office of origin of those records. Upon request, copies of the original records will be provided to the office of the other party.

8. The maps, records or reports resulting from this program shall be made available to the public as promptly as possible. The maps, records or reports normally will be published by the party of the first part. However, the party of the second part reserves the right to publish the results of this program, and if already published by the party of the first part shall, upon request, be furnished by the party of the first part, at cost, impressions suitable for purposes of reproduction similar to that for which the original copy was prepared. The maps, records or reports published by either party shall contain a statement of the cooperative relations between the parties. The Parties acknowledge that scientific information and data developed as a result of the Scope of Work (SOW) are subject to applicable USGS review, approval, and release requirements, which are available on the USGS Fundamental Science Practices website (https://www.usgs.gov/office-of-science-quality-and-integrity/fundamental-science-practices).

U.S. Department of the Interior
U.S. Geological Survey
Joint Funding Agreement
FOR
Water Resource Investigations

Customer #: 6000001189
Agreement #: 27ZHJFA00017
Project #: ZH00URA
TIN #: 99-0266119

9. Billing for this agreement will be rendered **quarterly**. Invoices not paid within 60 days from the billing date will bear Interest, Penalties, and Administrative cost at the annual rate pursuant the Debt Collection Act of 1982, (codified at 31 U.S.C. § 3717) established by the U.S. Treasury.

USGS Technical Point of Contact

Name:	Kolja Rotzoll Hydrologist
Address:	1845 Wasp Boulevard Bld 176 Honolulu, HI 96818
Telephone:	(180) 864-6770 Ext 5103
Fax:	(n/a)
Email:	kolja@usgs.gov

Customer Technical Point of Contact

Name:	Ryan Imata Hydrologic Program Manager
Address:	Ground Water Branch Commission on Water Resource Management
Telephone:	(808) 587-0225
Fax:	(n/a)
Email:	Ryan.r.imata@hawaii.gov

USGS Billing Point of Contact

Name:	Sharbra Gordon-Scott Budget Analyst
Address:	934 Broadway Suite 300 Tacoma, WA 98402
Telephone:	(253) 552-1698
Fax:	(253) 552-1581
Email:	sgordon-scott@usgs.gov

Customer Billing Point of Contact

Name:	Ciara Kahahane Deputy Director
Address:	Commission on Water Resource Management
Telephone:	(808) 587-0214
Fax:	(n/a)
Email:	Ciara.wk.kahahane@hawaii.gov

U.S. Geological Survey
United States
Department of Interior

Signature

By_______________________ **Date:** __________

Name: Scott VanderKooi

Title: Acting Center Director

State of Hawaii Commission on Water Resource Management

Signatures

By_______________________ **Date:** _________

Name:

Title:

By_______________________ **Date:** _________

Name:

Title:

By_______________________ **Date:** _________

Name:

Title:

Analysis of Groundwater Flow in the Central Aquifer Sector, Maui, Hawaiʻi

U.S. Geological Survey
Pacific Islands Water Science Center
January 2025

SUMMARY

Demand for water from Maui's Central aquifer sector, which contains the Kahului, Pāʻia, Makawao, and Kamaʻole aquifer systems, is expected to increase in the future. Sustainable groundwater development in the Central aquifer sector, however, is poorly understood. For example, the Hawaiʻi Commission on Water Resource Management (CWRM) has established a sustainable yield of 1 million gallons per day for the Kahului aquifer system, from which more than 5 million gallons of water per day was reportedly developed during 2023. The aquifer systems within the Central aquifer sector were delineated using selected topographic, geographic, political, surface-ditch, and geologic features (Mink and Lau, 1990). Because many of the aquifer-system lines do not correspond to features that control groundwater flow, withdrawal from one aquifer system will affect groundwater flow in other aquifer systems. For example, long-term withdrawal from the Makawao aquifer system, which is a land-locked aquifer system, will reduce groundwater flow to adjacent aquifer systems or induce groundwater inflow into the Makawao aquifer system from adjacent aquifer systems. Thus, management of groundwater in the aquifer systems of the Central aquifer sector can be challenging within the current management framework. A better understanding of groundwater flow in the Central aquifer sector is critical for (1) management of coastal, groundwater-dependent habitat for endangered native waterbirds, (2) evaluation of sustainable groundwater development, and (3) balancing of beneficial uses of groundwater.

This U.S. Geological Survey (USGS) study of groundwater in Maui's Central aquifer sector will address uncertainties in groundwater flow that are affected by changes in recharge and withdrawals. The objective of this study is to provide information needed to evaluate the validity of existing aquifer-system boundaries and potentially revise existing boundaries. Although delineating new boundaries is beyond the scope of this study, the information generated by this study is expected to be useful for this purpose. The approach for this study will be to use an existing island-wide groundwater-flow model of Maui to simulate conditions for selected recharge and withdrawal scenarios to be developed in consultation with CWRM. The scenarios will provide insight into how groundwater-flow directions and the north-south groundwater divide, which represent potential aquifer-system separators, might shift in response to different hydrologic conditions.

Results of this study will be documented in a USGS Scientific Investigations Report and related data release of model files. Regular virtual and in-person meetings, every 3–4 months, are anticipated to develop model scenarios and discuss study progress and results. Estimated cost for this 3-year study is $442,000. The USGS anticipates contributing approximately 10 percent of the total cost through available Federal matching funds.

Exhibit 2

PROBLEM

The resident population on the island of Maui, Hawaiʻi, increased from 38,691 in 1970 to 154,100 in 2020, which represents an increase of almost 300 percent (State of Hawaiʻi, 2023). Because of the increase in population, the groundwater demand for public water supply also has increased and groundwater withdrawals likely will continue to increase in the future.

In a typical freshwater-lens system, increased groundwater withdrawals will, in the long term, result in a decline in water levels, a rise in the transition zone between freshwater and saltwater, and a reduction of natural groundwater discharge to the ocean, springs, and streams, or in nearby groundwater areas. Coastal wetlands can be reduced in area or disappear if groundwater withdrawals cause water levels to decline in the vicinity of the wetlands. Furthermore, the wetland water quality, in terms of salinity, can be affected by groundwater withdrawals, which could affect habitat for wetland flora and fauna. Changes in future rainfall and groundwater recharge can also affect the availability of fresh water.

Maui's Central aquifer sector is formed by the Kahului, Pāʻia, Makawao, and Kamaʻole aquifer systems. The boundaries separating these aquifer systems were not drawn on the basis of known hydrogeologic boundaries. Instead, many of the aquifer-system boundaries were based on selected topographic, geographic, political, and surface-ditch features (Mink and Lau, 1990). The Hawaiʻi Commission on Water Resource Management (CWRM) has established a sustainable yield of 1 million gallons per day for the Kahului aquifer system, from which more than 5 million gallons of water per day was reportedly developed during 2023 (Robert Chenet, Hawaiʻi Commission on Water Resource Management, written commun., 2024). Simulated groundwater flow (Izuka and others, 2021) crosses the north-south-oriented boundary separating the Kahului and Pāʻia aquifer systems, which suggests that recharge and withdrawal from one aquifer system can affect conditions in other aquifer systems. Thus, management of groundwater in the aquifer systems of the Central aquifer sector can be challenging within the current management framework. A better understanding of groundwater flow in the Central aquifer sector is critical for (1) management of coastal, groundwater-dependent habitat for endangered native waterbirds, (2) evaluation of sustainable groundwater development, and (3) balancing of beneficial uses of groundwater.

This U.S. Geological Survey (USGS) study of groundwater in Maui's Central aquifer sector will address uncertainties in groundwater flow that are affected by changes in recharge and withdrawals. The objective of this study is to provide information needed to evaluate the validity of existing aquifer-system boundaries and potentially revise existing boundaries. Although delineating new boundaries is beyond the scope of this study, the information generated by this study is expected to be useful for this purpose. Results of this study will provide insight into how groundwater-flow directions and the north-south groundwater divide, which represent potential aquifer-system separators, might shift in response to different hydrologic conditions.

DESCRIPTION OF STUDY AREA

The main study area is the Central aquifer sector (fig. 1), Maui, Hawaiʻi, as defined by CWRM, although nearby areas that are hydrologically connected to the Central aquifer sector are also relevant and included in the analysis for this study. The Central aquifer sector is divided into the Kahului, Pāʻia, Makawao, and Kamaʻole aquifer systems by CWRM. The lines separating these four aquifer systems do not correspond to any known geologic structures and therefore neither impede flow from one aquifer system to another, nor exert a control on the effects of withdrawal from one aquifer system on groundwater conditions in other aquifer systems. The northeastern and southeastern boundaries of the Central aquifer sector generally are aligned with rift zones of Haleakalā, and these boundaries are expected to affect groundwater flow. CWRM manages groundwater withdrawals statewide by establishing sustainable-yield estimates for each aquifer system. For the Central aquifer sector of Maui, CWRM has estimated sustainable-yield values of 1, 7, 7, and 11 million gallons per day (Mgal/d) for the Kahului, Pāʻia, Makawao, and Kamaʻole aquifer systems, respectively.

The study area covers about 230 mi^2 and is bounded by the coast on the north, by Māliko Gulch and a line extending to Puʻu Nianiau and Kalahaku overlook on the northeast, the southwest rift zone of Haleakalā on the southeast, the coast on the southwest and south, and a line extending from Māʻalaea Bay to Kahului Bay on the west (fig. 1). The study area lies on the western flank of Haleakalā, which forms the eastern part of the island of Maui, the second largest island in the Hawaiian archipelago. The Island of Maui located between longitude 155º55′ W and 156º45′ W and between latitude 20º30′ N and 21º05′ N, is composed of two shield volcanoes, the older West Maui volcano that rises to an altitude of 5,788 feet (ft) at Puʻukukui, and the younger Haleakalā that rises to an altitude of 10,023 ft. The two volcanoes are separated by an isthmus, generally at altitudes less than 300 ft, which is covered with terrestrial and marine sedimentary deposits that are as much as 5 miles wide (Stearns and Macdonald, 1942).

Between the late 1800s to 2016, sugarcane was grown extensively on the western slopes of Haleakalā, including within the study area, typically below an altitude of about 1,000 ft. Areas inland of sugarcane cultivation were used for grazing or pineapple cultivation or were forested (Territorial Planning Board, 1939; Harland Bartholomew and Associates, 1957; U.S. Department of Agriculture, 1983; Engott and Vana, 2007; Melrose, 2016). Following the 2016 cessation of sugarcane cultivation in the area, much of the former lands that were cultivated remained largely unused. This land-use change also altered the water budget of the area by eliminating substantial areas of cultivated sugarcane that previously contributed to groundwater recharge. The study area also contains developed areas including those at Kahului, Makawao, Pukalani, and Kīhei (fig. 1).

Mean annual rainfall in the study area ranges from less than 15 in. at low altitudes in the southwest to greater than 100 in. above an altitude of 2,500 ft toward the northeast (Giambelluca and others, 2013). The prevailing trade-wind direction is from the northeast and controls the distribution of rainfall throughout much of the Hawaiian Islands. Rainfall is generally greatest where the prevailing northeasterly trade winds encounter the flank of a volcano, forcing warm, moist air into the cool, higher altitudes. The study area lies mainly on the drier, leeward side of Haleakalā.

Geology.—The geology of Maui was described in detail by Stearns and Macdonald (1942), and some of the geologic units were subsequently reclassified by Langenheim and Clague (1987) and Sherrod and others (2021). Haleakalā is formed mainly by lava flows of tholeiitic and alkalic basalt of the shield-stage Honomanū Basalt, which is almost entirely covered by post-shield-stage Kula and Hana Volcanics. The Kula Volcanics and the Hana Volcanics are the most widespread geologic units exposed at the land surface on Haleakalā.

The shield stage represents the most voluminous phase of eruptive activity of Haleakalā, during which more than 95 percent of the volcano was formed, mainly by thousands of relatively thin basalt lava flows. These flows emanated from fissures and vents near and radiating outward from the central summit area. The lavas of the Honomanū Basalt have typical dips of 2° to 22° with the flatter dips near the isthmus where flows approached the West Maui volcano. The basalts were laid down as very vesicular pāhoehoe and ʻaʻā flows with an average thickness of about 15 ft (Stearns and Macdonald, 1942, p. 61). Contrary to typical observations of shield-stage formations in which pāhoehoe is found in greater abundance near volcanic vents, pāhoehoe flows are abundant throughout the Honomanū Basalt even at the periphery of the volcano. In the study area, exposures of Honomanū Basalt are found in Māliko Gulch and in narrow areas along the coast to the west of Māliko Gulch (Stearns and Macdonald, 1942). Exposures are identified as Honomanū Basalt in the field where they are thin bedded, porphyritic, and often show characteristics typical of pāhoehoe flows. Field reconnaissance has shown that exposures of Honomanū Basalt can be found nearly 4 mi from the coast at an altitude of about 600 ft in Māliko Gulch and almost 1 mi from the coast in Kākipi Gulch at an altitude of about 100 ft (Gingerich, 1999). These exposures are much more extensive than those shown on existing geologic maps (Stearns and Macdonald, 1942; Sherrod and others, 2021), which show the Honomanū Basalt exposed in Māliko Gulch for less than a mile from the coast and no exposures in Kākipi Gulch.

The Kula Volcanics, which overlies the Honomanū Basalt, consists of post-shield stage lava flows of mainly alkalic basalt, hawaiite, mugearite, benmoreite, and basanite and associated intrusive rocks and pyroclastic and sedimentary deposits (Langenheim and Clague, 1987; Sherrod and others, 2021). In some places, Honomanū Basalt and Kula Volcanics are separated by a thin red soil layer that has been altered by the weight and heat of the overlying flows. The Kula Volcanics covers large areas of the underlying Honomanū Basalt and exposures range from 2,500 ft thick near the summit to 50 to 200 ft thick near the coast. Individual flows average about 20 ft in thickness near the summit and 50 ft near the periphery but flows as much as 200 ft thick are not rare (Stearns and Macdonald, 1942, p. 75). The usual dip of the flows is about 10°. The flows are generally thicker and narrower than the Honomanū Basalt and have more lenticular bedding due to the filling of swales and valleys eroded into the underlying rocks. Flows of the Kula Volcanics cover the surface of almost the entire study area.

The most recent eruptions produced lavas of mainly alkalic basalt and basanite, named the Hana Volcanics. The Hana Volcanics includes lava flows and associated intrusive rocks and pyroclastic and sedimentary deposits (Langenheim and Clague, 1987; Sherrod and others, 2021). Within the study area, the Hana Volcanics are mapped mainly in the southeastern part and probably are less important hydrologically than the Honomanū Basalt and Kula Volcanics.

Haleakalā has three primary rift zones (Stearns and Macdonald, 1942; Langenheim and Clague, 1987) and the study-area boundary is partly related to two of these, the northwest and southwest rift zones that extend from the central summit area. The two rift zones are marked by numerous volcanic vents, commonly related to cinder, spatter, and pumice cones visible at the surface (Stearns and Macdonald, 1942; Macdonald and others, 1983; Sherrod and others, 2021). The trends of these two rift zones are generally consistent with measured gravity anomalies (Kinoshita and Okamura, 1965). Dikes associated with rift zones are the dominant intrusive rocks in Hawaiian volcanoes. Due to the relative youth of Haleakalā, exposures of dikes are scarce and limited to the walls of the summit and the larger valleys (Stearns and Macdonald, 1942). A few dikes are mapped near the eastern corner of the Kamaʻole aquifer system near the summit area. Thousands of dikes are inferred to exist within the rift zones, with the number of dikes increasing toward the caldera and with depth.

The dikes and the rocks they intrude are commonly referred to as dike complexes. In Hawaiian volcanoes, dike complexes range in width from 1.5 to 3 mi and average about 1.9 mi (Macdonald and others, 1983). The dike complex associated with the northwest rift zone of

Haleakalā appears to be about 3 mi wide near the coast and may be greater than 5 mi wide at an altitude of 4,000 ft on the basis of the locations of the cinder and spatter cones that are in two parallel and roughly linear patterns. The vents of the southwest rift zone indicate a rift-zone width less than a mile wide. Dikes in a dike complex number about 100 to 200 per mile of width (Macdonald and others, 1983) and compose 10 percent or more of the rock volume (Takasaki and Mink, 1985). Downward, the number of dikes in the dike complex is expected to increase and may average 500 to 600 per mile of width of the complex (Macdonald and others, 1983). The dike complexes are hydrologically important because dikes have low permeability and tend to impound groundwater to high altitudes within inter-dike compartments. Also, dikes associated with rift zones tend to impede groundwater flow from groundwater areas on either side of the rift zone.

Within the study area, sedimentary deposits of recent alluvium, older alluvium and dune deposits are found in coastal areas and almost cover the entire surface of the Kahului aquifer system that forms the western part of the Central aquifer sector. The sedimentary deposits likely impede groundwater flow between West Maui volcano and Haleakalā.

Surface Water.—The drainage pattern of the stream valleys on Haleakalā is generally radial from the summit of area to the ocean. The streams originating on Haleakalā in the study area drain to the northwest and southwest. A few streams originating on West Maui volcano drain to the east and south within the study area. Streams in the study area are mostly ephemeral, except in places where groundwater discharge might locally sustain perennial flow.

Streamflow consists of direct runoff, base flow, and possibly flow added to some streams from the network of irrigation ditches in and near the study area. Base flow is presumed to represent groundwater discharge and is limited in the study area. As of 2024, the USGS does not maintain any continuous-record streamgaging stations within the study area, although one stream originating on the West Maui volcano that ultimately drains into the study area does have a streamgaging station. The USGS has also historically maintained other streamgaging stations in the area, although mainly for monitoring peak flows related to flooding (Fontaine, 1996; Mitchell and others, 2023).

Groundwater.— Groundwater recharge by direct infiltration of rainfall occurs over nearly the entire study area. Estimates of groundwater recharge in Maui for selected periods, land-cover conditions, and climate conditions have been published in recent years (Johnson and others, 2018; Izuka and others, 2018; Mair and others, 2019; Kāne and others, 2024; Mair and others, 2024). Groundwater recharge in the study area is generally greatest in wet mountainous areas and least in drier coastal areas, although irrigation can greatly enhance recharge in dry areas. Estimated groundwater recharge for recent land-cover conditions without sugarcane in the Central aquifer sector is greatest in the Makawao aquifer system and least in the Kahului aquifer system. Estimated groundwater recharge (recent land-cover conditions without sugarcane) in the Central aquifer-sector area ranges from 40.30 million gallons per day (Mgal/d) for a future drought condition with 100 percent of shrubland and forest areas within the cloud zone converted to grassland (Mair and others, 2024) to 107.53 Mgal/d for 1978–2007 rainfall and 2020 land-cover conditions (Kāne and others, 2024).

On the basis of available information, groundwater in the study area occurs in two main forms: (1) as dike-impounded groundwater associated with the rift zones near the northeastern and southeastern boundaries of the Central aquifer sector, and (2) as a freshwater lens floating on denser, underlying saltwater in dike-free (or mainly dike-free) areas (Gingerich, 2008). The freshwater-lens system is mainly dike free. However, numerous volcanic vents or vent-related features in some areas where a freshwater lens is expected were fed through dikes that could affect groundwater conditions.

Dike-Impounded Groundwater.—Within the study area, volcanic dikes are inferred to exist near the northeastern and southeastern boundaries where volcanic vents at the surface indicate the presence of subsurface dikes. Dikes are hydrologically important because they have low permeability and can compartmentalize and impound groundwater to higher altitudes than would exist in the absence of dikes. Groundwater recharge to the dike-impounded area is mainly in the form of infiltration of rainfall. Groundwater flows from the dike-impounded groundwater area towards the coast and contributes subsurface flow to the freshwater-lens system.

Freshwater Lens.—Within the high-permeability rocks of the Honomanū Basalt, a lens of freshwater floats on denser underlying saltwater. Where the Kula Volcanics exists near and below sea level, expected mainly near the coast, the freshwater lens will exist within that formation as well. The source of freshwater in the lens is groundwater recharge from infiltration of rainfall, irrigation water, and streamflow, inflow from the dike-impounded groundwater in the rift zones near the northeastern and southeastern boundaries of the study area, and possibly inflow across the western boundary of the study area from groundwater originating in the West Maui volcano. Fresh groundwater flows generally from inland recharge areas to the coast where it discharges at springs and by diffuse seepage at and near sea level.

In coastal aquifers of Hawaiʻi, a saltwater-circulation system exists beneath the freshwater lens (Souza and Voss, 1987). Saltwater flows landward in the deeper parts of the aquifer, rises, and then mixes with seaward flowing freshwater. This mixing creates a freshwater-saltwater transition zone. No wells are currently available in the study area to characterize the thicknesses of freshwater or the transition zone, although such deep monitor wells are available in the West Maui volcano.

Existing Groundwater Withdrawals.—Reported groundwater withdrawals (Robert Chenet, Hawaiʻi Commission on Water Resource Management, written commun., 2024) in the Central aquifer sector varied over time in response to changing irrigation demand and drinking-water needs. Since 1990, reported withdrawals from all groundwater sources in the Central aquifer sector peaked in 1996 at 120 Mgal/d and then, following the cessation of sugarcane cultivation on Maui in 2016, was between 8 and 17 Mgal/d during 2017–23. During 2023, reported withdrawals from the Central aquifer sector were 16.7 Mgal/d, and were greatest in the Pāʻia aquifer system (6.8 Mgal/d) and least in the Makawao aquifer system (1.0 Mgal/d). Reported 2023 withdrawals from the Kahului aquifer system totaled 5.2 Mgal/d, whereas CWRM has estimated a sustainable yield of 1 Mgal/d for this aquifer system.

OBJECTIVES

The objective of this study is to provide information needed to evaluate the validity of existing aquifer-system boundaries and potentially revise existing boundaries. Although developing new boundaries is beyond the scope of this study, the information generated by this study is expected to be useful for this purpose.

APPROACH

To meet the objectives of this study, an existing island-wide groundwater-flow model of Maui will be used to simulate steady-state conditions for selected recharge and withdrawal scenarios. The selected scenarios will be developed in consultation with CWRM. The existing numerical groundwater-flow model incorporates the latest conceptual understanding of hydrogeologic conditions on Maui (Izuka and others, 2021). Known or inferred geologic structures related to dikes and low-permeability weathered rocks and sedimentary deposits are represented in the model. The model was constructed using available groundwater-level, -withdrawal, and -discharge information. CWRM aquifer-system boundaries that are related to topographic, surface, geographic, or political features that do not affect groundwater flow are not represented in the model framework, although flow across these aquifer-system boundary lines can be quantified by the model.

The recharge and withdrawal scenarios will provide insight into groundwater-flow directions and how the north-south groundwater divide and generalized flow lines, which represent potential aquifer-system separators, might shift in response to different hydrologic conditions. The model will also be used to quantify groundwater discharge to coastal wetland areas within the Central aquifer sector in northern and southern Maui near Kanahā and Keālia Ponds, respectively. These wetlands provide habitat for endangered native waterbirds and changes in groundwater discharge to these wetlands can affect available habitat.

Existing recharge estimates based on recent land-cover and climate conditions and a range of future climate projections will be considered as input to the groundwater-flow model. If deemed appropriate, land-cover conditions that reflect plausible changes in agriculture or development can be incorporated in new water-budget computations. A range of recent, proposed, or hypothetical withdrawals scenarios can be incorporated in the groundwater-flow model.

DELIVERABLES

The anticipated products of this study are (1) a published USGS report in the Scientific Investigations Report series; (2) a data release documenting groundwater-flow model files; and (3) meetings (virtual and in person) to discuss model scenarios, study progress, and results.

BUDGET

The total cost for this 3-year study is estimated to be $399,000 for CWRM. The USGS will contribute $43,000 in matching funds The cost includes salary and overhead. No supply or equipment purchases are anticipated for this study.

Table 1: Budget

	Year 1	Year 2	Year 3	**Total**
USGS	25,000	18,000		43,000
CWRM	229,000	160,000	10,000	399,000
Total	254,000	178,000	10,000	**442,000**

WORK PLAN

The major tasks and associated periods of activity for this 3-year study are summarized in table 1. Work will begin as soon as funding becomes available. Preliminary results and meeting will be held throughout the duration of the study.

	Quarter											
Task	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Develop model scenarios	x	x										
Create model files		x										
Run model scenarios			x									
Analyze model results				x								
Document results					x							
Scientific Investigations Report												
Write draft			x	x	x	x	x					
Review								x				
Approve								x				
Publish									x	x	x	x
Data release												
Write draft							x					
Review							x					
Approve								x				
Publish												x
Meetings	x		x		x		x		x			

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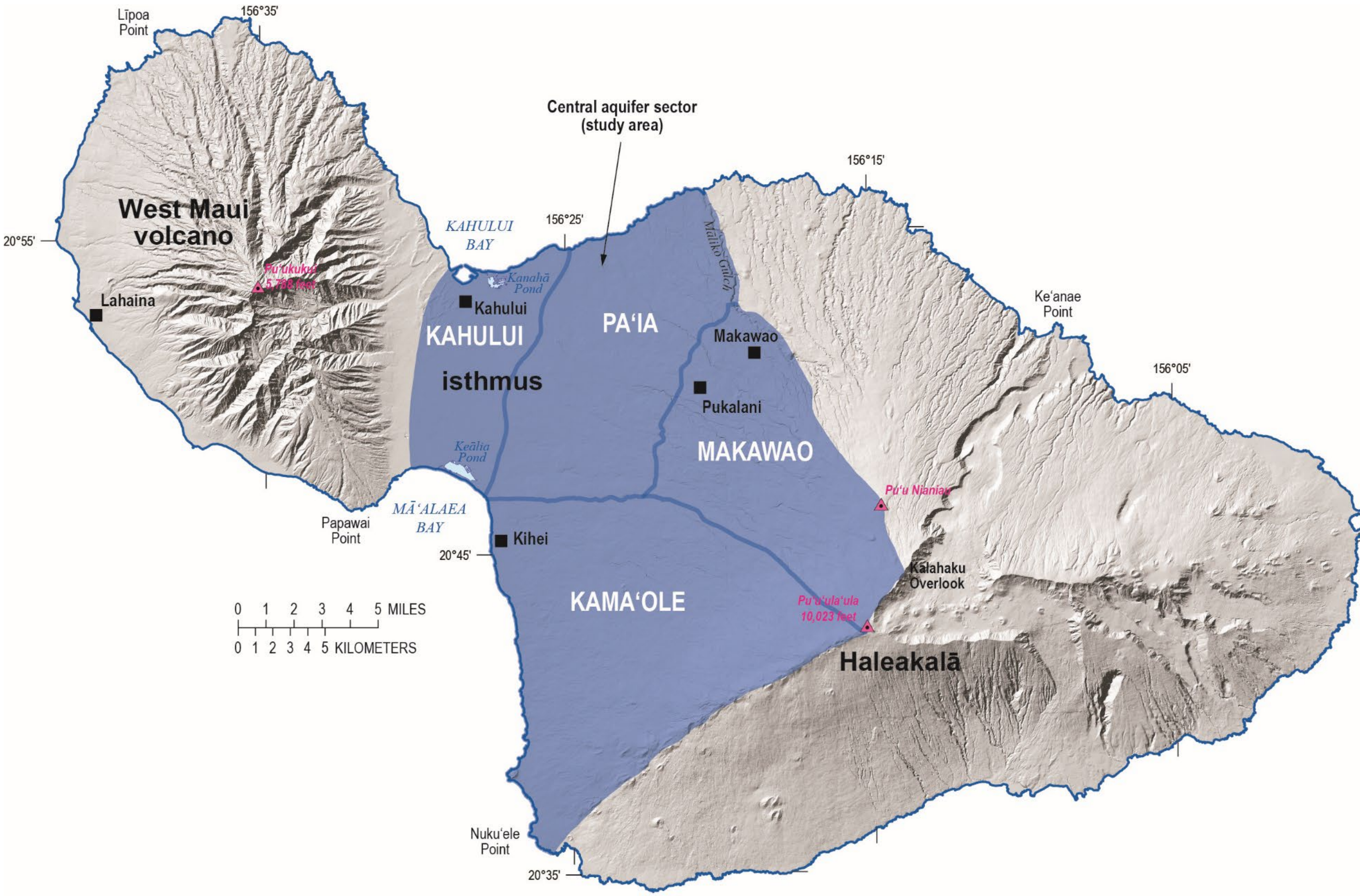

Figure 1. State of Hawai‘i Central aquifer sector study area, Island of Maui, Hawai‘i.