Elements Needed in Design of a Ground-Water-Quality Monitoring Network in the Hawaiian Islands

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 2041

Prepared in cooperation with Department of Health, State of Hawaii, Honolulu, Hawaii

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CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

CONVERSION FACTORS

[The following factors may be used to convert the English units published herein to the International System of Units (SI)]

English units	*Multiply by*	*To obtain SI units*
inches (in.)	25.4	millimeters (mm)
feet (ft)	.305	meters (m)
miles (mi)	1.61	kilometers (km)
feet per mile (ft/mi)	.189	meters per kilometer (m/km)
square miles (mi^2)	2.59	square kilometers (km^2)
cubic feet per second (ft^3/s)	.028	cubic meters per second (m^3/s)
million gallons (Mgal)	3,785	cubic meters (m^3)

ELEMENTS NEEDED IN DESIGN OF A GROUND-WATER- QUALITY MONITORING NETWORK IN THE HAWAIIAN ISLANDS

By K. J. TAKASAKI

ABSTRACT

The elements needed in the design of a ground-water-quality monitoring network in in the Hawaiian Islands are described and summarized. The elements are given by geohydrologic units which represent areas where there are similarities in the occurrence of ground water or in the geology pertinent to the occurrence of ground water. The goal is to establish a network of observation points to inventory and maintain surveillance of existing and potential sources of pollution of ground water. Of principal concern to Hawaii's environment is pollution of the potable ground-water supplies and of the near-shore recreational waters, the latter by the discharge of polluted ground water.

Existing monitoring efforts, although intensive in many areas, are not adequate because they are geared more toward (1) the detection and surveillance of pollutants in the conveyances of ground water instead of in the sources of ground water and (2) the monitoring of extensive nonpoint sources of pollution instead of from discrete point sources.

INTRODUCTION

PURPOSE AND SCOPE

The State of Hawaii, in response to provisions of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92–500), plans to establish and maintain a ground-water-quality monitoring program. The State Department of Health, which is responsible for implementing this program, has asked the U.S. Geological Survey to assist in its design. The program will include the establishment of a network of observation points or sites to inventory and maintain surveillance of existing and potential sources of pollution of ground water. Of principal concern to Hawaii's environment is the possible pollution of the potable ground-water supplies and of the near-shore recreational marine waters, the latter by the discharge of polluted ground water.

This report describes and summarizes the elements needed in the design of such a monitoring program for each major island. These elements include a description of the occurrence of ground water, of the rocks and geological features that control ground-water movement from the areas of recharge to areas of discharge, and of the extent of existing pollution of ground water. The report also includes a summary of the existing ground-water sampling effort, a noting of areas or sites where there is apparent need for samplings, a tabulation of the principal aquifers tapped by wells and tunnels, and an evaluation of the pollution potential of seawater, irrigation water, and common wastes.

Each major island is subdivided into geohydrologic units, and the elements listed above are given for each unit. The geohydrologic units represent areas where there are similarities in the occurrence of ground water or in the geology pertinent to the occurrence of ground water.

The report does not include the designation of specific wells for a monitoring network. Also, it does not specify the constituents to be monitored or the frequency of sampling. These need to be done, but not before the elements listed above are summarized and evaluated. The actual selection of wells or sites and the specification of the monitoring effort can then be focused on the needs, interests or priorities, and tailored to the availability of funds.

The work was done by the U.S. Geological Survey in cooperation with the Hawaii State Department of Health.

DEFINITION OF "GROUND WATER" AS USED IN REPORT

The term "ground water" refers to that water which occurs in the subsurface in a zone of saturation, where all interconnected voids in the rock are filled with water.

The term "fresh ground water" refers to ground water with a total dissolved solids (TDS) concentration less than 1,000 milligrams per liter (mg/l). Included in this TDS concentration range are all the domestic and most of the irrigation water supplies.

The term "saline ground water" refers to ground water with a TDS concentration ranging from 1,000 to 35,000 mg/1. In this report, ground water with a TDS concentration ranging from 1,000 to about 5,000 mg/1 is generally referred to as "brackish ground water."

SUITABILITY AND ADEQUACY OF PAST AND EXISTING SAMPLING EFFORTS

Ground-water sources, or points where samples can be collected from conveyances of ground water, are sampled at short periodic intervals in Hawaii for two principal reasons: (1) to detect pollution or the absence of pollution and (2) to monitor intrusion of saline water into ground-water reservoirs or the absence of intrusion. Ground water is also sampled at less frequent intervals in order to detect changes in its chemical and physical properties owing to pollution from large nonpoint sources. The past and existing sampling efforts have been geared toward detection and surveillance of pollutants in the conveyances of ground water instead of in the sources of ground water, and toward the monitoring of extensive nonpoint, instead of discrete point, sources of pollution to ground water. The ground-water-quality monitoring network, arising from this study, should be geared instead to the inventory and surveillance of existing and potential pollution from discrete point sources.

The existing effort, or even an expansion of it, does not fulfill the needs of a network for monitoring ground-water quality as required by the State, the chief reason being the lack of suitable sampling points, even though there are more than 1,000 active wells in Hawaii. Most wells are drilled for the extraction of ground water at some planned rate. The wells are necessarily drilled deep into the aquifer and are generally cased some depth below the static water level to allow for pumpage drawdown and to protect the pump impellers. The water in the top part of the aquifer, thus cased off, is the very part that needs to be sampled and monitored for surveillance of pollution introduced at or near ground surface. In most cases, the surveillance of existing and potential sources of pollution would require new wells drilled specifically for monitoring purposes. The prevention of pollution by eliminating the pollutant at the source would be a wiser course to follow than attempting detection and surveillance of the pollutant after it reaches the ground-water reservoir. In many instances, it will be almost impossible to detect the early stages of pollution despite ideal sampling conditions.

The sampling of near-shore coastal waters at low tidal periods appears, in many cases, to be the most effective method of monitoring for pollution from coastal waste-water injection wells. Each injection site or well, however, will need to be considered separately, owing to the large effect of the local coastal geology on the seaward movement of ground water.

DISCUSSION OF ELEMENTS NEEDED IN THE DESIGN OF A GROUND-WATER-QUALITY MONITORING NETWORK

GEOLOGIC AND HYDROLOGIC ENVIRONMENT

Takasaki (1974) discussed the general geologic and hydrologic environment in Hawaii, including a summary of the rock types and their water-bearing properties, ground-water occurrence and movement, ground-water storage, and a brief geologic history of the islands of Oahu, Maui, Hawaii, and Kauai. Some of that discussion is repeated in this report, particularly some of the more pertinent information as it applies to each of the designated geohydrologic units.

GROUND-WATER MOVEMENT

Ground water generally moves from areas of greatest recharge in the wet interior mountains to areas of greatest discharge at or near the shore. Land development is sparse in the wet recharge areas and is densely concentrated in drier areas along the shore. This natural deterrent to pollution by position of the recharge areas, upgradient from developed areas where most pollutants are generated, has kept much of Hawaii's ground water in its pristine quality state.

The quality of ground water is degraded as water moves downgradient under the developed areas, mostly by pollutants introduced from the land surface and by the intrusion of seawater. Near the coast, ground-water quality ranges from near fresh to saline and from unpolluted to highly polluted. Where municipal or other sewer facilities are absent, pollution of ground water in near-shore marine waters and the beaches is greatest where development is greatest. Unfortunately, where development is greatest, unpolluted near-shore waters and beaches are at a premium.

GROUND-WATER DEVELOPMENT

Ground water occurs as basal water near sea level and, at higher levels, as dike-impounded and perched water. Basal-water sources provide most of the ground-water supply, but dike-impounded and perched water at high levels provide highly important supplies. There are at least 1,500 wells, shafts, and tunnels tapping the ground-water sources. In addition, at least 375 test borings have been drilled to gain information on the aquifer and on the occurrence and movement of ground water. Most of these sites, except for some small-diameter test borings, are potential sampling sites for monitoring or observing ground-water quality.

SOURCES OF POLLUTION OF GROUND WATER

Sources of pollution can be classified as natural or induced and as point or nonpoint. The most important natural source is saline water from the ocean, which underlies basal water. This source, however, becomes one which is induced when the basal water is pumped and causes intrusion of saline water. The term "point source of pollution" as used herein means any discernible, confined, and discrete concentration from which pollutants are or may be discharged. Important point sources include injection wells used for disposal of sewage effluent or other pollutant-laden waste water, solid-waste dumps from which leachate may move down to the water table, and holding ponds from which sewage or agricultural and industrial waste may leak. Common nonpoint sources are the ocean, saline ground water, and seepage from extensively irrigated sugarcane fields. Cesspools can be point or nonpoint sources depending on their size and concentration. A summary of waste types and their nonocean methods of disposal is given by Takasaki (1974).

ESTIMATED USE OF WATER IN 1970

Nonocean disposals of municipal, rural, industrial, and agricultural waste waters contribute significantly to pollution of ground water. Although most waste waters are sewered and disposed of through ocean outfalls, a significant volume of untreated or partly treated waste water is injected into the subsurface. Most agricultural waste waters are ponded. Sometimes the water is reused, and the solids are spread on fields and farms. Otherwise, the waste water percolates to the water table or is channeled to sea.

Estimates of water use in the United States are compiled periodically by the U.S. Geological Survey. The latest assessment was made in 1970 (Murray and Reeves, 1972), during which time the following data for the State of Hawaii were assembled.

Water use in millions of gallons per day, 1970

	State	Kauai	Oahu	Maui	Molokai	Lanai	Hawaii
Public supplies:							
Population served (1,000 people)	(694)	(29)	(564)	(39)	(5)	(2)	(55)
Domestic	137	8	110	10	1	1	8
Industry	14	2	7	2	0	0	3
Rural use:							
Domestic	1	1	1	1	1	1	1
Livestock	8	1	2	2	1	0	4
Irrigation:							
Area in irrigation (1,000 acres)	(157)	(41)	(40)	(47)	(9)	(6)	(14)
Supply	1,280	386	394	460	2	2	36
Reclaimed sewage	6						
Public utilities (thermoelectric):							
Freshwater	128	36	28	25	0	0	39
Saline water	860	3	820	20	0	0	14
Industry (self-supported):							
Freshwater	274	74	43	49	0	0	108
Saline water	16	3	12	1	0	0	0

WELL-NUMBERING SYSTEM

The well-numbering system includes wells, shafts, tunnels, and test borings that tap or penetrate to ground-water bodies. The system is used for the islands of Oahu, Maui, Hawaii, and Kauai. The wells, shafts, tunnels, and test borings on Lanai and Molokai are identified by name or number based on an older, different procedure that is specific for that site but is not a unique location designator. This procedure on Lanai and Molokai is being converted to the well-numbering system used on the principal islands.

The system used for the principal islands is based on latitude and longitude. Each island is subdivided into rectangles by the 1-minute parallels and meridians, the rectangles measuring about a mile on each side. Each rectangle on each island is located by a four-digit number consisting of minutes of latitude followed by minutes of longitude. The identification of the island is provided by a prefix island code number which is separated by a hyphen. The island code numbers are:

1 Niihau
2 Kauai
3 Oahu
4 Molokai
5 Lanai
6 Maui
7 Kahoolawe
8 Hawaii

Within each rectangle, the wells are numbered serially according to the time drilled, where known. The well number then consists of an island code number, followed by a hyphen and a four-digit number that identifies the rectangle, followed by a hyphen and a two-digit serial number.

The numbers, which identify the wells in plate 1, represent only the two-digit serial number part of the numbering system. The island code, the rectangle identification, as well as the zero preceding the digits from 1 to 9 in the serial number have been left out to conserve space. The four-digit number for each island must be extracted from the numbered minute parallels and meridians shown in plate 1 of each principal island. For example, the complete well number for well 1 in plate 1 in the rectangle intersected by the 58th minute of latitude and 22d minute of longitude, is 2–5822–01.

The 1-minute rectangular grid system provides a nonduplicable system for all the islands, except the island of Hawaii. The island of Hawaii is an exception because it encompasses an area greater than 1 degree of latitude and longitude. In order to provide unique four-digit numbers for the island of Hawaii, it was necessary to assign arbitrary numbers to latitude and longitude coordinates beyond the 1- to 59-minute range. This was done by extending the range from 1 to 59 minutes to 1 to 89 minutes. In the extended range, the number 60 then replaces 00 following the number 59, and the number 89 replaces 59 for the number preceding 00.

PRESENTATION OF INFORMATION BY ISLANDS

The information is presented on a generalized geologic map for each major island (figs. 1, 3, 5, 7, 9) and a map showing ground-water areas for each major island (figs. 2, 4, 6, 8, 10; all figures at end of report) as well as on plates also containing tabular matter (pls. 1–5). Four tables are given on each plate and are explained as follows:

TABLE 1. Description of geohydrologic units, inventory of pollution sources, and location of monitoring sites.

Describes topography and rock units, occurrence and movement of ground water, sources of pollution and recipient water bodies, existing sampling effort, and a noting of areas where there are apparent needs for additional samplings.

Column 1, Geohydrologic unit, number.—Numbers in this column refer to areas labeled with bold numbers on the plate for each island.

Column 2, Geohydrologic unit, name.—Unit names in the column are principal place names or geographic features within the boundaries of the units.

Column 3, Topography and rock units.—Given first is a brief listing of the dominant topographic features in the area. Second is a listing of rock units that contain or control the ground water. Some rock units are given as lithologic terms, such as "alluvium," "beach deposits," or "tuff." Others include shortened stratigraphic names with lithologic terms. For example, in table 1, the term "Napali lavas" refers to lava flows of the Napali Formation, and the term "Koloa lavas" refers to lava flows of the Koloa Volcanic Series on the island of Kauai.

Column 4, Ground water, occurrence.—This column gives (1) a short description of the modes of occurrence of the ground water, that is, whether the water is in basal, perched, or dike-impounded aquifers; (2) the extent of development of the water; and (3) the significance of the area as a source of supply.

Column 5, Ground water, movement.—Simplified description of the movement of ground water from the various aquifers in each area. For example, perched water may move down to a basal aquifer; dike-impounded water may discharge into streams; and basal water may flow directly from the rocks into the sea.

Column 6, Sources of pollution and recipient water bodies.—This column gives, for each area, brief statements on the types and number of sources of pollution that might reach the ground water and the ground-water bodies in the area that might be affected by the pollution. Principal potential sources of pollution at waste-disposal sites as of 1972 have been tabulated and shown on maps by Takasaki (1974).

Column 7, Wells monitored.—Listed are wells identified by number in each area at which samples of water are taken on a regular schedule for chemical or biological analyses and determination of the concentration of chloride in the water. Also included in the column are beach sites, which are sampled by the State Department of Health. These near-shore sampling sites are primarily used to monitor for pollution from surface sources. Many of these sites can be used to monitor for pollution from ground-water sources, as well.

Column 8, Candidate monitor wells.—In this column are listed the wells that appear usable as sites for monitoring ground-water quality, classified according to the aquifer that they tap, and a short statement of the need for the monitoring of water quality in each area. For some areas, specific wells are identified; for some, the number of wells is given; and for others, reference is made to the plate, which shows the locations of wells on each island.

TABLE 2. Rock units.

Generalized stratigraphic sequence of rock units showing general character, water-bearing properties, and location in the geohydrologic units. The water-bearing properties of the rock units are, for the most part, designated as highly, moderately, or lowly permeable. The hydraulic conductivity (K) for these designations are roughly: highly permeable, K greater than 500; moderately permeable, K about 100; and lowly permeable, K less than 10.

TABLE 3. Aquifers tapped by wells, shafts, test borings, tunnels, and springs.

Denotes aquifers tapped in the geohydrologic units but not the development details of construction and hardware.

TABLE 4. Pollution potential of seawater, irrigation water, and common wastes.

The pollution potential of seawater, irrigation water, and common wastes is designated as high, medium, or low for each geohydrologic unit. The designation is primarily based upon geohydrologic conditions, and secondarily upon geomorphic and climatic conditions. Owing to variations in population density, in land use, and in the hydrologic elements within the units, the designation is, at best, a generalized one. It serves, however, to flag those areas and types of waste disposal that may require a closer look or preventive measures and identifies areas that do not warrant immediate concern.

The degree of pollution and subsequent effect on the usability or fate of the recipient ground water is not discernible without information on the identity and quality of the pollutant, and the quality and rate of movement of the recipient ground water.

ISLAND OF KAUAI

The high perennial fair-weather flow of most streams of Kauai indicates that much of the ground-water discharge is into stream channels and that the underflow discharge of water directly to sea is only a small fraction of that which discharges as streamflow. This is the result of high water levels in the Napali Formation under the higher slopes and in the Koloa Volcanic Series under the lower slopes, which promote the flow of ground water into stream channels that cut deep into saturated rock.

These factors should be considered in evaluating ground-water pollution resulting from the surface and subsurface disposal of wastes and in the monitoring and surveillance of the pollution. The areas of concern are in geohydrologic units 3, 5, 6, 8, 11, 13, and 16.

ISLAND OF OAHU

The Koolau volcano is chiefly composed of highly permeable basaltic lavas and the less permeable andesitic veneer common to most Hawaiian volcanoes is absent. This makes the Koolau Range a highly permeable rock mass. In contrast, much of the Waianae Range is veneered by andesite and is a less permeable rock mass than that of the Koolau Range.

The Koolau Range contains large bodies of ground water, which are easily accessible to pollution from disposal of waste at the surface or in the subsurface. Most waste-disposal sites, however, are in the coastal-plain areas where the Koolau Volcanic Series is overlain by thick sedimentary material. Pollutants from wastes introduced at or near the surface in the coastal areas will generally not enter water bodies in the Koolau lavas because water levels are higher in the lavas than in the sedimentary material. The pollutants entering water bodies in the sedimentary material will eventually discharge into the coastal waters, and wastes injected at shoreline may show up in the surf.

In the areas where the streams are gaining, as in the Kaneohe area, wastes injected into the subsurface near streams will likely be discharged as effluent flow in the stream channels.

ISLAND OF MAUI

The permeable basaltic lavas of the Haleakala volcano are completely veneered by less permeable andesite, which, in turn, is partly veneered by more permeable posterosional lavas. On West Maui, the basaltic lavas are less completely veneered by andesite and trachyte.

Major sources of pollution of ground water in the Haleakala mass are leachate from cesspools and irrigation-water return from sugarcane fields. There are no major domestic ground-water sources. Of principal concern in east Maui is the fate of treated effluent from the sewered areas which is planned for disposal by injection into wells. Also of some concern is the fate of sewage effluent and other wastes which are discharged into the ground by many injection wells in areas not yet provided with sewers.

Domestic ground-water sources in the Lahaina area of West Maui are subject to pollution from irrigation-water return and the intrusion of saline water. The pollution of near-shore coastal waters resulting from the discharge of polluted ground water in the highly developed western coast of West Maui is a major concern.

ISLAND OF MOLOKAI

The most important source of water, presently only partly developed by the Molokai tunnel, is high-level dike water. It mostly occurs in the high mountainous interior of windward Molokai. Basal water, especially in the leeward areas of east Molokai, provides important sources of supply. Perched-water supplies are small but provide some important high-level sources. Most of Molokai's domestic ground-water sources are located upgradient from developed areas and are subject to little pollution by man.

Near-shore waters are the recipient of all wastes injected into the subsurface.

ISLAND OF LANAI

High-level impounded ground water in the central part of the island is the most important water source. The water is impounded by dikes or faults or a combination of both. Nearly all of the irrigation and domestic water is supplied from this source.

This water body is recharged by rainfall, by irrigation-water return, and by cesspool effluent. The chemical quality of one of the high-level sources has not changed significantly since 1936. The water is relatively free of bacteria and is being used without treatment.

Basal water in rock surrounding the central area of high-level water is too brackish for domestic use.

ISLAND OF HAWAII

The small number of perennial streams on the island of Hawaii indicate the highly pervious nature of much of the surface rocks. Some streams flow perennially in their wet upper reaches but lose their water to the ground well before reaching the sea. Liquid waste injected into the subsurface, or the leachate from wastes on the surface behaves nearly the same as recharge from rainwater and will easily enter the underlying ground-water bodies.

Of principal concern is pollution of ground-water bodies and of the near-shore coastal waters from cesspool leachate and sewage-waste disposal in the subsurface.

Sedimentary materials are sparse and occur only in the Kohala area and the area of the northern Hamakua coast. Except locally, these are not important hydrologically.

REFERENCES CITED

Bowles, S. P., 1973, The water resources of Lanai: A report for Dole Co.

Davis, D. A., and Yamanaga, George, 1973, Water resources summary, island of Hawaii: Hawaii Div. Water and Land Devel. Rept. R47, 42 p.

Macdonald, G. A., Davis, D. A., and Cox, D. C., 1960, Geology and ground-water resources of the island of Kauai, Hawaii: Hawaii Div. Hydrography Bull. 13, 212 p.

Murray, C. R., and Reeves, E. B., 1972, Estimated use of water in the United States in 1970: U.S. Geol. Survey Circ. 676, 37 p.

Stearns, H. T., 1939, Geologic map and guide of Oahu, Hawaii: Hawaii Div. Hydrography Bull. 2, 75 p.

———1940, Geology and ground-water resources of Lanai and Kahoolawe, Hawaii, with chapters by G. A. Macdonald and J. H. Swartz: Hawaii Div. Hydrography Bull. 6, 176 p.

———1946, Geology of the Hawaiian Islands [2d printing]: Hawaii Div. Hydrography Bull. 8, 112 p.

———1966, Geology of the State of Hawaii: Palo Alto, Calif., Pacific Books, 266 p.

Stearns, H. T., and Macdonald, G. A., 1942, Geology and ground-water resources of Maui, Hawaii: Hawaii Div. Hydrography Bull. 7, 344 p.

———1947, Geology and ground-water resources of the island of Molokai, Hawaii: Hawaii Div. Hydrography Bull. 11, 113 p.

Takasaki, K. J., 1974, Hydrologic conditions related to subsurface and surface disposal of wastes in Hawaii: U.S. Geol. Survey Water Resources Inv. 1–74, 5 sheets.

FIGURES 1–10

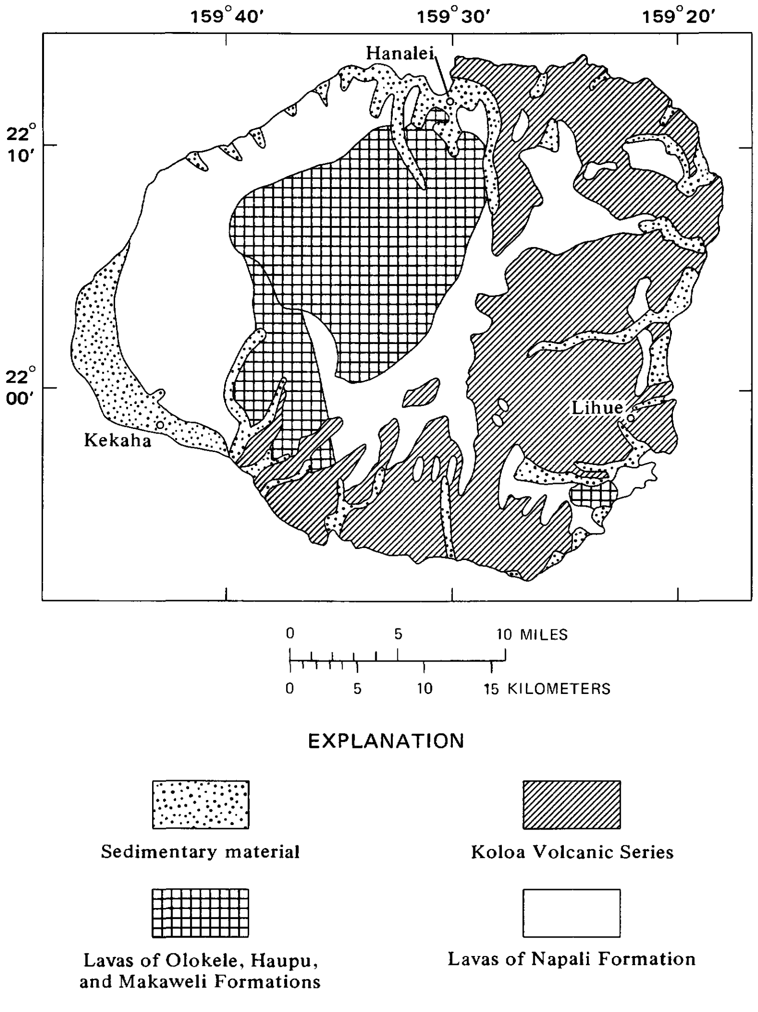

FIGURE 1.—Generalized geologic map of Kauai.

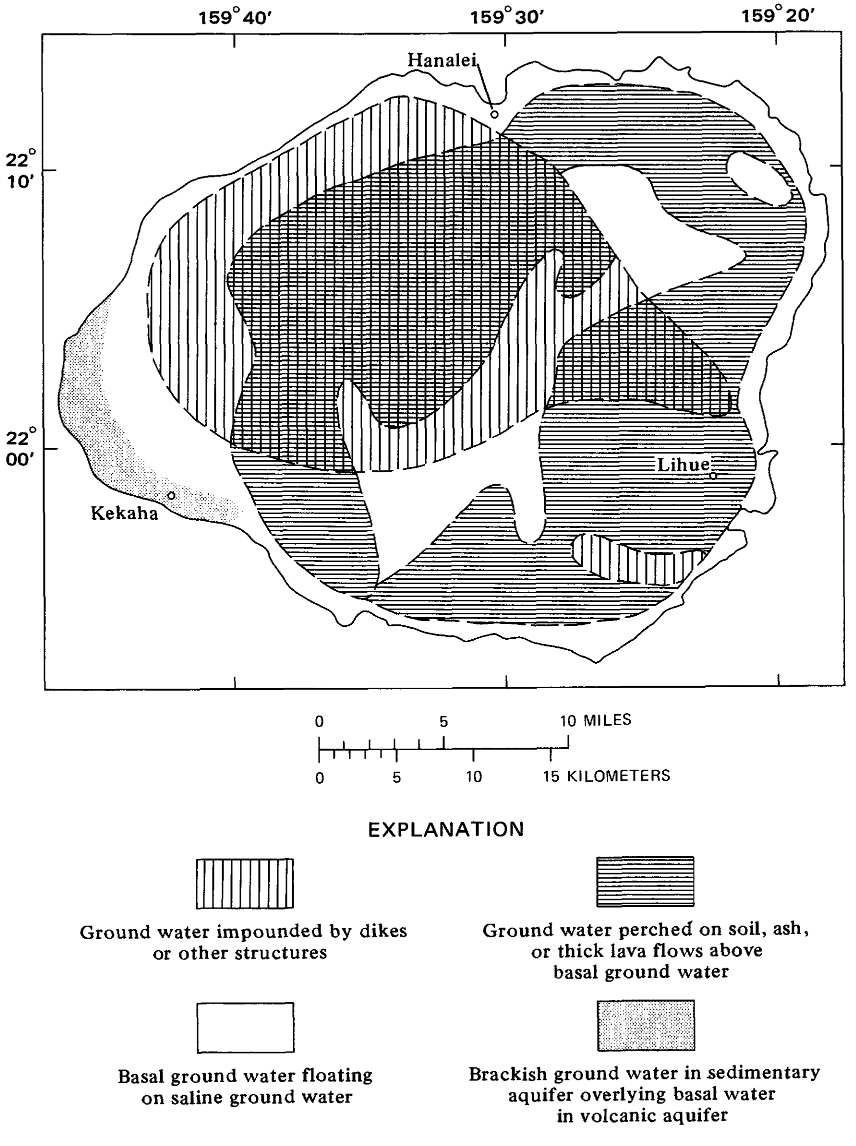

FIGURE 2.—Map of island of Kauai showing approximate outline of ground-water areas.

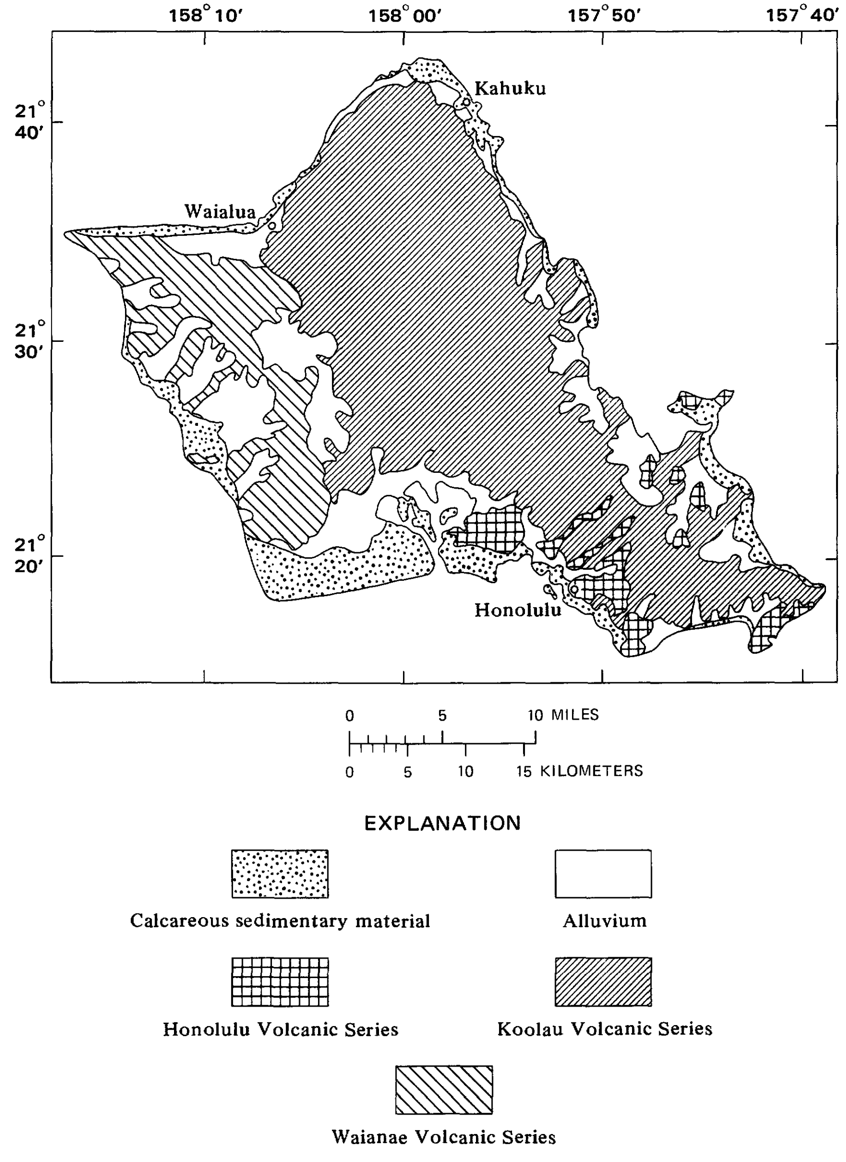

FIGURE 3.—Generalized geologic map of Oahu.

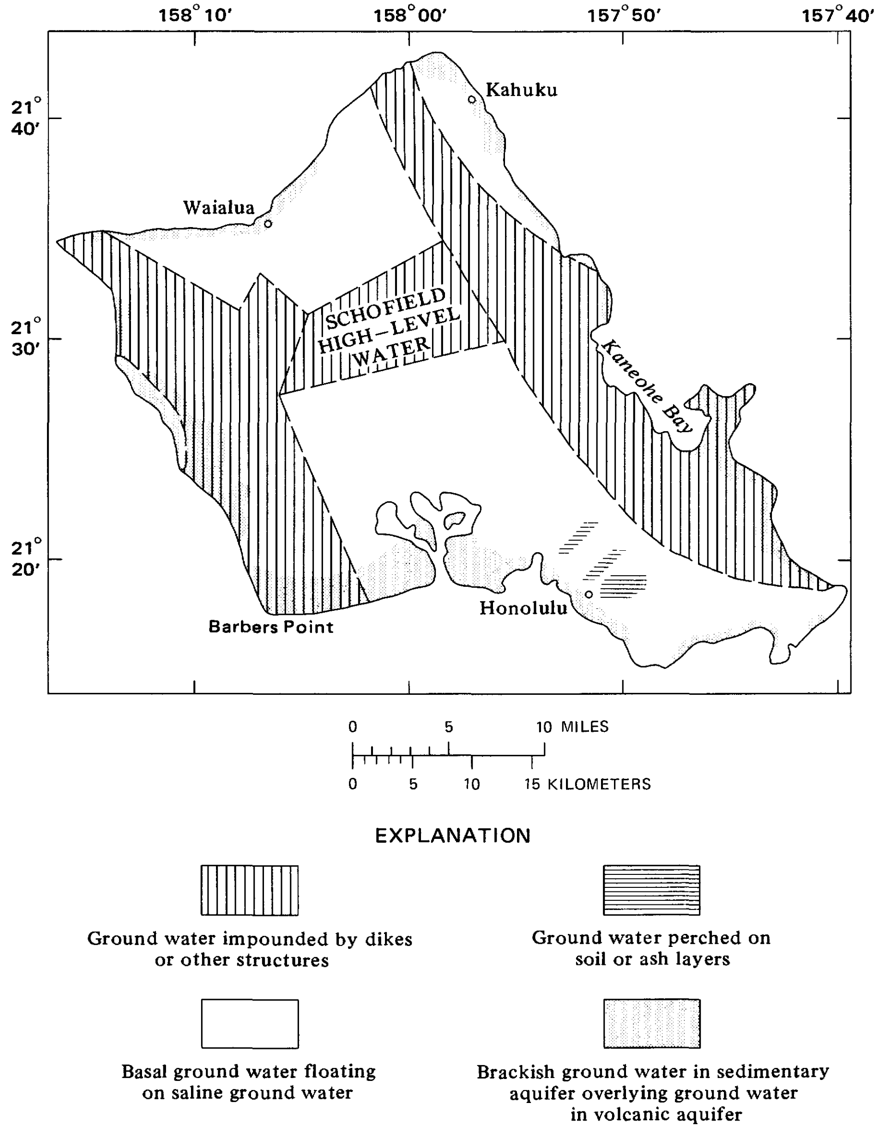

FIGURE 4.—Map of island of Oahu showing approximate outline of ground-water areas.

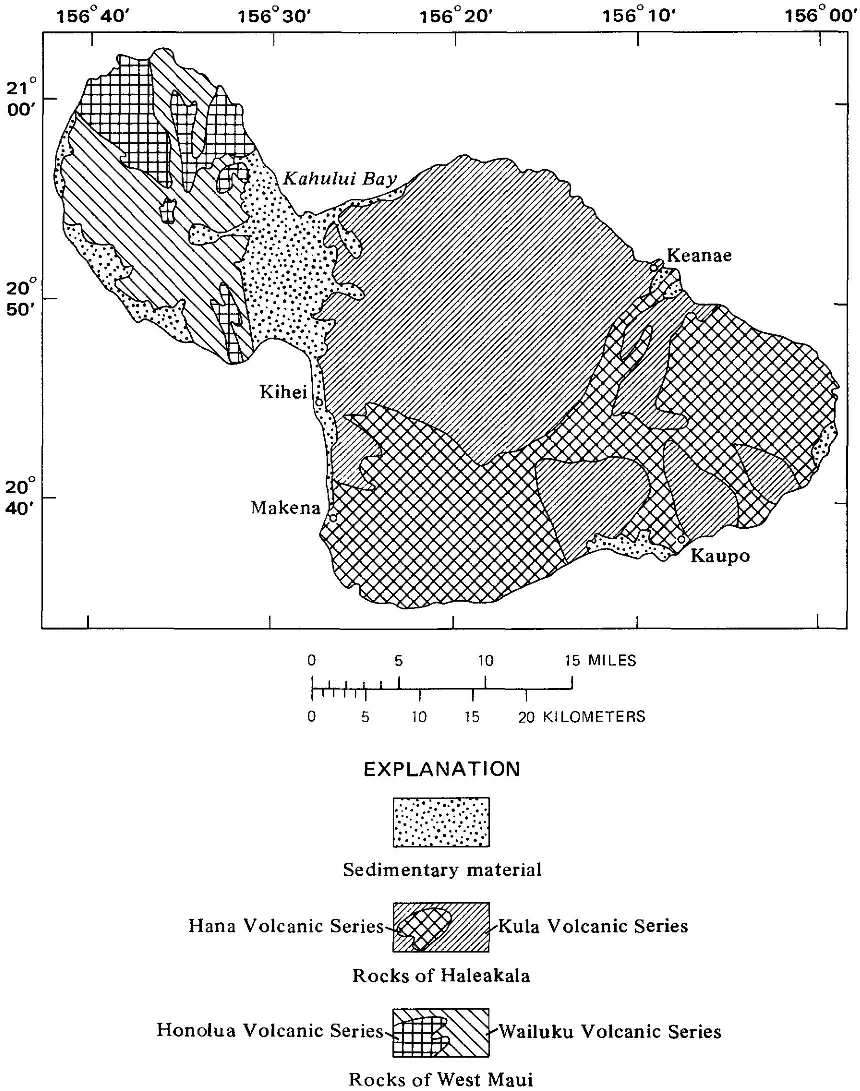

FIGURE 5.—Generalized geologic map of Maui.

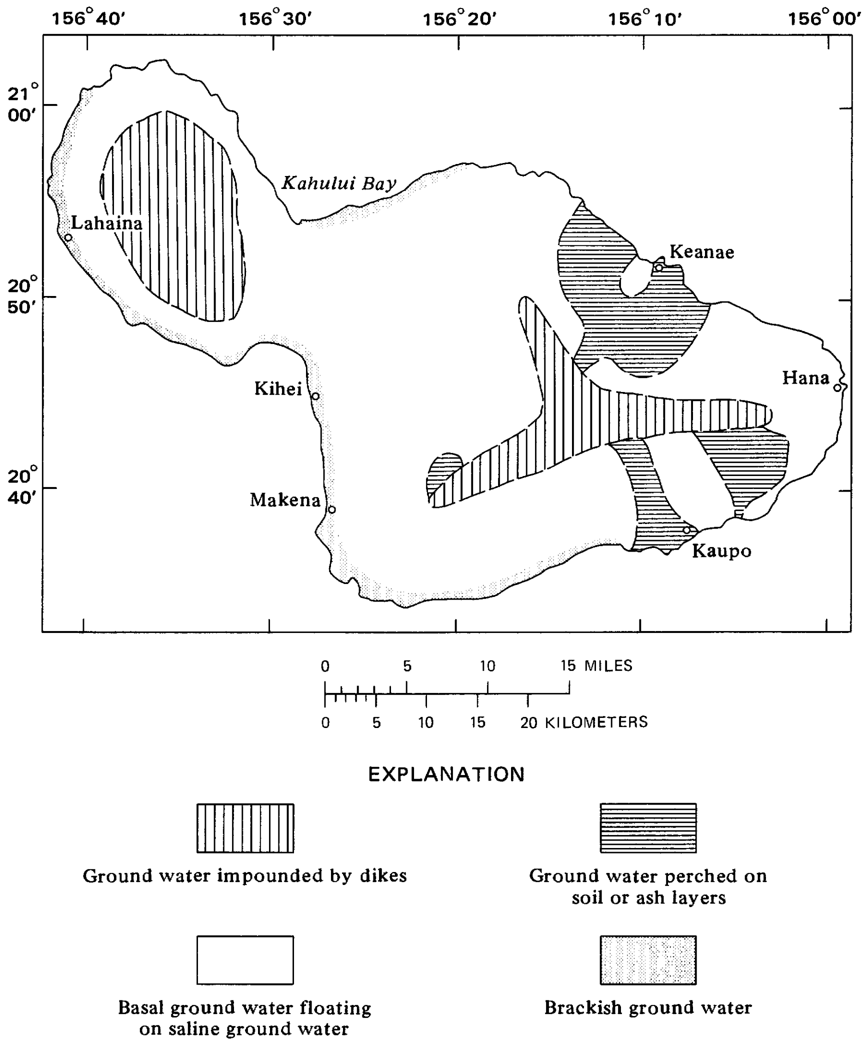

FIGURE 6.—Map of island of Maui showing approximate outline of ground-water areas.

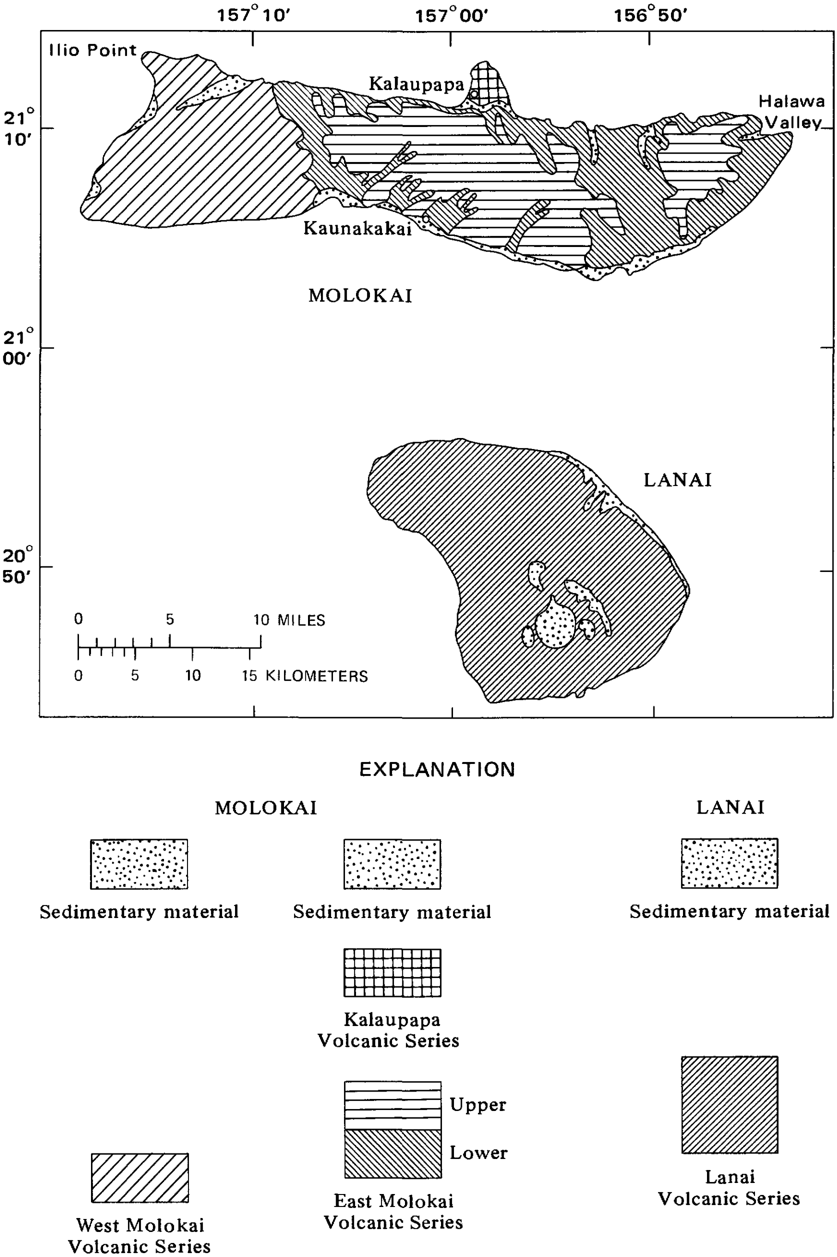

FIGURE 7.—Generalized geologic map of Molokai and Lanai.

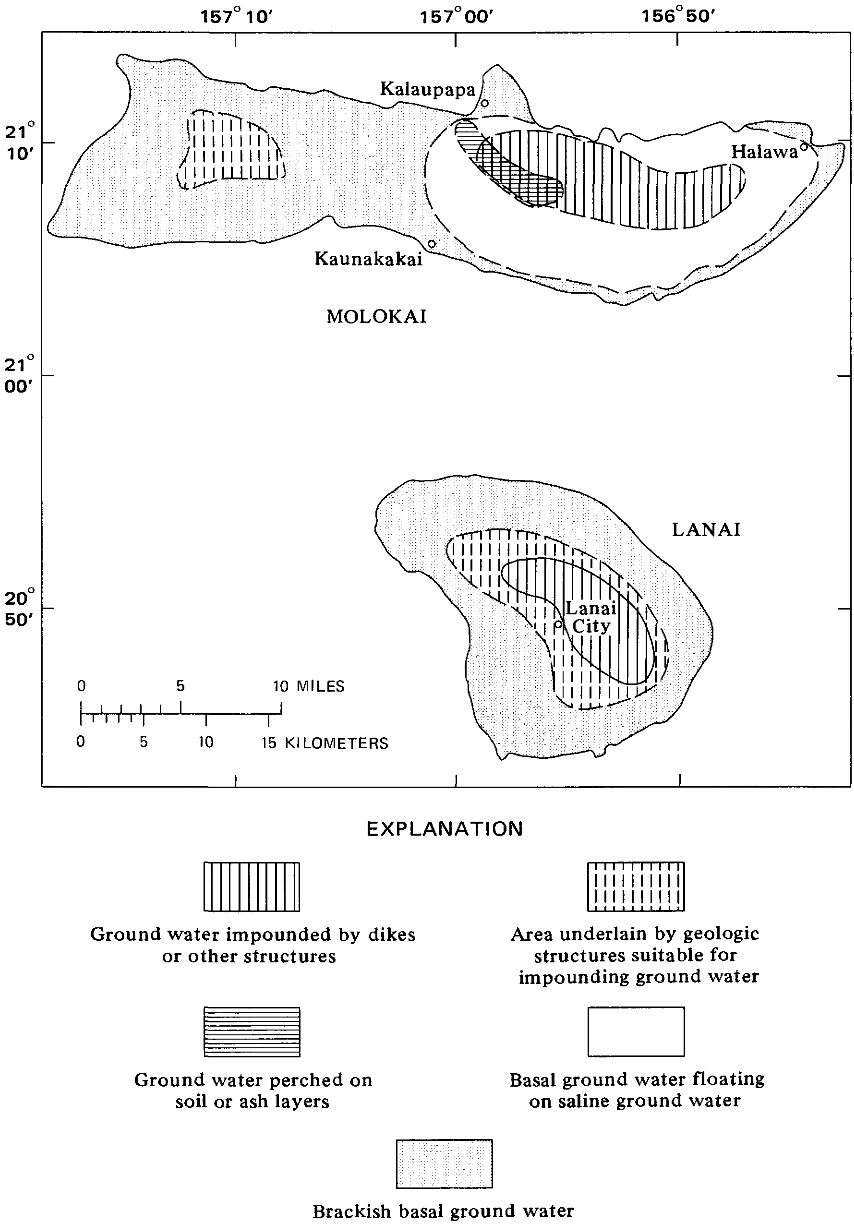

FIGURE 8.—Map of islands of Molokai and Lanai showing ground-water areas.

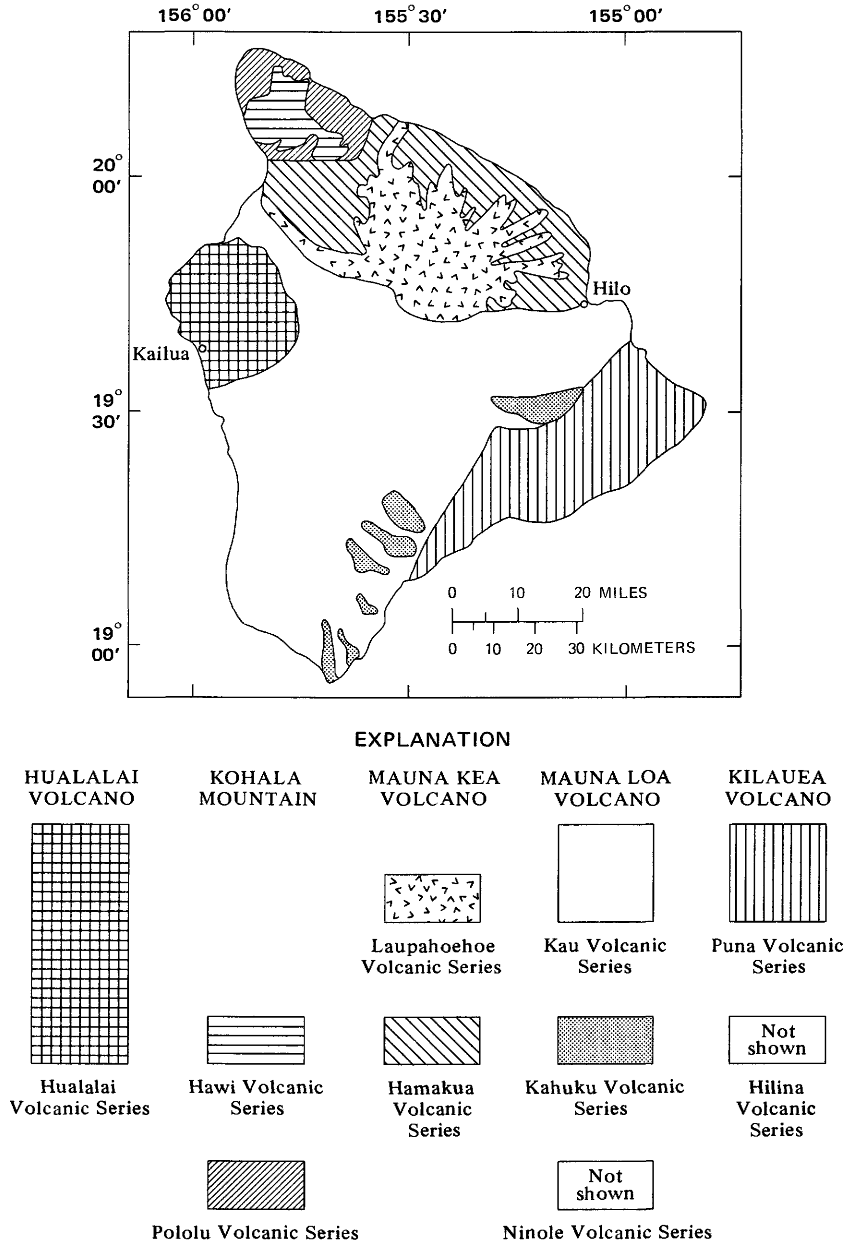

FIGURE 9.—Generalized geologic map of the island of Hawaii.

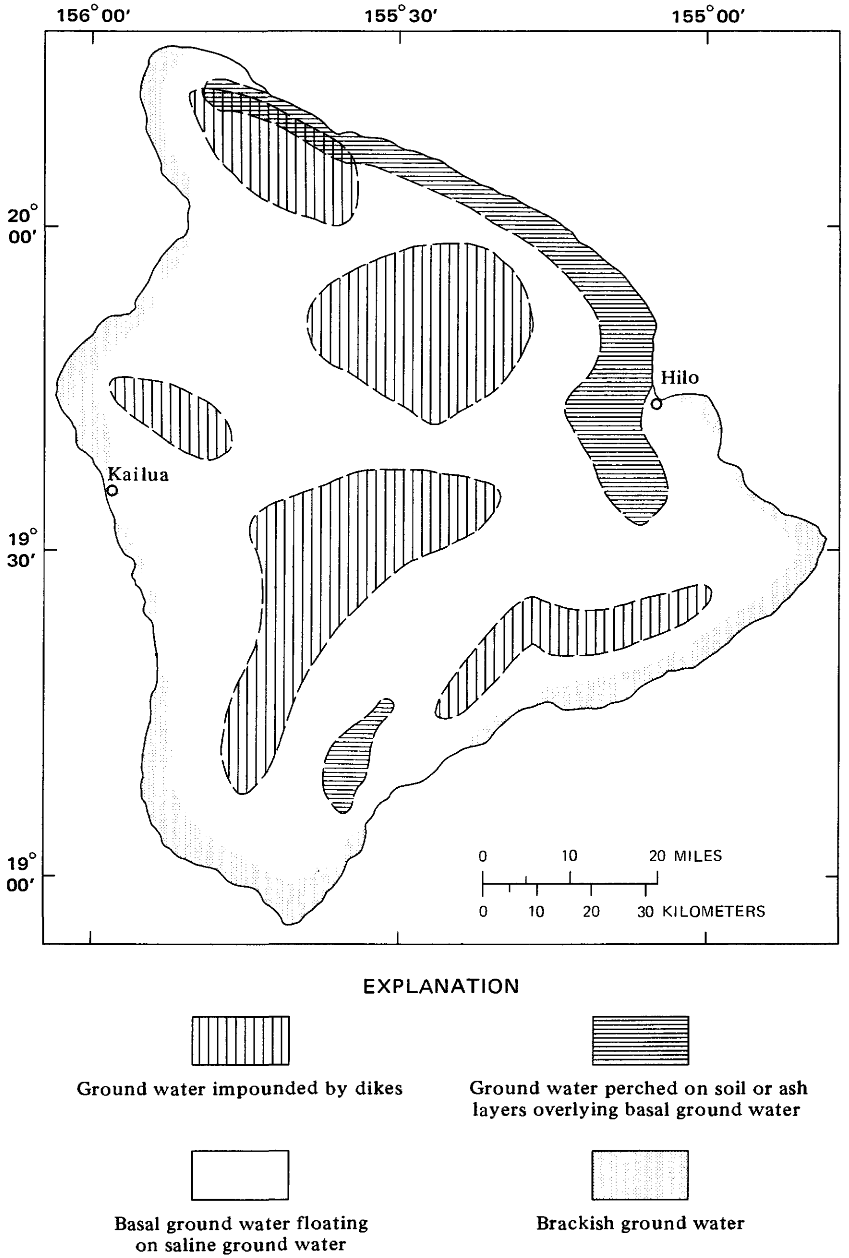

FIGURE 10.—Map of island of Hawaii showing approximate outline of ground-water areas.

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