EVALUATION OF THE SURFACE-WATER QUANTITY, SURFACE-WATER QUALITY, AND RAINFALL DATA-COLLECTION PROGRAMS IN HAWAII, 1994

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Conversion Factors

Multiply	By	To obtain
acre-foot per square mile (acre-ft/mi^2)	476.3	cubic meters per square kilometers
foot (ft)	0.3048	meter
million gallons per day (Mgal/d)	0.04381	cubic meter per second
inch (in.)	25.4	millimeter
square mile (mi^2)	2.590	square kilometer

Evaluation of the Surface-Water Quantity, Surface-Water Quality, and Rainfall Data-Collection Programs in Hawaii

By Richard A. Fontaine

Abstract

This report documents the results of an evaluation of the surface-water quantity, surface-water quality, and rainfall data-collection programs in Hawaii. Fourteen specific issues and related goals were identified for the surface-water quantity program and a geographic information systems (GIS) data base was developed summarizing information for all surface-water stream gages that have been operated in Hawaii by the U.S. Geological Survey. Changes in status, which for some gages includes discontinuing operation, need to be considered at 42 sites where data are currently collected.

The current surface-water quantity data base was determined to be adequate to address only two of the 14 specific issues and related goals. Alternatives were identified to address the areas where future issues and goals could not be adequately addressed. Options include new and expanded data collection, use of regional regression analyses, hydrologic and hydraulic modeling, and analysis and publication of existing data. A total of 47 streams were identified where additional stream-gaging stations are needed.

Evaluation of the surface-water quality program was limited to a description of the U.S. Geological Survey's historical and existing programs and available analyses of data. Limitations of the program are described which primarily included lack of data regarding suspended sediment, land-use effects, quality of stream discharge to oceans, background water quality and nonpoint sources of contamination.

Evaluation of the rainfall data program indicated that identified future goals could be discussed as either regional, systems related, current needs, forecasting, water quality, or trend analysis related.

To address these goals, data from about 2,000 rain gages, 528 of which are active, are available. Data were found to only partially meet identified goals. Alternatives discussed to address the limitations include the need for more recording gages, primarily in areas of high rainfall. Another area of concern was the potential that many plantations will close and the effect these closings would have on continued operation of the important long-term gages they operate.

Evaluation of data-collection programs in Hawaii needs to be an ongoing process. Equally important, data being collected need to be summarized and made available through data bases and published reports.

INTRODUCTION

Background

Water resources of the State of Hawaii are limited but vital. The limitations of the resource, coupled with ever-increasing water requirements, frequently places water users in direct conflict with each other and with the environmentally sensitive and unique aquatic ecosystems on the islands. The need to clarify water rights throughout the State led to the enactment, in 1987, of the State Water Code to "protect, control, and regulate the use of Hawaii's water resources for the benefit of its people" (Hawaii Commission on Water Resource Management, 1992a, p. II-1).

The Commission on Water Resource Management, Department of Land and Natural Resources, was created and given the responsibility to oversee implementation of the State Water Code. The Commission has the authority and responsibility to protect, control, and regulate the ground-water and surface-water resources of the State. To accomplish this task the Commission needs information on the quality and quantity of surface water, rainfall, ground water, and water use, and how these elements interact naturally and in response to stresses.

There is a long history of programs that were established to collect surface-water, ground-water, water-quality, rainfall, and water-use data in Hawaii. These data-collection programs developed over a number of years in response to a variety of needs. These needs were often site and area specific. Some of the early needs either may have been met or no longer exist. It is also possible that the data required to meet current and future needs do not exist and are not currently being collected. The surface-water, ground-water, water-quality, rainfall, and water-use data-collection programs in Hawaii need to be evaluated in light of recent regulatory developments to determine their adequacy. The evaluation is important because budgetary restrictions exist and it may not be possible to collect all the data required.

Previous evaluations of data-collection programs in Hawaii have emphasized either the description and summary of available data (Giambelluca and others, 1984: Matsuoka, 1981: and Miyamoto and others, 1986) or the analysis of individual elements within specific data-collection programs (Matsuoka and others, 1985: Nakahara, 1980: Takasaki, 1977: and Yamanaga, 1972). Analysis of individual programs, for example that of only surface water, commonly does not take into account the interrelations that exist among the various disciplines. In addition, evaluations have commonly focused on individual islands and not the State. This report evaluates the surface-water quantity, surface-water quality, and rainfall data-collection programs in Hawaii and is the result of a cooperative study between the Department of Land and Natural Resources and the U.S. Geological Survey.

Purpose and Scope

This report describes an evaluation of the surface-water quantity, surface-water quality, and rainfall data-collection programs in Hawaii through 1994. The evaluation was conducted in four major steps:

1. Current issues and long-term goals for the data-collection programs were determined. The issues and goals were based on information contributed from State, county, local, and federal agencies, universities, major water users, and environmental groups.

2. The current status of the data-collection programs were described and a geographic information system (GIS) data base was developed summarizing the historical and current surface-water quantity gages operated in Hawaii.

3. The data-collection programs were evaluated to determine first, which of the goals identified have been achieved, and second, which programs as they currently exist are adequate to address goals that have not been achieved.

4. Alternative data-collection and interpretive techniques that can be used to address identified deficiencies in the current data-collection programs were described.

The scope of the work was limited to the five major Hawaiian islands of Kauai, Oahu, Molokai, Maui, and Hawaii. The report is organized into three sections, one section for each of the data-collection programs being evaluated. Within the surface-water quantity and rainfall sections the four major steps in the evaluation are discussed. The surface-water quantity section focuses on the USGS data-collection programs and the rainfall section focuses on the data-collection programs of multiple agencies. No cooperative program between the U.S. Geological Survey and the Hawaii Department of Land and Natural Resources to collect surface-water quality data currently exists. Therefore, the evaluation of the surface-water quality program was limited to a description of historical and current data-collection activities, a discussion of the availability and analyses of data collected, and a summary of the limitations of the program. The evaluation of the surface-water quantity, surface-water quality, and rainfall data-collection programs will be presented for the five major islands as a group.

SURFACE-WATER QUANTITY DATA-COLLECTION PROGRAM

Issues and Goals of the Program

The first step in the evaluation of the surface-water data-collection program in Hawaii was to identify specific goals against which the adequacy of existing data and the current data-collection program could be reviewed. The evaluation proceeds with the question of whether the existing data are sufficient to address the identified goals. If yes, then additional data collection is not warranted. If no, then can the present data-collection program be expected to provide the data required? If the answer to this second question is yes then no immediate changes in the current data-collection program are needed. If the answer is no then alternative data-collection strategies need to be developed.

Goals for the surface-water quantity and rainfall (discussed later in the report) data-collection programs are based on information provided by cooperating agencies (primarily the Hawaii Department of Land and Natural Resources and the U.S. Geological Survey) and other users of the data. In this study, data users included State, county, local, and federal agencies, universities, major water users, and environmental groups. Evaluations of data-collection programs typically rely on methods such as the use of formal written questionnaires (W.O. Thomas, Jr., U.S. Geological Survey, written commun., 1993). In this study, information was obtained using a combination of telephone conversations, meetings, and written requests. In addition, reviews of existing literature such as the State Water Code (State of Hawaii, 1990), the Hawaii Water Plan (Hawaii Commission on Water Resource Management, 1990a, 1991a, 1991b, 1991c, 1992a, 1992b, 1992c), the Hawaii Stream Assessment (Hawaii Commission on Water Resource Management, 1990b), previous evaluations of the Hawaii surface-water program (Matsuoka and others, 1985 and Yamanaga, 1972), and issues surveys (Heitz, 1989) provided valuable information.

While soliciting information regarding the data-collection program, two facts became evident. First, interaction with data users regarding the adequacy of the programs needs to be an ongoing process. Goals for the data-collection programs are constantly evolving and the programs need to be flexible enough to meet these changing goals. Frequent interaction also serves to keep a focus on long-term goals, the importance of which needs to be continually reinforced. Second, data users generally think more in terms of broader issues and problems and often rely on those who collect the data to be able to translate the issues and problems into specific goals and recommended plans for action.

Interactions with data users identified several specific issues related to the surface-water quantity data-collection program. Several of the identified issues, for example 5, 6, and 7 (listed below) are highly related and can be served by identical networks. However, for the purposes of this report, each issue will be discussed individually. The most important issues, not necessarily in order of priority, are as follows:

1. Ground-water availability
2. Surface-water availability
3. Long-term baseline data-collection and trends
4. Streams for protection
5. Identification of perennial stream reaches
6. Ground water/surface water interaction
7. Perennial stream data
8. Intermittent stream data
9. Major streams and water-diversion systems
10. Hydrologic hazards
11. Land-use changes
12. Availability of data
13. Purposes for operating individual gages
14. Analysis of data collected

Goals for the surface-water data-collection program associated with each of the issues were then identified. The goals identified need to serve as a base for data-collection activities. Identified issues and goals need to be routinely reviewed and updated or modified as required.

1. Ground-water availability.--Information on the distribution of ground-water recharge over time and area is needed to estimate ground-water availability. Water-balance analyses are frequently used to estimate this recharge.

The goal of the surface-water data-collection program is to provide data describing the variability of total stream runoff over watershed or aquifer areas where ground-water availability needs to be quantified. Total runoff data need to be partitioned into direct runoff and ground-water (base-flow) components.

2. Surface-water availability.--Knowledge of the magnitude, variability, and frequency of surface-water runoff is critical when considering instream and off-stream water-use issues. According to the State Water Code, beneficial instream uses include, but are not limited to (1) maintenance of fish and wildlife habitats (2) outdoor recreational activities, (3) maintenance of ecosystems such as estuaries, wetlands, and stream vegetation, (4) aesthetic values such as waterfalls and scenic waterways, (5) navigation, (6) instream hydropower generation, (7) maintenance of water quality, (8) the conveyance of irrigation and domestic water supplies to downstream points of diversion, and (9) the protection of traditional and customary Hawaiian rights (Hawaii Commission on Water Resource Management, 1992a, p. 190). Offstream uses include diversions for irrigation and water supply.

The goal of the surface-water data-collection program is to provide information on streamflow characteristics at any site on any stream. Included as part of this goal is the need to determine the effects of upstream alterations on the natural flow regime at points downstream.

3. Long-term baseline data-collection and trends.--Long-term baseline data are collected to provide a series of consistent observations on streamflow. The data are used to identify trends in streamflow and to analyze the statistical structure of hydrologic time series (Benson and Carter, 1973, p. 9). These data provide a baseline for evaluating changes in the flow regimes of other streams associated with site-specific issues such as major alterations in land-use or changes associated with large-scale issues such as global climate change.

The goal of the surface-water data-collection program is to collect data indefinitely at specific sites on streams draining basins that have undergone no significant human-made changes and are expected to remain that way in the future. Long-term trend data need to be collected in a variety of physical and climatologic settings that provide a representative sampling of the variability of hydrologic characteristics that exist in Hawaii.

4. Identification of streams for protection.--The Hawaii State Water Code provides that candidate streams for protection be identified. Protection can be defined as the attempt to minimize unnatural reductions in streamflows and degradations of water quality. The first attempt at identifying streams for protection is summarized in the Hawaii Stream Assessment report (Hawaii Commission on Water Resource Management, 1990b, table 1). The report identified 43 streams Statewide that were potential candidates for protection. The Stream Protection and Management Task Force has subsequently been established to further this effort.

The goal of the surface-water data-collection program is to describe the variability of streamflow over time and along streams identified for protection. A watershed approach needs to be used for protecting streams. Therefore, collection of ancillary information such as land-use and water-use data may be needed to support descriptions of streamflow variability.

5. Identification of perennial stream reaches.--The Hawaii Stream Assessment (HSA) (Hawaii Commission on Water Resource Management, 1990b) classified streams as perennial if surface flow occurred year-round in all or part of their reaches. Using this criterion, 376 perennial streams were identified in Hawaii (Hawaii Commission on Water Resource Management, 1990b, p. 9). The identified perennial streams were further classified as either continuous (flows to the sea year-round) or interrupted (flows year-round in the upper elevations and intermittently at lower elevations). When classifying streams, their relation to both time and space are important (Langbein and Iseri, 1960, p. 18): it is important to know whether streams flow continuously or intermittently and over which reaches or stream segments do these conditions exist.

The goal of the surface-water data-collection program is to provide data that can be used to identify whether streams flow continuously or intermittently and over which reaches these conditions exist.

6. Ground-water/surface-water interaction.--Langbein and Iseri (1960, p. 18) noted that streams can also be classified in terms of their relation to ground water, such as whether the stream is gaining water from or losing water to ground water. The importance of understanding the interaction between ground water and surface water in Hawaiian streams was highlighted in the Hawaii Water Plan (Hawaii Commission on Water Resource Management, 1992a, p. 11). Pumping ground water from zones of saturation hydraulically connected to streams will reduce streamflow. The issue now becomes one of a tradeoff: do the benefits of developing the ground-water supply outweigh the effects associated with reduced streamflow? The reverse also needs to be considered. Diversion of streamflow from losing reaches will likely reduce the magnitude of recharge to the ground-water system from the stream.

The goal of the surface-water data-collection program is to be able to identify gaining and losing stream reaches and to relate their occurrence and distribution to the regional ground-water system.

7. Perennial stream data.--Hawaii citizens and decisionmakers recognize the need to balance uses of perennial streams with environmental protection (Hawaii Department of Land and Natural Resources, 1993, p. 6). In perennial streams, the entire flow regime from low to high flow and from wet season to dry season along the entire reach is critical to the aquatic organisms they support. Data are needed to evaluate the resource in terms of identifying what is present. These data become the benchmark from which to measure the changes that could result from either natural or human-induced stress.

As a result of their prominent role, perennial streams have been and will likely continue to be the focal point for most surface-water data-collection efforts in Hawaii.

The goal of the surface-water data-collection program is to provide the data necessary to describe the occurrence and distribution of streamflow along perennial streams. Data are also needed so that stream response to natural or human-induced stresses can be evaluated.

8. Intermittent stream data.--Because perennial streams have been the primary focus of surface-water interest in Hawaii, relatively little is known about the variability, persistence, and distribution of streamflow on intermittent streams. Intermittent streams frequently drain high-rainfall upland areas that generate significant volumes of runoff. Much of this runoff infiltrates through stream beds at lower elevations, providing an important source of ground-water recharge. Flooding can also be a significant issue on intermittent streams. In this report, no distinction is made between intermittent and ephemeral streams.

The goal of the surface-water data-collection program is to collect data that can be used to describe the variability, persistence, and distribution of streamflow on intermittent streams in Hawaii.

9. Major streams and water-diversion systems.--Several criteria are available for classifying streams by size including length, magnitude of streamflow, and drainage area. In the HSA streamflow was used for classifying streams by size (Hawaii Commission on Water Resource Management, 1990b, p. 44). However, only 139 of Hawaii's 376 perennial streams have gage data available (Hawaii Commission on Water Resource Management, 1990b, p. 43). All major stream systems are important because they drain large percentages of the area of individual islands and aquifer areas and account for significant volumes of the total runoff. For example, the Waimea, Wailua, Hanapepe, and Hanalei Rivers combined drain about 187 mi^2 or 34 percent of the total land area of the island of Kauai (553 mi^2). The major streams typically are also among the most heavily modified by instream and offstream uses.

Major water-diversion systems remove and transport large volumes of water from streams, usually for offstream uses. For example, the Koolau diversion system on Maui transports an average of 164 Mgal/d (Hawaii Commission on Water Resource Management, 1992a, app. D). This flow rate is greater than the average discharge of any of the large streams for all islands identified in the HSA (Hawaii Commission on Water Resource Management, 1990b, p. 55). Individual water-diversion systems commonly tap several stream or aquifer sources. Determination of flow in both major stream and water-diversion systems is therefore important both in terms of water accounting and regulation of its use.

The goal of the surface-water data-collection program is to provide the data required to account for sources and sinks of water along major streams and water-diversion systems.

10. Hydrologic hazards.--Hazards associated with hydrologic extremes, such as floods and droughts (Lee, 1990, and Giambelluca and others, 1991) and debris flows (Torikai and Wilson, 1992), are common in Hawaii. Median annual rainfall ranges from less than 7 in. near Kawaihae Bay, on the island of Hawaii, to 451 in. at the top of Mt. Waialeale, on Kauai (Hawaii Division of Water and Land Development, 1982). Lee and Valenciano (1986, p. 201) reported that rainfall intensities in excess of 10 in/d can be expected at least once a year somewhere in Hawaii. Data are required to improve the ability to estimate probabilities of occurrence and likely magnitudes of hydrologic hazards. These estimates in turn are the basis for design of either structural and/or non-structural mitigative measures and development plans that avoid high-risk areas. The estimates also provide the basis for any type of advance-warning system. Data are also required to evaluate the performance and safety of hazard-prevention structures already built.

The goal of the surface-water data-collection program is to provide the data required to estimate probabilities of occurrence and likely magnitudes of hydrologic hazards for all streams in Hawaii. The program also needs to provide data required to evaluate the adequacy and safety of preventative measures taken.

Hazards included are those associated with floods and extended periods of deficient streamflow.

11. Land-use changes.--Rainfall-runoff relations in drainage basins are controlled by the interaction of several variables, one of the most significant being land use. Changes in land use, such as conversion from agricultural to residential development, are common in Hawaii. The effects of such changes on flood magnitudes and frequencies and ground-water recharge needs to be considered. Streamflow data are also required to evaluate the water-quality implications of land-use changes. Another category of land-use change is stream channelization. More than 19 percent of Hawaii's perennial streams have been channelized to some extent (Hawaii Commission on Water Resource Management, 1990b, p. 98). The effects of these changes need to be understood.

The goal of the surface-water data-collection program is to collect data on streams draining basins that sample a variety of land uses found in Hawaii. At the same time streamflow data are being collected, the status of land-use changes within the subject drainage basins needs to be monitored. These data provide the basis for evaluating effects of changes on rainfall-runoff relations.

12. Availability of data.--Collecting data is only the first part of a data-collection program: data need to meet quality-control standards that ensure acceptable accuracy, and data need to be provided to users in a timely fashion.

The goal of the surface-water data-collection program is to collect all data according to established guidelines such as those outlined by Rantz and others (1982). In addition all collected data will be routinely published in reports (made available to data users in a timely fashion) and stored in electronic data bases.

13. Purposes for operating individual gages.--Thomas and Benson (1970, p. 2) noted that gaging of all sites on natural-flow streams is neither possible nor desirable. This also applies to regulated stream systems. There are several issues that restrict the scope of gaging activities but perhaps the most limiting is the lack of financial resources. Given that funding is restricted it is especially important to ensure that funds allocated to surface-water data-collection activities be wisely spent.

The goal of the surface-water data-collection program is to identify specific purposes for which each gaging operation is being supported. The purposes identified provide the basis for evaluating the need to continue operation. Gages being operated without specific purposes should be discontinued and the funds allocated elsewhere. Where continued operation of gages is questionable, techniques such as those developed by Wahl and Crippen (1984) can be used to determine which ones to terminate.

14. Analysis of data collected.--The data that are being collected and published need to be analyzed on a regular basis. These analyses are needed to determine if gages are collecting the data required and to determine if sufficient data have been collected to address the purposes for operating the gage. For example, long-term baseline stations are operated to provide the extended data sets needed to test for possible trends. The data must be analyzed on a regular basis to test for trends and to ensure that the watersheds in which the stations are being operated are still free of human-induced changes.

The goal of the surface-water data-collection program is to provide, at regular intervals, statistical summaries and interpretive analyses of the data being collected. These results provide the basis for determining if the required data are being collected and if continued data collection is warranted at specific gages.

Description of the Program

The purpose of this study was to evaluate the surface-water data-collection program in light of the currently identified issues and goals. A description or summary of both historical and current data-collection activities in Hawaii and the availability of the data collected is required to adequately accomplish this evaluation. The USGS is the principal source of both historical and current surface-water information in the State. As a result, the primary focus of this report is on data collected by or included in files maintained by the USGS. Surface-water data-collection activities of the USGS can be classified into one of four principal categories. The four categories are (1) continuous-record gages, (2) crest-stage gages, (3) low-flow partial-record gages, and (4) miscellaneous measurement sites. Continuous-record gages are those where some type of data, such as water-surface elevation, is recorded on a continuous basis. The continuous data can be used to compute streamflow for any particular instant or for selected periods of time, such as a day. Crest-stage gages provide only the peak elevation of the stream that occurred between servicing visits to the gage. Peak elevation data can be used to compute discharges for selected flood peaks. Typically only the maximum flood peak for each water year is published. Low-flow partial-record gages are typically non-recording gages where systematic, instantaneous measurements of streamflow and stream elevation are made during times of low flow. The discharge measurements are used to make estimates of selected low-flow statistics, such as median streamflow, at the sites. Miscellaneous measurement sites are locations where only random, instantaneous measurements of streamflow are made. The random measurements generally are made as part of large scale synoptic surveys and are commonly only one-time events. The only data stored or computed is the measured instantaneous discharge.

Historical Program

Water has long been an integral part of life in Hawaii. To raise their staple food, taro, Hawaiians constructed "auwais" or ditches to provide the irrigation water required. With the onset of the sugar industry the need for water increased greatly. Irrigation of sugarcane as a commercial crop began when the Rice Ditch was completed on Kauai in 1856 (U.S. Geological Survey, 1961, p. 2). As early as 1913, Martin and Pierce (1913, p. 15) noted that providing water for domestic use in the rapidly growing towns, especially Honolulu, required attention.

Before 1909 several plantation and ditch companies operated their own gaging stations, and some of these data are included in USGS reports and data files (Hawaii Territorial Planning Board, 1939, p. 9). Many of these private agencies continue to collect surface-water data. The surface-water data-collection program operated by the U.S. Geological Survey in Hawaii officially began in 1909 when an agreement with the Territory of Hawaii was signed (Yamanaga, 1972, p. 1) and 12 continuous-record gages were established. The initial program expanded rapidly and by 1914 there were 87 continuous-record gages in operation (Matsuoka and others, 1985, p. 4). Most of these early gages were operated to evaluate water-supply potential for agricultural irrigation needs. Long-term gage records are not required to simply quantify water-supply potential for irrigation, and as a result several of the early gages were only operated for short periods. The gaging program continued to expand, although at a more gradual pace, and by 1940 there were a total of 143 gages in operation.

Whereas the purpose for most of the early gages was to evaluate water supply, gages were also operated for other reasons. Eventually the emphasis included flow characteristics of streams in general and gaging operations were expanded to streams in remote areas. Frequently, concentrated groups of gages were established to meet specific needs of cooperating agencies. For example (1) in the early 1930's several gages were installed to measure springflow along the shores of Pearl Harbor, (2) in the 1920's and 1930's numerous gages were operated along the northeastern Hana coast of Maui specifically to evaluate water availability, and (3) in the early 1940's gages were operated on the northern slopes of the Kohala Mountains, Hawaii, to investigate the feasibility of extending an existing ditch system. The trend of establishing detailed networks of gages to address specific needs continues even today. For example, to evaluate possible effects of H-3 freeway construction on Oahu, several gages are currently being operated in North Halawa valley and the windward area in the vicinity of Kaneohe, Oahu (Wong and Hill, 1992).

During most of the 1940's and early 1950's the size of the gaging program in Hawaii remained relatively stable. During the mid-1950's expansion of the program resumed and by 1966 a total of 197 continuous-record gages were being operated by the USGS in Hawaii. Since 1966 the size of the gaging program has declined substantially, to the point where in 1994 a total of 89 gages are in operation. The number of continuous-record gages in operation has not been this small since 1920. Decisions to discontinue operation of gages were based on various economic, technical, and political reasons (Matsuoka and others, 1985, p. 4). Primarily, gages were discontinued because they had met their original objectives and the interest and/or funding was not available to continue their operation to meet potential future needs.

Since 1909 a total of 139 of Hawaii's 376 perennial streams have been gaged at one time or another (Hawaii Commission on Water Resource Management, 1990b, p. 43). Figure 1 shows a graphical representation of the continuous-record stream-gaging program in Hawaii. The maximum number of continuous-record gages operated in any given year on Kauai was 52 in 1966, on Oahu 61 in 1967, on Molokai 13 in 1969-70, on Maui

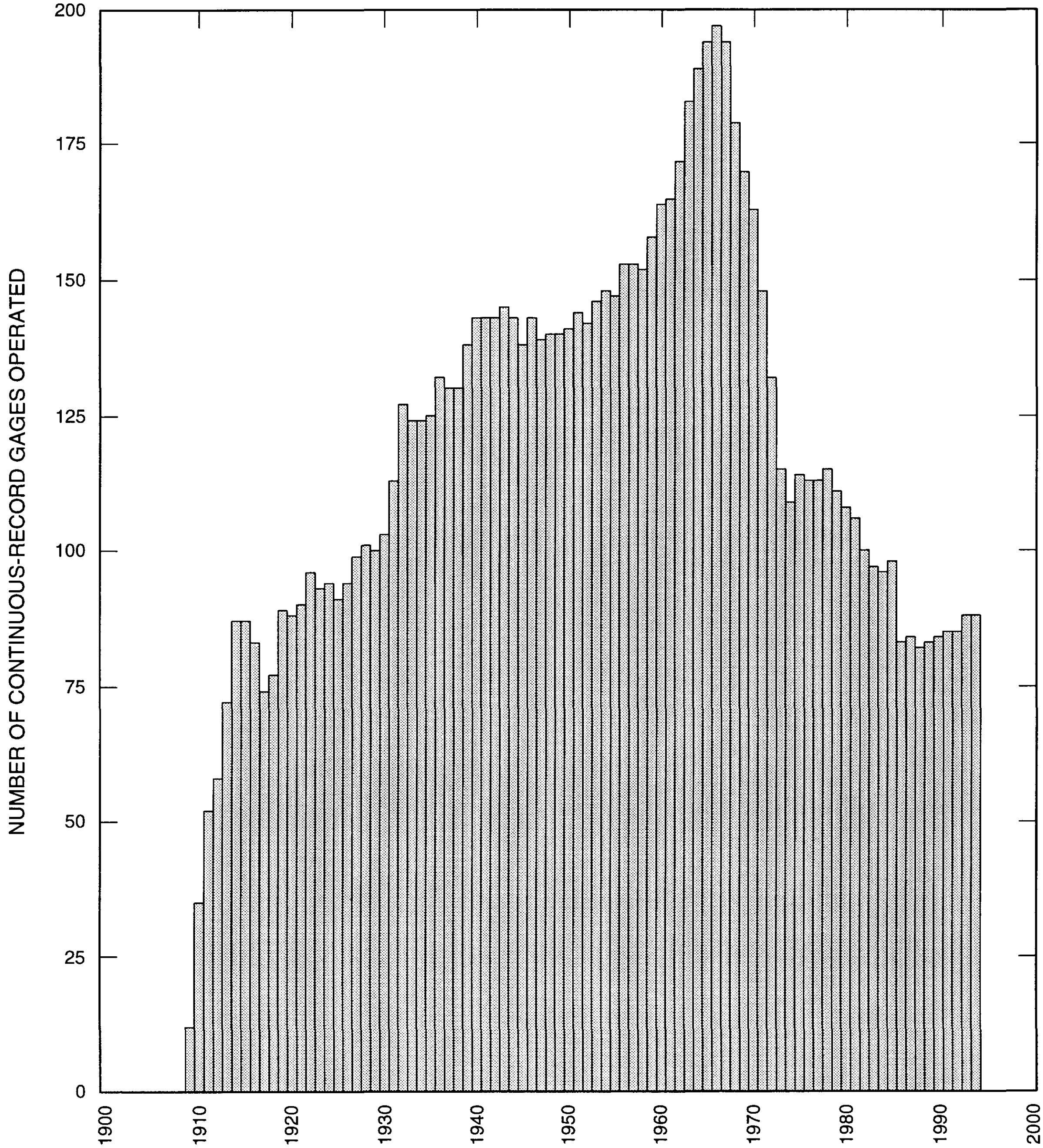

Figure 1. Number of continuous-record stream gages operated by the U.S. Geological Survey in Hawaii, 1909-94.

56 in 1940-44, and on Hawaii 37 in 1966. Currently (1994) 19, 34, 8, 10, and 18 continuous-record gages are being operated on Kauai, Oahu, Molokai, Maui, and Hawaii, respectively.

The development of densely populated urban areas, primarily on Oahu, led to the need for an expanded data base on flood peaks. To meet this need a program to operate crest-stage gages was initiated with the City and County of Honolulu. In 1958 a total of 22 crest-stage gages were operating on Oahu. The program on Oahu was subsequently enlarged and in 1962–64, in cooperation with the State of Hawaii and other federal agencies, extended to the outer islands. The size of the crest-stage program has held reasonably constant since 1974, and in 1994 a total of 107 gages are in operation. Of the total, 13 are operated on Kauai, 41 on Oahu, 8 on Molokai, 24 on Maui, and 21 on Hawaii.

Operation of low-flow partial record stations has been recognized as a cost effective means to expand surface-water data-collection activities. As funding for continuous-record gages decreased and the size of the gaging program was reduced, use of low-flow partial-record gages has increased. The first low-flow partial-record gages in Hawaii were established in 1961 on the islands of Kauai and Oahu. Since that time the maximum number operated in any given year was 24, in 1983. In 1986 the number of low-flow gages was reduced from 20 to 9. Currently (1994) a total of 12 low-flow partial-record gages are being operated, six each on Oahu and Molokai.

Miscellaneous measurements have frequently been made at random times and locations since the start of the USGS gaging programs in Hawaii. Although the exact number of sites and measurements made is unknown, published miscellaneous measurements through 1991 water year total about 9,600. Significant numbers of miscellaneous measurements in addition to these were probably made but never published.

Historically, 668 continuous-record, crest-stage, and low-flow partial-record gages have been operated by the USGS in Hawaii: 126 on Kauai, 211 on Oahu, 38 on Molokai, 187 on Maui, and 106 on Hawaii. A list of the gages operated, by island, and general information regarding each of them is included in tables 1 through 5 (at end of report).

To facilitate analyses of this information on gages operated in Hawaii, a geographic information system (GIS) data base was developed. All the information included in tables 1 through 5 have been stored in the GIS data base. In addition, the latitude and longitude, drainage area, and altitude of each gage were added to the data base.

GIS data bases can include both point and spatial information and therefore facilitate graphical analyses of data that would not be possible with simple tabular listings. For example, the GIS data base was used to develop plates 1 through 5. On each plate all the gages operated on each of the islands are located and classified as to type and current status (active or inactive).

Current Program

Currently (1994) there are 89 continuous record, 107 crest-stage, and 12 low-flow partial-record gages being operated in Hawaii by the U.S. Geological Survey. Selected information regarding these active gages are shown in tables 1 through 5 and their locations and type are illustrated in plates 1 through 5. In this section uses of data and funding for the current program will be discussed.

Data-Use Categories

Evaluations of stream-gaging programs in the United States (Benson and Carter, 1973, and Fontaine and others, 1984) and Canada (Perks and others, 1989) clearly identify the prominent role of documenting the uses of data collected at stream gages. The utility of a stream gage is defined by uses of the data it produces. Previous studies have documented the uses of data from gages in Hawaii (Yamanaga, 1972, and Matsuoka and others, 1985) based on surveys of known data users. In the 1972 evaluation of the Hawaii stream-gaging program, Yamanaga identified four major data-use classes. In the 1985 evaluation, Matsuoka and others identified nine major data-use classes. In the present study the previously identified classes were consolidated under six headings: regional hydrology, hydrologic systems, current needs, hydrologic forecasts, water quality, and long-term trends. Current data uses for active continuous-record, crest-stage, and low-flow partial-record gages, have been updated for this study and are summarized along with information on sources of funding in tables 6 through 8. How these uses fit in with the goals identified in the previous section will be considered later in the report in the section describing the evaluation of the surface-water quantity data-collection program.

Regional hydrology.--The best measures of streamflow characteristics are those estimated using

Table 6. Data uses and funding sources for active, continuous-record stream-gaging stations in Hawaii, 1994
[--, no or not applicable]

	Data Use							Funding		
	Regional hydrology									
Station	Low flows	Peak flows	Hydrologic systems	Current needs	Hydrologic forecasts	Water quality	Long-term trends	Federal program	Other federal agency program	Cooperative program
Kauai										
16010000	yes	yes	yes[1]	--	--	--	--	--	--	yes[2]
16019000	yes	yes	yes	--	--	yes	yes	yes	--	--
16031000	--	--	--	--	--	yes[3]	--	yes	--	--
16036000	--	yes	yes	--	--	--	--	--	--	yes[2]
16049000	--	yes	yes	--	--	--	--	--	--	yes[2]
16060000	--	yes	yes	--	--	--	--	--	--	yes[2]
16061200	--	--	yes[4]	--	--	--	--	--	--	yes[2, 19]
16062000	--	--	yes[4]	--	--	--	--	--	--	yes[2, 19]
16068000	yes[5]	yes[5]	yes[1, 5]	--	--	--	yes[5]	--	--	yes[2]
16069000	--	--	yes[1]	--	--	--	--	--	--	yes[2, 19]
16071000	--	yes	yes	yes[6]	--	--	--	--	yes[7]	--
16071500	yes	yes	--	--	--	--	--	--	--	yes[2]
16077000	--	--	yes[1]	--	--	--	--	--	--	yes[2, 19]
16079000	--	--	yes[1]	--	--	--	--	--	--	yes[2, 19]
16088000	--	--	yes[1]	--	--	--	--	--	--	yes[2, 19]
16091000	--	--	yes[1]	--	--	--	--	--	--	yes[2, 19]
16097500	yes	yes	--	--	--	--	yes	--	--	yes[2]
16103000	--	yes	--	yes[6]	--	--	--	--	yes[7]	--
16108000	yes	yes	--	--	--	--	yes	--	--	yes[2]
Oahu										
16200000	yes	yes	--	--	--	--	yes	--	--	yes[2]
16208000	--	yes	yes	--	--	--	--	--	--	yes[2]
16211600	yes	yes	--	--	--	--	yes	--	--	yes[2]
16212800	yes	yes	--	--	--	--	--	--	--	yes[2]
16213000	--	yes	--	--	--	yes[3]	--	yes	--	--
16216000	--	yes	yes	--	--	--	--	--	--	yes[2]
16225800	yes	yes	--	yes[8]	--	yes[8]	--	--	--	yes[9]
16226000	yes	yes	--	--	--	--	yes	--	--	yes[2]
16226200	yes	yes	--	yes[8]	--	yes[8]	--	--	--	yes[9]
16229000	yes[5]	yes[5]	yes[5]	--	--	--	yes[5]	--	--	--
16229300	yes	yes	--	yes[6]	--	--	--	--	yes[7]	--
16232000	--	--	yes	--	--	--	--	--	--	yes[2]
16240500	--	yes	yes	--	--	--	--	--	--	yes[2]
16249500	--	--	yes	--	--	--	--	--	--	yes[11]
16249900	--	--	yes	--	--	--	--	--	--	yes[11]
16254000	--	yes	yes	--	--	--	--	--	--	yes[2]

Table 6. Data uses and funding sources for active, continuous-record stream-gaging stations in Hawaii, 1994--Continued

Station	Data Use: Regional hydrology: Low flows	Data Use: Regional hydrology: Peak flows	Data Use: Hydrologic systems	Data Use: Current needs	Data Use: Hydrologic forecasts	Data Use: Water quality	Data Use: Long-term trends	Funding: Federal program	Funding: Other federal agency program	Funding: Cooperative program
16260500	--	yes	--	yes	--	--	--	--	--	yes[2, 20]
16265600	yes	yes	--	yes[8]	--	yes[8]	--	--	--	yes[9]
16270900	--	yes	--	yes[8]	--	yes[8]	--	--	--	yes[9]
16272200	--	--	yes	--	--	yes	--	--	yes[7]	--
16273950	yes	yes	--	yes[8]	--	yes[8]	--	--	--	yes[9]
16275000	--	yes	yes	yes[8]	--	yes[8]	--	--	--	yes[9, 10]
16283200	--	yes	yes	--	--	--	--	--	--	yes[10]
16283600	--	yes	yes	--	--	--	--	--	--	yes[10]
16283700	--	yes	yes	--	--	--	--	--	--	yes[10]
16284200	--	yes	yes	--	--	--	--	--	--	yes[10]
16294900	--	yes	yes	--	--	--	--	--	--	yes[2]
16296500	--	yes	yes	--	--	--	--	--	--	yes[2]
16302000	--	--	yes	--	--	--	--	--	--	yes[10]
16303000	yes[12]	yes[12]	yes	--	--	--	yes	--	--	yes[10]
16304200	yes	yes	--	--	--	--	--	--	--	yes[10]
16325000	yes	yes	--	--	--	--	--	--	--	yes[2]
16330000	--	yes	--	--	--	--	--	--	--	yes[2]
16345000	yes	yes	--	--	--	--	--	--	--	yes[2]
Molokai										
16400000	yes	yes	--	--	--	yes[3]	yes	yes	--	yes[2]
16404200	yes	yes	--	--	--	--	--	--	--	yes[2]
16405100	--	--	yes[1]	--	--	--	--	--	--	yes[11]
16405300	--	--	yes[1]	--	--	--	--	--	--	yes[11]
16405500	--	yes	yes	--	--	--	--	--	--	yes[2]
16408000	--	yes	yes	--	--	--	--	--	--	yes[2]
16414000	--	yes	yes	yes[6]	--	--	yes	--	yes[7]	--
16419500	--	yes	yes	--	--	--	--	--	--	yes[2]
Maui										
16501200	yes	yes	yes[13]	--	--	--	yes	yes	--	--
16508000	yes	yes	--	--	--	--	yes	--	--	yes[2]
16509000	--	yes	yes	yes	--	--	--	--	--	yes[2]
16518000	yes	yes	yes	--	--	--	--	--	--	yes[2]
16587000	yes[5]	yes[5]	yes[5]	--	--	--	yes[5]	--	--	yes[2]
16599500	--	--	yes	--	--	--	--	--	--	yes[14]
16604500	yes	yes	--	--	--	--	--	--	--	yes[2]
16614000	yes	yes	--	--	--	--	--	--	--	yes[2]
16618000	yes[15]	yes[15]	yes[15]	--	--	yes[15]	yes[15]	yes	--	--
16620000	yes	yes	--	--	--	--	yes	--	--	yes[2]

Table 6. Data uses and funding sources for active, continuous-record stream-gaging stations in Hawaii, 1994--Continued

	Data Use								Funding		
	Regional hydrology										
Station	Low flows	Peak flows	Hydrologic systems	Current needs	Hydrologic forecasts	Water quality	Long-term trends	Federal program	Other federal agency program	Cooperative program
Hawaii										
16700000	yes[5]	yes[5]	yes[5]	--	--	--	yes[5]	--	--	yes[2]
16700900	--	--	yes[16]	--	--	--	--	--	--	yes[17]
16700950	--	--	yes	--	--	--	--	--	--	yes[17]
16704000	--	yes	yes[18]	--	--	--	--	--	--	yes[2]
16713000	--	yes	yes[18]	--	--	--	--	--	--	--
16717000	yes	yes	yes	--	--	--	yes	--	--	--
16720000	yes	yes	yes	--	--	--	yes	--	--	yes[2]
16720300	yes	yes	yes	--	--	--	--	--	--	yes[2]
16720500	--	--	yes[1]	--	--	--	--	--	--	yes[11]
16724800	--	--	yes[1]	--	--	--	--	--	--	yes[11]
16725000	--	yes	yes	--	--	--	--	--	--	yes[2]
16726000	--	--	yes[1]	--	--	--	--	--	--	yes[11]
16727000	--	--	yes[1]	--	--	--	--	--	--	yes[11]
16737500	yes	yes	--	--	yes	--	--	--	--	yes[2]
16756000	--	yes	yes	--	--	--	--	--	--	yes[2]
16758000	--	yes	yes	--	--	--	--	--	--	yes[2]
16759000	--	yes	yes	--	--	--	--	--	--	yes[2]
16764000	yes	yes	--	--	--	--	yes	--	--	yes[2]

1 Irrigation use
2 State of Hawaii, Department of Land and Natural Resources
3 (NASQAN) station
4 Power and irrigation use
5 Long-term index station
6 Monitoring of flood data
7 U.S. Army Corps of Engineers
8 Construction effects, H-3 highway project
9 State of Hawaii, Department of Transportation
10 City and County of Honolulu, Board of Water Supply
11 State of Hawaii, Department of Agriculture
12 Records for station 16303000 when combined with records for ditch station 16302000 represent unregulated streamflow
13 Power, irrigation and domestic use
14 Maui County Department of Water
15 Hydrologic benchmark station
16 Domestic use
17 Hawaii County Department of Water
18 Hydropower system operation
19 Money from East Kauai Water Co. through State
20 Money from Royal Hawaiian Country Club through State

Table 7. Data uses and funding sources for active, crest-stage gaging stations in Hawaii, 1994

[--, no or not applicable]

Station	Data Use							Funding		
	Regional hydrology									
	Low flows	Peak flows	Hydrologic systems	Current needs	Hydrologic forecasts	Water quality	Long-term trends	Federal program	Other federal agency program	Cooperative program
Kauai										
16038000	--	--	--	yes[1]	--	--	--	--	--	yes[2]
16052000	--	--	--	yes[1]	--	--	--	--	--	yes[2]
16052500	--	yes	--	--	--	--	--	--	--	yes[2]
16055000	--	--	--	yes	--	--	--	--	--	yes[2]
16071800	--	--	--	yes[1]	--	--	--	--	--	yes[2]
16073500	--	yes	--	--	--	--	--	--	--	yes[2]
16080000	--	--	--	--	--	--	--	--	--	yes[2]
16081200	--	yes	--	--	--	--	--	--	--	yes[2]
16084500	--	yes	--	--	--	--	--	--	--	yes[2]
16085000	--	yes	--	--	--	--	--	--	--	yes[2]
16097900	--	yes	--	--	--	--	--	--	--	yes[2]
16104200	--	--	--	yes[1]	--	--	--	--	--	yes[2]
16130000	--	yes	--	--	--	--	--	--	--	yes[2]
Oahu										
16210500	--	yes	--	--	--	--	--	--	--	yes[3]
16211200	--	yes	--	--	--	--	--	--	--	yes[3]
16211300	--	yes	--	--	--	--	--	--	--	yes[3]
16211400	--	yes	--	--	--	--	--	--	--	yes[3]
16211500	--	yes	--	--	--	--	--	--	--	yes[3]
16211700	--	yes	--	--	--	--	--	--	--	yes[3]
16211800	--	yes	--	--	--	--	--	--	--	yes[3]
16212200	--	yes	--	--	--	--	--	--	--	yes[3]
16212300	--	yes	--	--	--	--	--	--	--	yes[3]
16212450	--	yes	--	--	--	--	--	--	--	yes[3]
16212500	--	yes	--	--	--	--	--	--	--	yes[3]
16212601	--	yes	--	--	--	--	--	--	--	yes[3]
16212700	--	yes	--	--	--	--	--	--	--	yes[3]
16212750	--	yes	--	--	--	--	--	--	--	yes[3]
16223000	--	yes	--	--	--	--	--	--	--	yes[3]
16224500	--	yes	--	--	--	--	--	--	--	yes[3]
16228000	--	yes	--	--	--	--	--	--	--	yes[3]
16228200	--	yes	--	--	--	--	--	--	--	yes[3]
16228600	--	yes	--	--	--	--	--	--	--	yes[3]
16228900	--	yes	--	--	--	--	--	--	--	yes[3]
16235400	--	yes	--	--	--	--	--	--	--	yes[3]
16237500	--	yes	--	--	--	--	--	--	--	yes[3]
16247100	--	yes	--	--	--	--	--	--	--	yes[3]
16247500	--	yes	--	--	--	--	--	--	--	yes[3]
16247900	--	yes	--	--	--	--	--	yes[4]	--	--
16248800	--	yes	--	--	--	--	--	--	--	yes[3]

Table 7. Data uses and funding sources for active, crest-stage gaging stations in Hawaii, 1994--Continued

Station	Data Use: Regional hydrology: Low flows	Data Use: Regional hydrology: Peak flows	Data Use: Hydrologic systems	Data Use: Current needs	Data Use: Hydrologic forecasts	Data Use: Water quality	Data Use: Long-term trends	Funding: Federal program	Funding: Other federal agency program	Funding: Cooperative program
16249000	--	yes	--	--	--	--	--	--	--	yes[3]
16249100	--	yes	--	--	--	--	--	--	--	yes[3]
16264800	--	--	yes	yes[1]	--	--	--	yes[4]	--	--
16265000	--	yes	--	--	--	--	--	--	--	yes[3]
16274499	--	yes	--	--	--	--	--	--	--	yes[3]
16279500	--	yes	--	--	--	--	--	--	--	yes[3]
16283480	--	yes	--	--	--	--	--	--	--	yes[3]
16304500	--	yes	--	--	--	--	--	--	--	yes[3]
16310501	--	yes	--	--	--	--	--	--	--	yes[3]
16311000	--	yes	--	--	--	--	--	--	--	yes[3]
16317800	--	yes	--	--	--	--	--	--	--	yes[3]
16318000	--	yes	--	--	--	--	--	--	--	yes[3]
16331000	--	yes	--	--	--	--	--	--	--	yes[3]
16340000	--	yes	--	--	--	--	--	--	--	yes[3]
16350000	--	yes	--	--	--	--	--	--	--	yes[3]
Molokai										
16411320	--	yes	--	--	--	--	--	--	--	yes[2]
16411400	--	yes	--	--	--	--	--	--	--	yes[2]
16411600	--	yes	--	--	--	--	--	--	--	yes[2]
16411640	--	yes	--	--	--	--	--	--	--	yes[2]
16411800	--	yes	--	--	--	--	--	--	--	yes[2]
16413500	--	yes	--	--	--	--	--	--	--	yes[2]
16415400	--	yes	--	--	--	--	--	--	--	yes[2]
16419000	--	yes	--	--	--	--	--	--	--	yes[2]
Maui										
16500100	--	yes	--	--	--	--	--	--	--	yes[2]
16500300	--	yes	--	--	--	--	--	--	--	yes[2]
16500800	--	yes	--	--	--	--	--	--	--	yes[2]
16502400	--	yes	--	--	--	--	--	--	--	yes[2]
16502800	--	yes	--	--	--	--	--	--	--	yes[2]
16502900	--	yes	--	--	--	--	--	--	--	yes[2]
16603300	--	yes	--	--	--	--	--	--	--	yes[2]
16603700	--	yes	--	--	--	--	--	--	--	yes[2]
16603800	--	yes	--	--	--	--	--	--	--	yes[2]
16603850	--	yes	--	--	--	--	--	--	--	yes[2]
16607000	--	yes	yes	--	--	--	--	--	yes[4]	--
16616500	--	yes	--	--	--	--	--	--	--	yes[2]
16619700	--	yes	--	--	--	--	--	--	--	yes[2]
16630200	--	yes	--	--	--	--	--	--	--	yes[2]
16638500	--	--	yes	--	--	--	--	--	yes[4]	--
16643300	--	yes	--	--	--	--	--	--	--	yes[2]
16646200	--	yes	--	--	--	--	--	--	--	yes[2]

Table 7. Data uses and funding sources for active, crest-stage gaging stations in Hawaii, 1994--Continued

Station	Data Use							Funding		
	Regional hydrology									
	Low flows	Peak flows	Hydrologic systems	Current needs	Hydrologic forecasts	Water quality	Long-term trends	Federal program	Other federal agency program	Coop-erative program
16647500	--	yes	--	--	--	--	--	--	--	yes[2]
16650500	--	yes	--	--	--	--	--	--	--	yes[2]
16658500	--	yes	--	--	--	--	--	--	--	yes[2]
16659000	--	yes	--	--	--	--	--	--	--	yes[2]
16660000	--	yes	yes	--	--	--	--	--	yes[4]	--
16663500	--	yes	--	--	--	--	--	--	--	yes[2]
16664000	--	yes	--	--	--	--	--	--	--	yes[2]
Hawaii										
16701300	--	yes	yes	--	--	--	--	--	yes[4]	--
16701400	--	yes	--	--	--	--	--	--	--	yes[2]
16717400	--	yes	--	--	--	--	--	--	--	yes[2]
16717600	--	yes	--	--	--	--	--	--	--	yes[2]
16717650	--	yes	--	--	--	--	--	--	--	yes[2]
16717800	--	yes	--	--	--	--	--	--	--	yes[2]
16717850	--	yes	--	--	--	--	--	--	--	yes[2]
16717920	--	yes	--	--	--	--	--	--	--	yes[2]
16717950	--	yes	--	--	--	--	--	--	--	yes[2]
16752600	--	yes	--	--	--	--	--	--	--	yes[2]
16755800	--	yes	--	--	--	--	--	--	--	yes[2]
16756500	--	yes	--	--	--	--	--	--	--	yes[2]
16759040	--	yes	--	--	--	--	--	--	--	yes[2]
16759060	--	yes	--	--	--	--	--	--	--	yes[2]
16759080	--	yes	--	--	--	--	--	--	--	yes[2]
16759180	--	yes	--	--	--	--	--	--	--	yes[2]
16759300	--	yes	--	--	--	--	--	--	--	yes[2]
16762000	--	yes	--	--	--	--	--	--	--	yes[2]
16767000	--	yes	--	--	--	--	--	--	--	yes[2]
16770000	--	yes	--	--	--	--	--	--	--	yes[2]
16770500	--	yes	--	--	--	--	--	--	--	yes[2]

1 Stage only
2 State of Hawaii, Department of Land and Natural Resources
3 City and County of Honolulu, Department of Public Works
4 U.S. Army Corps of Engineers

Table 8. Data uses and funding sources for active, low-flow partial-record stations in Hawaii, 1994
[--, none; DOT, State of Hawaii, Department of Transportation; DLNR, State of Hawaii, Department of Land and Natural Resources]

Station	Data use: Regional hydrology: Low flows	Data use: Regional hydrology: Peak flows	Data use: Hydrologic systems	Data use: Current needs	Data use: Hydrologic forecasts	Data use: Water quality	Data use: Long-term trends	Funding: Federal program	Funding: Other federal agency program	Funding: Cooperative program
Oahu										
16227100	yes	--	yes	yes	--	yes	--	--	--	DOT
16265700	yes	--	yes	yes	--	yes	--	--	--	DOT
16266500	yes	--	yes	yes	--	yes	--	--	--	DOT
16267500	yes	--	yes	yes	--	yes	--	--	--	DOT
16269500	yes	--	yes	yes	--	yes	--	--	--	DOT
16274100	--	--	yes	yes	--	yes	--	--	--	DOT
Molokai										
16403400	yes	--	yes	--	--	--	--	--	--	DLNR
16403500	yes	--	yes	--	--	--	--	--	--	DLNR
16403600	yes	--	yes	--	--	--	--	--	--	DLNR
16403700	yes	--	yes	--	--	--	--	--	--	DLNR
16403800	yes	--	yes	--	--	--	--	--	--	DLNR
16403900	yes	--	yes	--	--	--	--	--	--	DLNR

long-term records. Collecting long-term records at all sites where data are required is not economically feasible. The objective of regional hydrology stations is to provide streamflow data at a representative number of sites in an area so that streamflow characteristics can be estimated regionally at ungaged sites. Regional estimates of streamflow characteristics can be based on statistical methods such as multiple regression analysis, by interpolating between gaged points, or by relating a short-term or partial-record station to a long-term station.

For a station to be used to define regional hydrology, the data collected at the site must be largely unaffected by artificial storage or diversion. In this data-use class, the artificial effects on streamflow are not necessarily small, but the effects are limited to those caused primarily by land-use and climate changes. Large amounts of artificial storage may exist in the basin upstream of the gage, provided the outflow from the reservoir is uncontrolled.

In this study two classes of regional hydrology stations are considered, low flow and peak flow. Low-flow regional hydrology stations are those where the effects of regulation or diversion, if they exist in the basin, are less than 10 percent on daily flow. Peak-flow regional hydrology stations are those where the effects of regulation or diversion, if they exist in the basin, are less than 10 percent on the annual peak flow. Benson (1962, p. 8) determined that for humid regions, if usable storage in a watershed was less than 103 acre-ft/mi^2, the effect on peak discharges would in general be less than 10 percent. Stations where regulation or diversion exists can be considered regional hydrology stations if the effects are known or the diverted flows are gaged so that it is possible to reconstruct what unregulated flows at the station would have been. If a station is classified as both a low-flow and a peak-flow regional hydrology station, it can also be used to provide regional estimates of intermediate streamflow characteristics such as flow duration and mean monthly and annual flows.

Hydrologic systems.--Hydrologic-systems data are those used for accounting, or in other words, to describe current hydrologic conditions and the sources, sinks, and fluxes of water through networks and regions that are either natural or regulated or both. These data are collected at stations located on diversions, ditches, and return flows and stations that are useful for defining the interaction of water systems. The benchmark and index stations are included in the hydrologic systems category because they are accounting for long-term and current conditions of the hydrologic systems they gage. Benchmark gages are part of a Nationwide program operated by the USGS. Index stations are part of individual State programs to monitor current hydrologic conditions.

Current needs.--Stations where data are needed to meet legal obligations, for planning and design, for project operation, and for specific research projects are considered current-needs stations. This classification includes stations that provide streamflow data needed for any instant or for any specific day, week, month, or year and generally for a specific location.

Streamflow data needed to meet legal obligations are used for the verification or enforcement of existing treaties, compacts, and decrees. Legal obligation stations are only those that the USGS is required to operate to satisfy a legal responsibility. Streamflow data required to meet planning and design needs are used for a specific project such as dams, levees, floodwalls, navigation systems, water-supply diversion, hydropower plant, or waste-treatment facilities. Planning and design stations are limited to those instituted for specific planning and design purposes where this need is still valid.

Project operation data are used, on an ongoing basis, to assist water managers in making operational decisions such as reservoir releases, hydropower operations, or diversions. Project operation stations are operated such that the data are routinely available to water managers on a rapid or as-needed reporting basis. Research data are used for specific water-investigation studies. Research stations are typically operated only for a few years or for the life of the study.

Hydrologic forecasts.--Stations in this category are those that regularly provide data for use in hydrologic forecasts, the most common of which are those associated with floods for specific river reaches or locations. Hydrologic forecast stations are operated to provide data to forecasters on a rapid-reporting or real-time basis.

Water quality.--Stations where data are collected in support of water-quality or sediment-transport monitoring activities are considered water-quality stations. Streamflow data collected at water-quality stations are essential to the determination of chemical loads and sediment transport. Hydrologic benchmark and national stream quality accounting network (NASQAN) stations are two types of water-quality stations. Water-quality samples from benchmark stations are used to track trends and indicate the general water-quality characteristics of streams that are relatively free of human influences. NASQAN stations in Hawaii are part of a Nationwide USGS network to determine water-quality trends of selected significant streams.

Long-term trends.--Stations where data are collected to provide long-term series of consistent observations on streamflow are considered long-term trend stations. Long-term trend stations provide data used to analyze the statistical structure of hydrologic time series. Long-term trend stations also provide data which can be used as a baseline for evaluating possible changes in the flow regimes of other streams.

Long-term trend stations need to be located on streams draining basins that have undergone no significant human-made changes and are expected to remain that way in the future. Long-term trend stations should be located in a variety of settings with different physical and climatologic characteristics.

Funding

There are three principal sources of funding for the USGS streamflow data-collection programs in Hawaii: the federal program, the other federal agencies (OFA) program, and the cooperative program. In the federal program, funds are directly allocated to the USGS for a specific program such as the hydrologic benchmark program (Lawrence, 1987). In the OFA program, funds for data collection have been transferred to the USGS by federal agencies such as the U.S. Army Corps of Engineers. In the cooperative program, funds come jointly from the USGS cooperative program and from any non-federal, government agency, such as the State of Hawaii. Sources of funding for all the active continuous-record gages are shown in table 6.

Summary of Data Uses and Funding

Data from 30 of the active continuous-record gages have uses that fall into just one of the six data-use classes and 37 have uses that fall into two data-use classes. Data from the 22 remaining stations have uses that fall into three or more classes. Data from station 16618000, Kahakuloa Stream near Honokohau, Maui, are used in five of the six data-use classes. Funding for 52 of the 89 gages comes through the cooperative program between the Hawaii Department of Land and Natural Resources and the USGS. Funds for 24 additional stations also come through the cooperative program between the USGS and the Hawaii Department of Agriculture (8 gages), the City and County of Honolulu, Board of Water Supply (8 gages), the Hawaii Department of Transportation (6 gages), the Hawaii County Department of Water (2 gages), and the Maui County Department of Water Supply (1 gage). One of the 24 stations is funded by two agencies and is included in the totals for both. Six gages are funded through the federal program and five are funded through OFA program. One gage is funded through both the federal and the cooperative programs and is included in the totals for both. In 1994 three gages are being operated without funding.

Ninety-six of the 107 crest-stage gages currently (1994) in operation exist primarily to provide regional information on peak flows. The remaining 11 gages are operated to meet site-specific project needs. Sixty-two of the gages are funded in cooperation with the Hawaii Department of Land and Natural Resources. Thirty-nine are funded in cooperation with the City and County of Honolulu, Department of Public Works. The six remaining gages are funded through the OFA program with the U.S. Army Corps of Engineers.

In 1994, twelve low-flow partial-record gages are in operation in the State. Six are on Oahu and are funded in cooperation with the Hawaii Department of Transportation. These gages are being operated as part of a special project related to construction of the H-3 freeway. Data from these gages are used to provide regional information on low flows, to evaluate hydrologic systems, to meet the research needs related to the project, and to supplement water-quality data collected at the gages. The remaining six gages are on Molokai and are funded with the Hawaii Department of Land and Natural Resources. Data from these gages are used to evaluate regional low flows and the Pelekunu Stream hydrologic system.

Availability of Data

Equally important as collecting high-quality data is making the data available to users. Data can be furnished in a real-time mode, in periodic releases of provisional data, and in published reports. Data furnished in a real-time mode can be made available by direct-access telemetry equipment or satellite links that connect users directly to data collection sites. Periodic releases of provisional data can be made by USGS personnel after preliminary processing of data collected in the field has taken place. Streamflow data collected in Hawaii are provided in a series of reports published annually (Matsuoka and others, 1993). In Hawaii the annual data reports are the primary means by which data are distributed to users. Beginning with the 1990 water year, all USGS annual data reports for a given year for the entire country are reproduced on a CD-ROM disc that is available to data users. Both provisional and final data can also be transmitted through various electronic media such as the Internet.

As part of the USGS's program of making data available to the public, a large-scale computerized system was required. The national WATer Data STOrage and REtrieval system (WATSTORE) was established in 1972 to meet this need (Hutchinson, 1975). A variety of useful products, ranging from data tables to complex statistical analyses, can be produced using WATSTORE. Data users can obtain direct access rights to this computerized data base by contacting:

USGS
National Water Data Exchange
421 National Center
Reston VA 22092

Evaluation of the Program

The previous sections of the report provided an updated listing of issues and goals for the surface-water data-collection program and described the current and historical data programs. To evaluate the program, two steps must be completed. First, the existing gaging program and previously identified uses of the data need to be considered (tables 6–8) to answer such questions as: Have the stations currently in operation met the needs for which they were first established? Is their continued operation warranted given the previously identified uses? To accomplish this step, a method is needed to evaluate the data that have been collected. Second, goals identified in this report will be considered individually using the existing surface-water data-collection program and available historical data. The question to be addressed is: will the existing data-collection program and historical data be sufficient to address the goals?

Methodology

This section describes the methodology used in this report to determine whether continued operation of a gaging station is warranted. The methodology is appropriate for analysis of crest-stage and low-flow partial-record gages as well as continuous-record gages. The underlying assumption in this methodology is that gaging stations are to remain in operation only if a valid use is found for the data and funds to pay for the operation of the gage are available. An alternative method needs to be considered in cases where, solely because of a lack of funds, a subset of gaging stations, all with valid reasons for operating, need to be discontinued. In such a situation an objective method is required to select which gaging station will be discontinued. The objective method proposed by Wahl and Crippen (1984) is an example of such an alternative method.

To determine if the data being collected still meet some specific use, the following information, by data-use category is provided. Simply determine what categories of data use are appropriate for the gage in question (for example use data in tables 6–8) and review the following to ensure classification of the gage in this data-use category is still appropriate. When this process is completed and none of the identified data uses are appropriate, then the gage should be discontinued.

Regional hydrology data uses imply that the data collected at a gage are unaffected by artificial storage or diversion. In addition, the data must be needed to estimate long-term streamflow characteristics, both at the site in question and at ungaged locations. The first step is to ensure that the low or peak flows at the site are not affected by regulation. Criteria to establish that a site is regulated are given in the section describing data-use classes. The next step is to determine how many years of data are required to provide streamflow characteristics of sufficient accuracy. For low-flow partial-record gages, the question becomes that of how many base-flow measurements at the gage are required.

To adequately consider how many years of data are required it is important to recognize that even at continuous-record gages, estimated streamflow characteristics are not error-free. The magnitude of the error generally is described in terms of the standard error. For each streamflow characteristic estimated at a gage there is a 68 percent chance that it is within one standard error, plus or minus, of the true value. The magnitudes of standard errors vary among gaging stations and the various streamflow characteristics considered. In general, the standard error is a function of the variability of flow at the site in question and the length of record at the gage. The accuracy of a mean statistic, for example the mean annual discharge, is given by,

$$SE = 100\ (Cv)\ /N^{0.5} \qquad (1)$$

where:

SE is the standard error, in percent;

Cv is the coefficient of variation, or the ratio of the standard deviation to the mean of the data (Iman and Conover, 1983, p. 103); and

N is the number of events; for example, if the mean being calculated is mean annual, then N is years of record and if the mean being calculated is mean monthly for September, then N is the number of Septembers for which a monthly mean is available.

The data in figure 2 and table 9 provide an example of how standard errors vary by streamflow characteristic and length of record. These data are based on average standard errors computed for five stations on Oahu (stations 16200000, 16228000, 16229000, 16238500, and 16240500), each with more than 60 years of record. Techniques used to compute the standard errors were those developed by Hardison (1969). The standard-error data included in figure 2 and table 9, for flood-peak characteristics, are also appropriate at crest-stage gages.

The data shown in table 9 and figure 2 illustrate several interesting points. The magnitude of the standard error is significantly higher for stations with short record lengths. Increasing the length of record at a station will initially yield large reductions in the magnitude of the standard error, but the relative magnitude of these improvements will eventually decrease with increasing record length. The smaller the probability of a characteristic, for example 100-year flood compared with 10-year flood, the higher the standard error. The shorter the time period for the characteristic, for example mean monthly compared with mean annual, the higher the standard error. Again, it is important to em-

Table 9. Average standard error for selected streamflow characteristics compared with length of record for five long-term stream-gaging stations on Oahu, Hawaii

	Standard error (percent)					
Years of record	**100-year flood peak**	**10-year flood peak**	**7-day 10-year low flow**	**Long-term median discharge**	**Mean monthly discharge**	**Mean annual discharge**
5	66	45	47	24	42	17
10	45	30	33	15	29	12
20	30	21	23	12	21	9
30	26	18	18	10	17	7
40	21	16	16	8	15	6
50	18	14	14	6	13	5

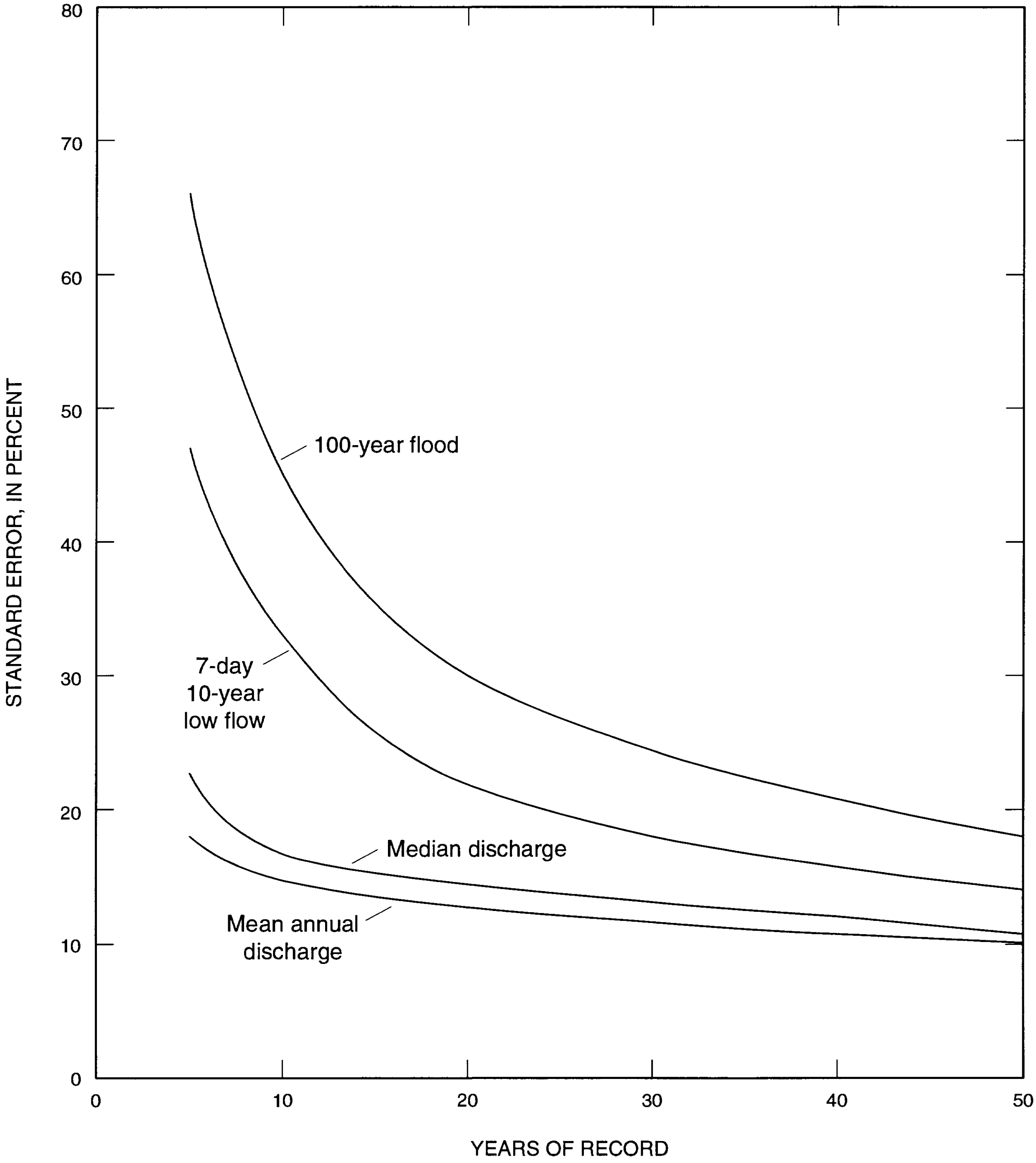

Figure 2. Average relation of standard error to length of record for selected streamflow characteristics at five long-term gaging stations on Oahu, Hawaii.

phasize that the data in table 9 and figure 2 represent averages for five stations on Oahu. The magnitude of these standard errors will vary from station to station; however, the trends displayed should remain comparable.

The answer to the question of how many years of data are required for stations with regional hydrology uses depends on the streamflow characteristics needed and the individual gaging station in question. Currently, identified data uses for continuous-record gaging stations generally do not list what streamflow characteristics are needed at the station. It is assumed that the entire suite of possible characteristics are desired, except at crest-stage gages where the only characteristic of concern is flood peaks. In general, the shape of standard error curves plotted in figure 2 and the magnitudes of the standard errors imply that stations in Hawaii need to be operated a minimum of 20 years, and ideally between 30 to 40 years. The decision to operate a station the minimum of 20 years or to continue to 40 years needs to be based on the relative importance of the stream and data needs in question. These criteria could also be relaxed at continuous-record stations if, for example, the only characteristic of interest was mean annual discharge. For the five stations on Oahu analyzed, the average standard error for mean discharge was 12 percent, with ten years of record. Operating these stations an additional 10 years reduces the standard error by only 3 percent (to 9 percent). To make these decisions, standard error plots need to be prepared for the characteristics and stations of interest. An absolute minimum of 10 years of record is required to estimate several types of streamflow characteristics such as flood-frequency data (Water Resources Council, 1981, p. 2).

At low-flow partial-record stations, base-flow discharge measurements are made during low-flow periods that are independent of one another. These measurements are then correlated with concurrent daily discharges at nearby index stations. The relation between the index and partial-record station is used to estimate low-flow characteristics at the partial stations, given the value for the characteristic at the index station. The accuracy of the estimated streamflow characteristic at the partial-record station is a function of the number of measurements made at the station, the strength of the correlation between the partial-record and index stations, and the length of record at the index station (Hardison and Moss, 1972).

Stedinger and Thomas (1986, fig. 1b) graphically demonstrated the relation between standard error for the 7-day 10-year low flow and the number of base-flow measurements at a partial-record station. These results are reproduced in figure 3. In this example, curves were developed for varying degrees of correlation between a partial-record station and an index gage with 50 years of record. In this example the index station with 50 years of record had a standard error of 16 percent for the 7-day 10-year low-flow characteristic. This value is similar to the average of 14 percent calculated for five Oahu stations (table 9). Standard errors initially decrease rapidly with increasing numbers of measurements. The rate of decrease eventually declines as the standard errors approach but never equal the standard error for the characteristic at the index station. Similar relations would be expected for other low-flow characteristics and correlations with index stations that have shorter record lengths. Standard errors would approach but never equal those for the index station. The minimum standard error would be higher because of the reduced record length and therefore the higher standard error at the index station.

The data shown in figure 3 indicate that a low-flow partial-record station needs to be established with the goal of obtaining a minimum of 10 and ideally 20 independent base-flow measurements. Ideally, these measurements should span the range of the low-flow characteristics that are to be estimated. More than 20 base-flow measurements will not result in significantly improved standard errors and continued operation as a regional hydrology station is not justified. For such stations, greater improvements could be made if the index stations used in the analysis had a higher correlation with the partial-record station or had longer term record. The data in figure 3 demonstrate the importance of having an adequate network of long-term index stations.

Under the data-use category of regional hydrology, at least two additional factors need to be considered. First to be considered is whether the data for the period of record at the gage are homogeneous or not. Computation of long-term streamflow characteristics assumes the period of record is homogeneous. If factors that influence the comparability of the data over time are evident then continued operation of the station may be needed. Second, before a continuous-record regional hydrology station is discontinued it should be determined if long-term data for this station are important for use in extending the short-term records or partial

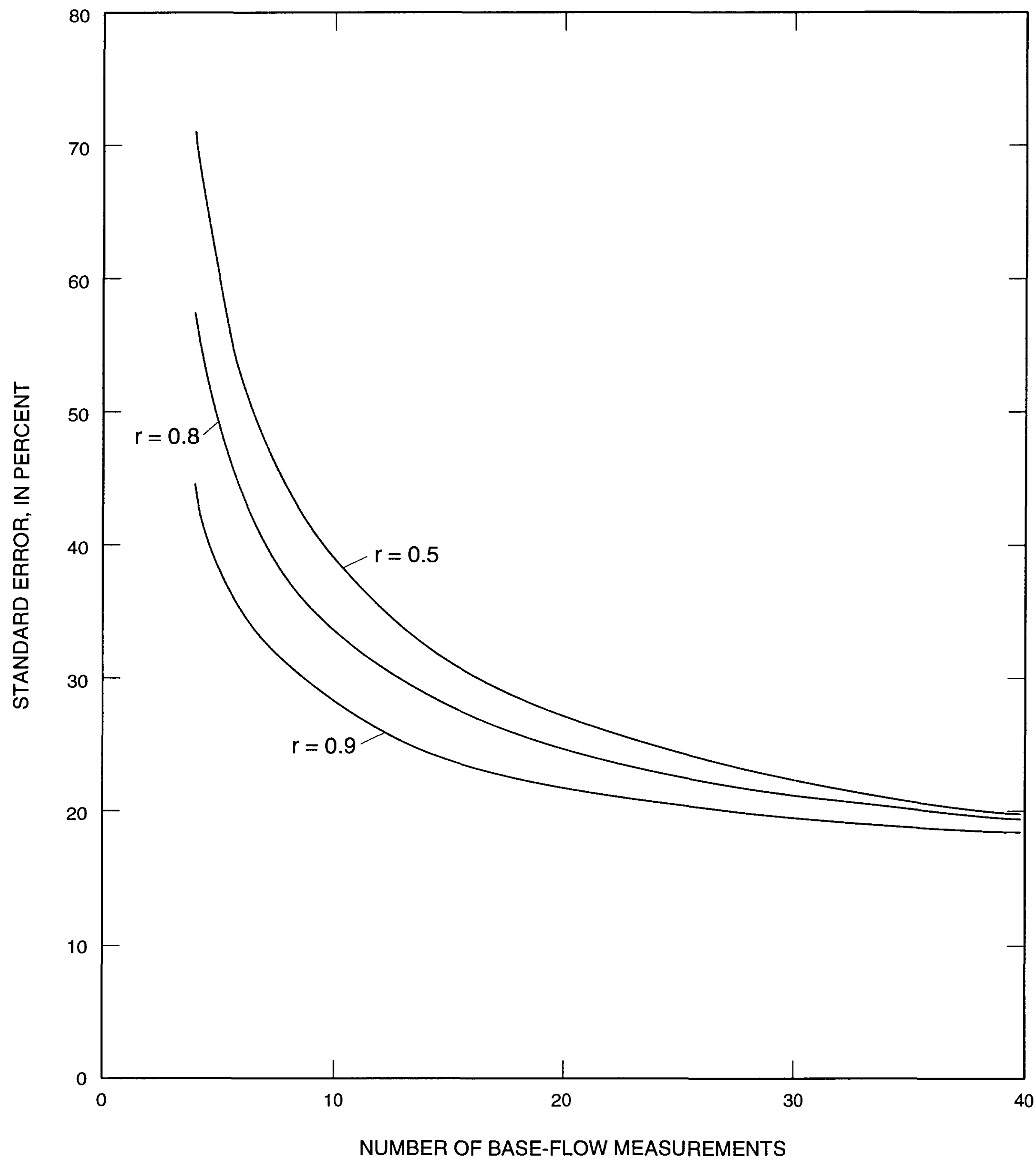

Figure 3. Relation of standard error for estimated 7-day 10-year low flow to number of base-flow measurements at a partial-record station. The relations are based on varying correlation coefficients (r) between the station and an index gage with 50 years of record (from Stedinger and Thomas, 1986, fig. 1b).

records of adjacent stations. This question is frequently overlooked but is important. In a recent analysis of median streamflows for perennial streams in Hawaii (Fontaine and others, 1992), a limitation found in the streamflow data base was the lack of streamflow-gaging stations that had been operated over the entire period of analysis. As shown in figure 4 (from Fontaine and others, 1992, fig. 6), few stations had records available for all or most of the base period (1912-86), and none were available on the island of Hawaii.

Hydrologic-systems data uses include a larger variety of stations than any of the other identified data-use categories. In Hawaii, 60 of the 89 continuous-record stations and all 12 of the low-flow partial-record stations currently (1994) in operation have hydrologic systems data uses (table 6). As a result, issues that need to be considered when determining if continued operation of a gage is warranted will be diverse and commonly site specific. Issues to be considered for some of the most significant types of hydrologic-systems data-use stations will be given here.

Stations identified as having hydrologic systems data uses can be collecting data that represent either natural or regulated conditions, although regulated sites are generally in the majority. Of the 60 continuous-record stations that currently have hydrologic systems data uses, 13 represent natural streamflows and 47 represent regulated streamflows (table 6). Five of the 13 natural streamflow stations are included in this data-use category because they are either index or benchmark stations. These stations will continue to have hydrologic systems data uses as long as they continue to function as either index or benchmark stations. Index and benchmark stations are also included under the data-use category of long-term trends. The criteria presented for long-term trend stations to determine if their continued operation is warranted are more restrictive and will be the controlling factors for these sites.

The remaining unregulated continuous-record stations that have hydrologic systems data uses are included in this data-use category primarily because they define natural inflows to stream systems that are regulated in their lower reaches. Most stations in this data-use category are operated for one of three reasons: (1) to define the long-term streamflow characteristics of inflows to the regulated system, (2) to provide continuous, actual sequences of streamflow data for systems where the pattern of regulation is variable and dependent on inflow conditions, or (3) to define specific streamflow characteristics throughout a defined hydrologic system. Continued operation of stations that fall into the category identified above in reason (1) is controlled by the length of time required to accurately determine streamflow characteristics. These criteria were discussed in detail for the regional hydrology data-use category and the same guidelines apply here. In summary, actual length of operation is streamflow-characteristic and site dependent, however, most stations need to be operated a minimum of 20 and ideally between 30 to 40 years. Continued operation of stations that fall into the category identified above in reason (2) is controlled by the need for actual sequences of daily streamflow data. The issue to evaluate when considering the need to continue operation of these station is whether the actual daily streamflow data are still required to operate or monitor the hydrologic system. If not, then continued operation of the station to meet hydrologic system data uses is no longer warranted. All 12 of the low-flow partial-record stations currently (1994) in operation fall into the category identified above in reason (3) for which the same rules as noted in regional hydrology data uses apply. A minimum of 10 and ideally 20 discharge measurements are required.

Most stations with hydrologic systems data uses monitor regulated streamflows. The hydrologic systems data uses for regulated stations are as diverse as the various systems for which they provide data. Currently, in Hawaii, 19 of the regulated hydrologic data-use stations are operated on ditches or diversions. At some locations, a ditch station and a stream station are operated together. At these locations, discharge recorded at the two stations, when combined, can be used to represent the natural flow of the stream. Continued operation of these ditch stations is controlled by the need to continue operation of the stream station at the site. Some hydrologic data-use ditch stations are operated to monitor operation of the diversion systems. An example would be to determine the amounts of leakage taking place in the ditches as part of maintenance operations. Operation of these types of ditch stations should continue as long as maintenance of the system is a concern. For ditches where maintenance is not an issue, and the regulatory pattern is relatively constant with time, continued operation is required only as long as necessary to establish the characteristics of the diversion taking place. The length of record required to define these characteristics can be determined following procedures developed for

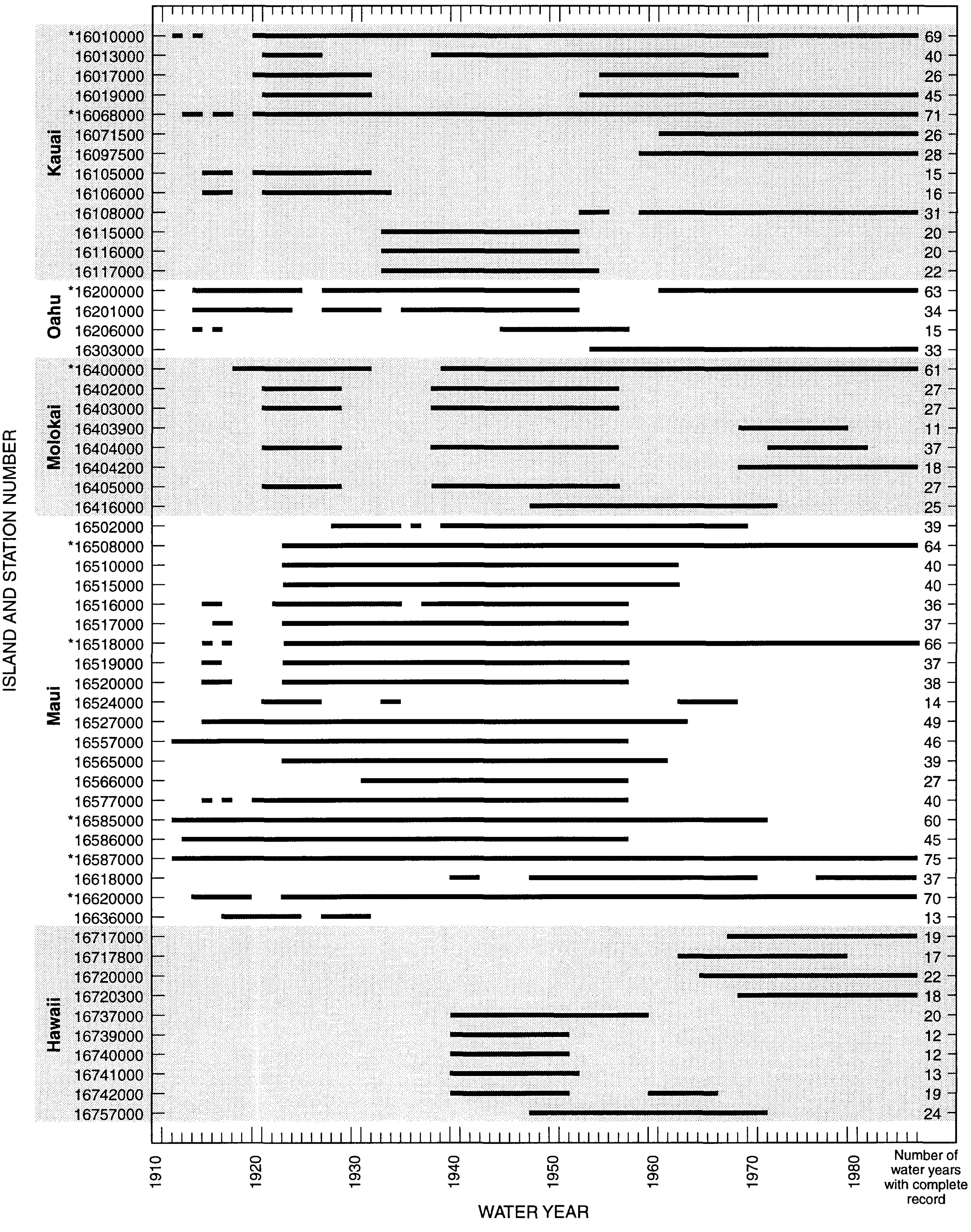

Figure 4. Water years with complete record for the streamflow-gaging stations used in the median flow regression analyses, 1910 through 1986. Stations marked with an asterisk (*) were used as index stations in the analyses (from Fontaine and others, 1992, fig. 6).

regional hydrology stations. Errors associated with estimation of streamflow (or ditch flow) characteristics are directly related to the variability of flow at the station. Flow in ditches is usually significantly less variable than that for streams. As a result determination of accurate ditch-flow characteristics would require relatively shorter record lengths. If the regulatory patterns of the ditch vary significantly over time then operation of the station in question needs to continue as long as information regarding characteristics of the diverted flow are needed.

The remaining hydrologic data-use stations are operated on regulated stream reaches to either define streamflow characteristics at some specific point or to aid in the description of larger regulated hydrologic systems. The length of record required to define streamflow characteristics on a regulated stream depends in large measure on the patterns of regulation within the drainage basin upstream of the site of interest. If regulatory patterns are consistent over time, then rules developed for regional hydrology stations would apply and between 20 and 40 years of record, for most sites, would be adequate. If regulatory patterns are changing significantly with time then definition of streamflow characteristics will require continued operation of the station. The only exception to this rule is where the pattern of changing regulation is known and can be quantified. This information can then be incorporated into the calculation of streamflow characteristics.

Another aspect to be considered when determining if continued operation of a hydrologic system data-use station is justified is the transfer value of the data. Regional methods of transferring streamflow characteristics to ungaged sites are appropriate only in unregulated systems. Fontaine and others (1992) noted that estimates of median streamflows can be made at miscellaneous sites in regulated systems if at least some partial records are collected at the site (for example discharge measurements) and long-term continuous records are available at some proximate, comparably regulated station. At almost all sites in windward Oahu where this methodology was tested, Fontaine and others (1992, p. 34) noted that the continuous-record site that gave the best results was located in the same drainage basin as the miscellaneous site. This result implies that continued operation of hydrologic system stations on regulated streams can be justified as long as flow data are required at additional locations in the basin and no other continuous-record stations are available to serve as the index station.

Current-needs uses are generally well defined and are time and site specific. Data are required for set periods of time at some fixed location. Current-needs gages are typically funded by agencies that are not involved the Statewide stream-gaging program. The funding agencies are concerned with the specific current issues they need to address and generally have no desire to fund operation of gages beyond the time period of interest. Data collected at current-needs stations are typically analyzed and used on an ongoing basis. Issues that need to be addressed when considering continued operation of current-needs stations are provided by the site-specific nature of the goals and funding sources for these types of gages.

Hydrologic forecast uses imply that the data collected at a gage are regularly used to provide forecasts. Currently, in Hawaii, no surface-water gaging stations provide data that are used regularly to provide hydrologic forecasts. Besides funding only two questions need to be addressed when considering continued operation of hydrologic forecast stations. First, can data collected at the station be used to provide forecasts that are accurate and advanced enough for adequate warning and response. Second, are the data still required and used to make forecasts. For example, streamflow data may have been required only to establish rainfall/flood-peak relations. Once the relations were established then only the rainfall data would be regularly used to make the hydrologic forecasts. This example could be common in Hawaii where streams peak rapidly and as a result, streamflow data alone do not provide adequate advance warning of potential floods.

Water-quality uses imply that the streamflow data collected at a gage are used to support water-quality or sediment-transport monitoring activities at the station. Besides funding, two questions need to be addressed when considering continued operation of water-quality data-use stations. First, are water-quality data still being collected at the station. Second, are streamflow data required to determine chemical loads and sediment transport at the station. If not then continued operation as a water-quality data-use station is not warranted.

Long-term trend uses require that data be collected at a station for as long a period as possible. If funding is still available, then two requirements need to be met when considering continued operation of long-term trend stations. First, the drainage basin upstream of the station should be free of significant artificial changes and is expected to remain so in the future. Second, long-term trend stations need to be located in a variety of settings with different physical and climatologic characteristics. If other long-term trend stations provide data from essentially the same setting then continued operation of the gage may not be justified.

For all stations, evaluations of the need to continue operation of gaging stations need to be made in conjunction with cooperating agencies. Circulating letters to cooperators and data users identifying any stations slated to be discontinued could be useful. In this way potential data uses not previously recognized may be identified and additional sources of funding may be found.

Current Program

In 1994, there are 89 continuous-record, 107 crest-stage, and 12 low-flow partial-record gages operated in Hawaii by the USGS. This section of the report summarizes the results of the evaluation of these gages. The evaluation followed the methodology given in the previous section to determine if continued operation is warranted. This evaluation focused only on data uses and funding sources identified at the time of the evaluation (tables 6–8). Results from this evaluation are summarized in tables 10, 12, and 13.

Continuous-record gages.--On Kauai, 19 continuous-record gages are in operation in 1994. On the basis of the evaluation of these gages, the following changes in status need to be considered. Station 16010000 on Kawaikoi Stream has been operated for 77 years. The station is currently being operated to meet regional hydrology and hydrologic-systems data uses. The length of available data is sufficient to meet these needs and discontinuing the station could be considered if no other data uses are identified. Stations 16077000, 16088000, and 16091000 are operated on Makaleha, Anahola, and Lower Anahola Ditches respectively. These stations have 56, 69, and 55 years of record and are operated to meet hydrologic systems needs related to diversion of irrigation water. Currently, use of the above ditch systems is limited and discontinuing the stations could be considered.

On Oahu, 34 continuous-record gages are in operation in 1994. Evaluation of these gages resulted in the following changes in status that could be considered. Stations 16208000 on the South Fork Kaukonahua Stream and 16212800 on Kipapa Stream have both been operated for 36 years. Data from station 16208000 is used for peak-flow regional hydrology and hydrologic systems and data from station 16212800 is used only for regional hydrology. Discontinuing the stations could be considered when they have a total of 40 years of record. Stations 16225800 and 16226200 on North Halawa Stream are being operated as part of a special project. The stations also provide data for regional hydrology uses. When the special project is completed, station 16225800 will have about 8 years of record and station 16226200 will have about 15 years of record. Continued operation of the stations beyond the end of the special project and the current source of funding needs to be considered. If stations 16225800 and 16226200 are operated until they have at least 10 and 20 years of record, respectively, the extra years of record will expand the number of streamflow characteristics that can be determined at the stations and significantly improve their accuracy. Funding for station 16229000 on Kalihi Stream (federal program) has been discontinued. Valid uses for the data collected at this station still exist (long-term trends) however, unless new sources of funds become available the station will be discontinued. Station 16232000 on Nuuanu Stream is operated to provide hydrologic systems data. The 77 years of record available at the station are adequate to meet this data need and discontinuing the station could be considered. Stations 16265600, 16270900, and 16273950 on the Right Branch of Kamoolii Stream, Luluku Stream, and South Fork Kapunahala Stream are being operated as part of a special project. The stations also provide data for regional hydrology uses. When the special project is completed the stations will have about 15, 18, and 9 years of record, respectively. Continued operation of stations 16265600, 16770900, and 16273950 beyond the end of the special project and the current source of funding needs to be done until the stations have a minimum of 20, 20, and 10 years of record, respectively. The extra years of record will expand the number of streamflow characteristics that can be determined at the stations and significantly improve their accuracy. Station 16330000 is being operated primarily to provide regional hydrology information. In 1994, there were 35 years of record available at the station. When a total of 40 years of record has been collected, discontinuing the station could be considered.

On Molokai there are eight continuous-record gages in operation in 1994. Evaluation of these gages resulted in only one change in status that could be considered. Currently two stations (16405500 and 16408000) are operated on Waikolu Stream. Data from these stations are used to define peak streamflows and describe the hydrologic system. Waikolu Stream is an important source of water on Molokai and significant volumes of water are diverted from the stream. Station 16408000 has 68 years of record, which is sufficient to define peak streamflows. If the pattern of water diversion is known, and is not changing from year to year, then continued operation of station 16408000 to define the hydrologic system may not be necessary. For this station, the available data are sufficient and the station could be either discontinued or possibly converted to a less costly partial-record station.

On Maui, 10 continuous-record gages are in operation. Evaluation of these gages resulted in the following changes in status that could be considered. Station 16509000 has 16 years of record and is being operated as part of a special project. The data collected are used to meet current needs, to describe the hydrologic system, and to define flood peaks. The station needs to be operated a minimum of 20 years to increase the accuracy of estimated streamflow characteristics. When the special project ends, discontinuing the station could be considered as long as 20 years of record are available. Station 16518000 has been operated for 73 years and the data are used to describe regional hydrology and hydrologic systems. The available data are sufficient to meet the currently identified needs and discontinuing the station could be considered if no other data uses are identified.

On the island of Hawaii, 18 continuous-record gages are in operation in 1994. Evaluation of these gages resulted in the following changes in status that could be considered. Station 16700900 on Olaa Flume Springs and station 16700950 on Lyman Springs No. 2 have been operated for 19 and 12 years, respectively. Data from these stations are used to describe hydrologic systems used as water supplies. Use of surface-water sources for water supply is decreasing and additional data at these stations might not be required, therefore discontinuing the stations could be considered. Funding for stations 16713000 and 16717000 (federal program) has been discontinued, however, valid uses for the data collected at the stations still exist. Station 16713000 has 14 years of record and the data are used to define peak streamflows and regional hydrology. Operation of the station for a minimum of 20 years needs to be considered. Station 16717000 has 27 years of record and the data are used to define regional hydrology, hydrologic systems, and long-term trends and continued operation is needed. However, unless new sources of funds become available the stations will be discontinued. Station 16727000 has 16 years of record and is located on a branch of the Upper Hamakua Ditch that is infrequently used. Discontinuing this station could be considered. Station 16737500 on Waimanu Stream has 3 years of record and is operated as part of a special project that is due to end in 1994. Discontinuing the station at the end of the project could be considered. Stations 16756000 on Kohakohau Stream and 16758000 on Waikoloa Stream are operated to provide data to describe peak streamflows and hydrologic systems. The two stations have 37 and 46 years of data, respectively, and these data are sufficient to address currently identified needs. Discontinuing the stations could be considered.

In this discussion 25 continuous-record stations were identified where changes in status could be considered. These stations and possible actions to be considered are summarized in table 10. It is important to emphasize that these are simply possible actions that need to be discussed in detail with cooperators and data users prior to implementation.

Crest-stage gages.--There are 107 crest-stage gages currently (1994) in operation in Hawaii (table 7). Ninety-six of the gages are operated primarily to provide regional hydrology information on peak streamflows and the 11 remaining gages are operated to meet current needs for site-specific projects. As noted in the section on methodology, the ideal maximum length of record for a crest-stage gage in Hawaii, in terms of regional hydrology data uses, is about 40 years. Five gages in Hawaii have more than 40 years of record: stations 16038000, 16052000, 16080000, 16228000, and 16607000. Each of the stations was evaluated to determine if additional years of record need to be considered to further improve estimates of peak streamflows and if other data uses need to be considered.

Stations 16038000 and 16052000 are located near the mouths of the Waimea and Hanapepe Rivers in Kauai. The gages have been operated for 50 and 44 years respectively and they provide only maximum stage data (table 1). The stations were operated to meet current needs that can be addressed with the length of record available. In addition there are active continuous-record gages located just upstream of both gages

Table 10. Continuous-record stations in Hawaii where a change in status needs to be considered, 1994

Station	Remarks	Possible action
	Kauai	
16010000	Record length sufficient to meet current needs	Discontinue
16077000	Limited current use of ditch	Discontinue
16088000	Limited current use of ditch	Discontinue
16091000	Limited current use of ditch	Discontinue
	Oahu	
16208000	Collect at least 4 more years of record	Discontinue in 4 years
16212800	Collect at least 4 more years of record	Discontinue in 4 years
16225800	Operated as part of a special project, desirable to operate station a minimum of 10 years	Discontinue at end of special project if 10 years of record are available
16226200	Operated as part of a special project, desirable to operate station a minimum of 20 years	Discontinue at end of special project if 20 years of record are available
16229000	Data needs still exists, funding terminated	Discontinue if no new funding available
16232000	Record length sufficient to meet current needs	Discontinue
16265600	Operated as part of a special project, desirable to operate station a minimum of 20 years	Discontinue at end of special project if 20 years of record are available
16270900	Operated as part of a special project, desirable to operate station a minimum of 20 years	Discontinue at end of special project if 20 years of record are available
16273950	Operated as part of a special project, desirable to operate station a minimum of 10 years	Discontinue at end of special project if 10 years of record are available
16330000	Collect at least 5 more years of record	Discontinue in 5 years
	Molokai	
16408000	Record length sufficient to meet current needs if diversion plans remain constant	Discontinue if diversion stays the same
	Maui	
16509000	Operated as part of a special project, desirable to operate station a minimum of 20 years	Discontinue at end of special project if 20 years of record are available
16518000	Record length sufficient to meet current needs	Discontinue
	Hawaii	
16700900	Data needs of cooperator may be changing	Discontinue if needs change
16700950	Data needs of cooperator may be changing	Discontinue if needs change
16713000	Data needs still exists, funding terminated	Discontinue if no new funding available
16717000	Data needs still exists, funding terminated	Discontinue if no new funding available
16727000	Limited current use of ditch	Discontinue
16737500	Special project ending	Discontinue
16756000	Record length sufficient to meet current needs	Discontinue
16758000	Record length sufficient to meet current needs	Discontinue

(plate 1). Therefore, discontinuing both stations at the end of the current water year could be considered.

Station 16080000 on Kapaa Stream on Kauai has been operated for 58 years (table 1). Given the length of record and variability of flood peaks at the station, the standard errors for the estimated 10-year and 100-year floods are 7.8 and 10.4 percent. Operating this station another 10 years would only reduce these standard errors to 7.1 and 9.4 percent. Also, two additional crest-stage gages are active in the Kapaa Stream basin (plate 1). Therefore, discontinuing the station at the end of the current water year could be considered.

Station 16228000 on Moanalua Stream on Oahu has been operated for 67 years (table 2). Given the length of record and variability of flood peaks at the station, the standard errors for the estimated 10-year and 100-year floods are 11.8 and 15.3 percent. Operating this station another 10 years would only reduce these standard errors to 11.1 and 14.1 percent. Also, two crest-stage gages are active downstream of the station (plate 2). Therefore, discontinuing the station at the end of the current water year could be considered.

Station 16607000 on Iao Stream on Maui has been operated for 42 years (table 4). Given the length of record and variability of flood peaks at the station, the standard errors for the estimated 10-year and 100-year floods are 11.8 and 15.3 percent. Operating this station another 10 years would only reduce these standard errors to 10.6 and 13.7 percent. Continued operation of this station solely to meet regional hydrology data uses is questionable. As noted in table 7, the station is funded as part of the other federal agency (OFA) program and also provides data to meet current needs. The current needs for data at this station still exist and therefore operation needs to be continued. When the current needs at the station are satisfied, then discontinuing the station could be considered.

The five stations just discussed are those indicated in table 11 as having more than 40 years of record. An additional 48 stations have from 31 to 40 years of record. In the near future, when these stations have more than 40 years of record, there will be a need to determine if continued data collection at these sites is needed. An alternative would be to reallocate the funds used to support those stations and establish new stations in locations where no data exist.

In this discussion, five crest-stage gages were identified where changes in status could be considered. These stations and possible actions are summarized in table 12. It is important to emphasize that these are simply possible actions that need to be discussed in detail with cooperators and data users before implementation.

Low-flow partial-record stations.--There are 12 low-flow partial-record stations currently (1994) in operation in Hawaii, six each on Oahu and Molokai. The six stations on Oahu are all operated as part of a project established to evaluate the effects of constructing the H-3 freeway. The stations were identified (table 8) as hav-

Table 11. Years of record for active crest-stage gages in Hawaii, 1994

Years of record	Number of crest-stage gages					
	Kauai	Oahu	Molokai	Maui	Hawaii	Total
0–10	0	0	0	0	0	0
11–20	0	1	0	0	0	1
21–30	4	19	8	14	8	53
31–40	6	20	0	9	13	48
41–50	2	0	0	1	0	3
51–60	1	0	0	0	0	1
61–70	0	1	0	0	0	1
70+	0	0	0	0	0	0
Total	13	41	24	21	21	107

Table 12. Crest-stage stations in Hawaii where a change in status needs to be considered, 1994

Station number	Remarks	Action to be considered
16038000	Record length sufficient to meet current needs	Discontinue
16052000	Record length sufficient to meet current needs	Discontinue
16080000	Record length sufficient to meet current needs	Discontinue
16228000	Record length sufficient to meet current needs	Discontinue
16607000	Operated only to meet current needs	Discontinue when needs are met

ing low-flow regional hydrology, hydrologic systems, current-needs, and water-quality data uses. The special project is scheduled for completion in the late 1990's. When the project ends all the identified data uses except regional hydrology will have been met. As noted in table 2 the six stations (16227100, 16265700, 16266500, 16267500, 16269500, and 16274100) have been operated as low-flow partial-record stations for 5 to 10 years. As many as 10 discharge measurements per year were made during this period at each station. Given that the total number of discharge measurements is significantly greater that the ideal maximum of 20, continued operation solely as low-flow partial-record stations for regional hydrology purposes is not justified. Discontinuing all six of the stations at the end of the current project could be considered.

The six low-flow partial-record stations on Molokai were identified as having low-flow regional hydrology and hydrologic systems data uses (table 8). As noted in table 3 each of the six stations (16403400, 16403500, 16403600, 16403700, 16403800, and 16403900) has been operated for more than 20 years. During this time a minimum of three discharge measurements per year were made. The total number of measurements is greater than the ideal maximum of 20 and continued operation solely for the purpose of describing low-flow characteristics in the Pelekunu hydrologic system is not justified. Discontinuing all six of the stations at the end of the current water year could be considered.

In this discussion, 12 low-flow partial-record gages were identified where changes in status need to be considered. These stations and possible actions to be considered are summarized in table 13. It is important to emphasize that these are simply possible actions that need to be discussed in detail with cooperators and data users before implementation.

Future Goals

Earlier in the report 14 specific issues related to needs for streamflow data were identified. Discussion of each issue provided future goals that the surface-water data-collection program in Hawaii could strive to meet. In this section of the report each of the 14 issues and their related goals will be evaluated individually. The question to be addressed is whether the existing data-collection program and historical data available will be sufficient to address the future goals identified. If the answer to these questions is either no or only partially, then alternatives will need to be considered.

The current and historical data available to meet future goals were discussed in the section of the report on the description of the surface-water data-collection program. Additional sources of data are available that can be used to potentially address future goals. These additional sources are primarily contained in reports that describe statistical analyses of streamflow data and methods that can be used to extrapolate data collected at gaged locations to ungaged sites. The most significant of these reports are described below, in chronological order. Yamanaga (1972), in an evaluation of the streamflow data program in Hawaii, developed regional equations that can be used to estimate selected streamflow characteristics for ungaged sites on the islands of Kauai, Oahu, Molokai, Maui, and Hawaii. Regional equations

Table 13. Low-flow partial-record stations in Hawaii, where a change in status needs to be considered, 1994

Station number	Remarks	Action to be considered
	Oahu	
16227100	Operated as part of special project	Discontinue at end of special project
16265700	Operated as part of special project	Discontinue at end of special project
16266500	Operated as part of special project	Discontinue at end of special project
16267500	Operated as part of special project	Discontinue at end of special project
16269500	Operated as part of special project	Discontinue at end of special project
16274100	Operated as part of special project	Discontinue at end of special project
	Molokai	
16403400	Record length sufficient to meet current needs	Discontinue
16403500	Record length sufficient to meet current needs	Discontinue
16403600	Record length sufficient to meet current needs	Discontinue
16403700	Record length sufficient to meet current needs	Discontinue
16403800	Record length sufficient to meet current needs	Discontinue
16403900	Record length sufficient to meet current needs	Discontinue

were developed to estimate mean annual and mean monthly discharges, annual flood peaks with recurrence intervals from 2 to 50 years, annual maximum 1-day and 7-day mean discharges with recurrence intervals of 2 and 50 years, and annual minimum 7-day and 30-day mean discharges with recurrence intervals of 2 and 20 years. Nakahara (1980) developed improved regional equations that can be used to estimate annual flood peaks with recurrence intervals from 2 to 100 years at ungaged sites on Oahu. Matsuoka (1981 and 1983) provided statistical summaries of zero-flow days, monthly means, annual means, high- and low-flow volumes and flow-duration data for continuous-record gaging stations using data collected through 1979 water year. Fontaine and others (1992) developed regional equations that can be used to estimate median discharges for ungaged perennial streams on the islands of Kauai, Oahu, Molokai, Maui, and Hawaii. In addition, estimates of median discharges were provided for 27 regulated, low-flow partial-record, windward Oahu sites (Fontaine and others, 1992). Wong (1994) provided updated flood-frequency data for continuous-record and crest-stage gages on Oahu and developed improved regional equations that can be used to estimate annual flood peaks with recurrence intervals from 2 to 100 years at ungaged sites on Oahu.

1. Ground-water availability.--Future goals associated with the issue of ground-water availability are partially met. In figure 5 approximate locations of areas where ground-water demands are projected to increase are identified (S.S. Anthony, USGS, oral commun., 1994). For the purposes of this evaluation, the areas identified in figure 5 will be those on which the issue of ground-water availability will focus. The primary data-use categories (table 6) applicable to this issue are regional hydrology (low flows) and hydrologic systems.

On Kauai two areas where ground-water demands are projected to increase are the eastern coastal area from Lihue to Anahola and the southeastern area from Hanapepe to Lihue (fig. 5). In the Lihue-Anahola area, the largest watersheds are those drained by Hanamaulu, Konohiki, Kaehulua, Kapaa, and Anahola Streams and the Wailua River (plate 1 and table 1). Runoff from the Wailua River has been extensively monitored and four long-term, continuous-record gages (16060000, 16068000, 16071000, and 16071500) are still active in the basin. Runoff from Anahola Stream was monitored near the middle of the watershed at station 16089000 for 70 years and near the mouth, at station 16093200, for 17 years. Kapaa Stream was monitored near the middle of the watershed at station 16080000 for 49 years. Continuous runoff from Hanamaulu, Konohiki, and Kaehulua Streams has also been gaged at one time; however, none of the sites were operated for more than 2 years and all were active from 1911–13. Runoff from Kapaa Stream near its mouth and for all of the Hanamaulu, Konohiki, and Kaehulua Streams is not well defined and alternatives may be needed for these areas. In the Hanapepe-Lihue area the largest watersheds are those drained by the Hanapepe River and Huleia and Lawai Streams. In this area the only long-term, continuous-record gage operated was station 16049000 on the Hanapepe River below Manuahi Stream (69 years of record). This station is also the only active, continuous-record gage in the area. Short-term records (less than 6 years) are available for several sites in the Huleia Stream watershed. Runoff for all of the Hanapepe-Lihue area is poorly defined (except for the Hanapepe River at station 16049000) and alternatives for this area may need to be considered.

A possible alternative to gaging in areas where limited data exist are regional regression equations. Yamanaga (1972) developed separate equations for the windward and leeward areas of the major Hawaiian islands that can be used to provide estimates of mean annual discharge. These equations can be used to provide estimates with standard errors of 34 percent for windward areas and 28 percent for leeward areas. As noted in figure 2, these standard errors are significantly greater than the error associated with a gage with 5 years of record, which has an error of about 17 percent. In addition, the existing equations cannot be used to provide estimates of the division of mean annual runoff between direct runoff and base flow and the equations do not account for effects of regulation. Gaging alternatives may still need to be considered if these limitations are significant or if errors associated with regression equations are too high.

On Oahu, two areas where ground-water demands are projected to increase are the central corridor area from Pearl Harbor to Haleiwa and the windward area from Waimanalo to Hauula (fig. 5). Runoff data from the part of the central corridor that drains towards Haleiwa is available at 11 upland, continuous-record, surface-water gages, four of which are active (plate 2 and table 2). These 11 gages provide a reasonable geographic sampling of the upland areas and all but two have more than 15 years of record. Only two gages have been

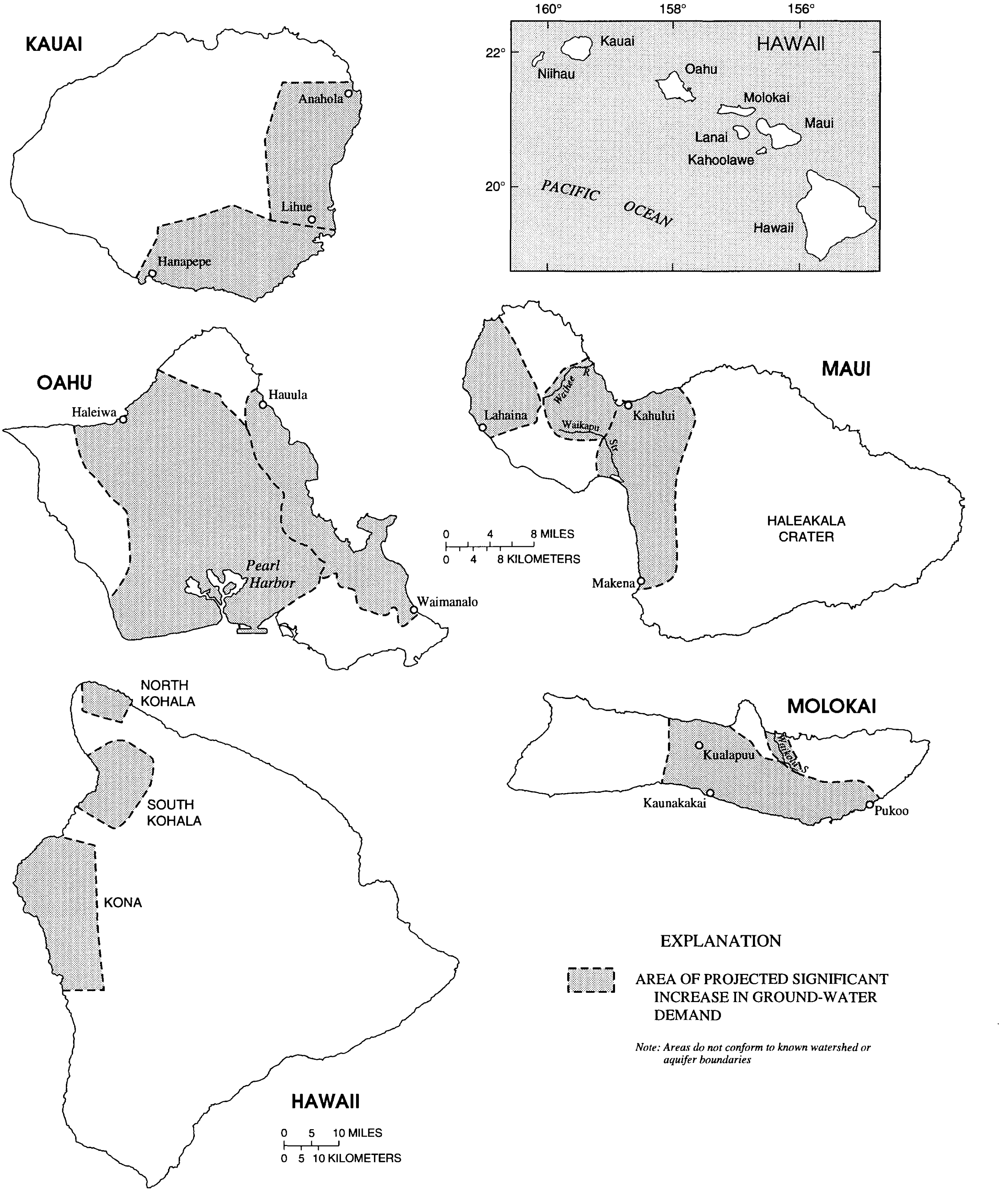

Figure 5. Approximate locations of areas where significant increases in ground-water demands are projected, Hawaii (Commission on Water Resource Management, written commun., 1994).

operated near the mouths of streams that drain the north-central area of the island towards Haleiwa, stations 16330000 and 16343000, and only station 16330000 on Kamananui Stream is active. Runoff near the mouths of streams in this area is not well defined and alternatives may need to be considered. Runoff data from the south-central area that drains towards Pearl Harbor is available at six midland to upland gages, four of which are active. There are no upland gages in the area between Kipapa and North Halawa Streams and runoff is not well defined in this area. Alternatives may need to be considered here. The remaining upland areas have a reasonable geographic coverage of gages. Long-term runoff data are available near the mouths of Waikele and Waiawa Streams at stations 16213000 and 16216000, both of which are active. In addition, data from inactive stations 16223000 and 16224500 (16 and 25 years of record), are available near the mouths of Waimalu and Kalauao Streams. Runoff from the mouths of streams in the area is reasonably well defined. Runoff from the windward area from Waimanalo to Hauula has been extensively gaged. Data from plate 2 and table 2 indicate that 27 continuous-record gages with more than 3 years of record have been operated in this area. Sixteen of the 27 gages are still active. These data provide a reasonable geographic and hydrologic coverage of runoff in the area.

On Molokai two areas where ground-water demands are projected to increase are the area adjacent to and including Waikolu Stream and the area from Kualapuu across the island to Kaunakakai and then along the coast to Pukoo (fig. 5). Runoff in Waikolu Stream is well defined. Continuous-record gages have been operated near the mouth (station 16408000 with 68 years of record) and in the headwaters of the basin (station 16405500 with 32 years of record). In addition diversions from the stream into the Molokai tunnel have been gaged at station 16405100 for 27 years. All of these gages are presently in operation and should provide the runoff data required to evaluate ground-water availability in the area. Runoff from the Kaulapuu-Kaunakakai-Pukoo area is poorly defined. Data from plate 3 and table 3 indicate that only three continuous-record, surface-water gages have been operated in the area (stations 16414000, 16415000, and 16416000). Each of the stations has at least 25 years of record but only one is currently in operation. Alternatives to evaluate runoff from this area may need to be considered.

On Maui three areas where ground-water demands are projected to increase are the Lahaina coastal area, the area bounded by Waihee River and Waikapu Stream, and the central area from Kahului across the island and along the coast to Makena (fig. 5). Runoff in the Lahaina area is poorly defined. Only five continuous-record, surface-water stations with at least 3 years of record have been operated in the area (plate 4 and table 4). None of the five stations (16630000, 16634000, 16636000, 16638000, and 16638500) are currently active, all but one were operated sometime between 1911–32, and only two have more than 4 years of record. Alternatives to evaluate runoff from this area may need to be considered. Runoff in the Waihee-Waikapu area is only minimally defined. Continuous-record, surface-water stations with at least 3 years of record operated in this area include station 16614000 on the Waihee River, station 16608000 on North Waiehu Stream, station 16604500 on Iao Stream, and station 16650000 on Waikapu Stream. The four gaged streams are the most significant in the area, however, none of the stations has more than 10 years of record and only the Iao Stream and Waihee River gages are currently in operation. In addition, all of the four gages are located in the middle levels of their respective watersheds, and no data have been collected near their mouths. Alternatives to evaluate runoff in this area may need to be considered. Runoff in the Kahului-Makena area is poorly defined. No continuous-record, surface-water stations have been operated in this area. The only gages with significant data bases in the area are crest-stage gages. Surface drainage in the lower elevations of this area is to a large extent controlled by the agricultural activities there. However several intermittent streams, that drain the west slopes of Haleakala flow through the area and no continuous-record data exist for the streams. Alternatives to evaluate runoff in this area may need to be considered.

On Hawaii three areas where ground-water demands are projected to increase are the North Kohala area, the South Kohala area, and the Kailua-Kona area. Runoff in the North Kohala area is poorly defined. Historically, no continuous-record, surface-water gages have been operated in this area (plate 5 and table 5). The only gage operated in this area is station 16752600 which is a crest-stage gage on Hapahapai Gulch. Alternatives to evaluate runoff in this area may need to be considered. Runoff in the South Kohala area is poorly defined. Continuous-record, surface-water stations in this area include stations 16756000 on Kohakohau Stream, station 16756500 on Keanuiomano Stream, stations 16757000 and 16758000 on Waikoloa Stream, and station 16759000 on Hauani Gulch. All of the sites have eight or more years of record and stations 16756000, 16758000, and 16759000 are active surface-water stations. However, all five stations are located in wetter headwater reaches of Waiulaula Gulch. None of the other stream systems have been gaged and data are not available for the drier, lower reaches of the South Kohala area. Alternatives to evaluate runoff in this area may need to be considered. Runoff in the Kailua-Kona area is partially defined. Few streams exist in this area and surface runoff takes place only during storms. Three continuous-record, surface-water stations have been operated in the Waiaha Stream watershed (stations 16759200, 16759300, and 16759000). Each of the stations has a minimum of 10 years of record; however, only station 16759300 is still active and is now operated as a crest-stage gage. Alternatives to evaluate runoff in this area may need to be considered.

The adequacy of the current surface-water data-collection program in Hawaii for describing surface runoff is limited in many of the areas where increasing ground-water demands have been identified (fig. 5). A summary of the adequacy of the gaging program to describe surface runoff in these areas is provided in table 14. In many of these areas of increasing ground-water demands, alternatives to better define surface runoff may need to be considered.

*2. **Surface-water availability.***--Future goals associated with the issue of surface-water availability are being partially met. Historically, 668 continuous-record, crest-stage, and low-flow partial-record gages have been operated by the USGS in Hawaii (plates 1-5). Data collected at these stations provide an extensive data base that can be used to define streamflow characteristics at the gaged locations. The primary data-use categories (table 6) applicable to the issue of surface-water availability are regional hydrology (low and peak flows) and hydrologic systems. In the past, when considering the issue of surface-water availability, the streamflow characteristic of greatest interest was some measure of average flow such as the mean annual discharge. As noted in figure 2, reasonably accurate estimates of mean annual discharge can be made with less than 10 years of gage record. Almost half of the continuous-record gages in Hawaii have less than 10 years of record (table 15). Future issues regarding surface-water availability will require information on several additional streamflow characteristics such as low flows and flood frequencies. To obtain accurate estimates for these characteristics, record lengths greater than 10 years will be required (fig. 2). The issue of record length will need to be considered when future decisions regarding operation of continuous-record gages are made.

Historically, the primary focus of surface-water availability issues has been on perennial streams, and

Table 14. Adequacy of Hawaii's current (1994) surface-water data-collection program for describing surface runoff in areas of increasing ground-water demands.

Region	Description of surface runoff	Remarks
		Kauai
Lihue-Anahola	Good	Data lacking for Hanamaulu, Konohiki, and Kaehulua Streams, and near mouth of Kapaa Stream
Hanapepe-Lihue	Poor	Data lacking except for Hanapepe River
		Oahu
North central (Haleiwa side)	Fair	Data lacking near the mouths of streams
North central (Pearl Harbor side)	Fair	Data lacking in upland areas between Kipapa and North Halawa Streams
Waimanalo-Hauula	Good	Twenty-seven continuous-record gages operated in area
		Molokai
Waikolu Stream	Good	Three active continuous-record gages in watershed
Kaulapuu-Kaunakakai-Pokoo	Poor	Inadequate geographic and hydrologic distribution of gages
		Maui
Lahaina area	Poor	No active continuous-record gages in area
Waihee-Waikapu	Fair	Lack of long-term data and gages near mouths of streams
Kahului-Makena	Poor	No continuous-record gages operated in area
		Hawaii
North Kohala	Poor	No continuous-record gages operated in area
South Kohala	Poor	All gages operated to date in headwaters of Waiulaula Gulch, none in other areas
Kailua-Kona	Fair	No active continuous-record gages in area

Table 15. Years of record for continuous-record stream gages in Hawaii, 1994

	Number of continuous-record gages					
Years of record	**Kauai**	**Oahu**	**Molokai**	**Maui**	**Hawaii**	**Total**
1–10	53	62	8	64	28	215
11–20	7	22	2	22	20	73
21–30	6	11	9	5	10	31
31–40	11	16	2	13	4	46
41–50	3	4	1	6	3	17
51–60	11	3	0	5	0	19
61–70	4	2	2	7	2	17
70+	4	3	0	5	0	12
Total	99	123	24	127	67	440

this focus will likely continue in the future. To date stream gages have been operated, at one time or another, on 139 of Hawaii's 376 perennial streams. A list of the 376 perennial streams and indications as to those that have been gaged is provided in the Hawaii Stream Assessment (Hawaii Commission on Water Resource Management, 1990b, p. 36) and is not included in this report. There are notable geographic areas where stream gaging on perennial streams has been limited (plates 1-5). Examples include the west coast of Kauai (except for the Hanapepe and Waimea Streams), the Waianae and north shores of Oahu, most of the island of Molokai, the southeast and central isthmus areas of Maui, and most of the island of Hawaii (except the Hilo area and parts of the Kohala Mountain region). The issue of geographic distribution of streams with little or no gage data will need to be addressed in the future. Alternatives such as partial-record stations and regional regression analyses can be used at locations where less accurate data can be used. A limited number of these regional regression reports are available for Hawaii (Fontaine, 1992; Nakahara, 1980; Wong, 1994; and Yamanaga, 1972). Regional reports are, in most cases, not appropriate for streams where the effects of regulation are significant. Alternatives that include some degree of data collection need to be considered on regulated streams where streamflow characteristics are required. Gaged streams where the effects of regulation are significant have been identified in tables 1–5. Ungaged perennial streams that are regulated have been identified in the Hawaii Stream Assessment (Hawaii Commission on Water Resource Management, 1990b, p. 36) and are not listed in this report.

A limited number of continuous-record gages have been operated on ephemeral streams in Hawaii. However, most of the gages operated on ephemeral streams have been crest-stage gages (tables 1–5). At this time only flood-frequency characteristics are estimated using data collected at crest-stage gages. A limited number of additional streamflow characteristics can be extrapolated to ungaged ephemeral streams using available regional regression equations. Data-collection alternatives for most ephemeral streams will need to be considered as the needs to address surface-water availability issues arise.

3. Long-term baseline data-collection and trends.--Future goals associated with the issue of long-term baseline data-collection and trends can, with minor exceptions, be adequately met with the existing data network. Alternatives to address the factors discussed below need to be considered. Twenty stations are currently being operated that have the data use of long-term trends, as noted in table 6. These stations and their length of available record are summarized in table 16. The data-use category of long-term trends has essentially the same description as does the goal statement for the issue of long-term baseline data-collection and trends. Therefore all of the 20 stations listed in table 16 can be used to address this future goal.

Currently (1994) there are four long-term trend stations on Kauai, five on Oahu, two on Molokai, five on Maui, and four on Hawaii (fig. 6). To address future goals associated with the issue of long-term baseline data-collection and trends, the existing network of 20 long-term stations needs to provide an extended data base containing data that is not significantly affected by humans and which provides a representative sample of the variability of hydrologic and climatologic characteristics that exists in Hawaii.

The four long-term trend stations on Kauai remain free of regulation, however, only one station (16068000) has more that 60 years of record. The existing stations are in the northern and eastern areas of island. The hydrology of the southern and western parts

Table 16. Active, continuous-record, long-term trend stream-gaging stations in Hawaii, 1994

Station	Station name	Years of record
	Kauai	
16019000	Waialae Stream at altitude 3,820 feet near Waimea	52
16068000	East Branch of North Fork Wailua River near Lihue	78
16097500	Halaulani Stream at altitude 400 feet near Kilauea	35
16108000	Wainiha River near Hanalei	38
	Oahu	
16200000	North Fork Kaukonahua Stream above Right Branch near Wahiawa	70
16211600	Makaha Stream near Makaha	34
16226000	North Halawa Stream near Aiea	43
16229000	Kalihi Stream near Honolulu	79
16303003	Punaluu Stream near Punaluu (combined flow of stations 16302000 and 16303000)	40
	Molokai	
16400000	Halawa Stream near Halawa	69
16414000	Kaunakakai Gulch near Kaunakakai	43
	Maui	
16501200	Oheo Gulch at Dam near Kipahulu	5
16508000	Hanawi Stream near Nahiku	71
16587000	Honopou Stream near Nahiku	82
16618000	Kahakuloa Stream near Honokohau	42
16620000	Honokohau Stream near Honokohau	75
	Hawaii	
16700000	Waiakea Stream near Mountain View	63
16717000	Honolii Stream near Papaikou	27
16720000	Kawainui Stream near Kamuela	29
16764000	Hilea Gulch tributary near Honuapo	27

of Kauai is not being measured by the current long-term trend network. The five long-term trend stations on Oahu provide a reasonable coverage of the hydrology of the island. In addition, two of the stations have at least 70 years of record. Two issues will need to be addressed. Funding for the Kalihi Stream station (16229000) has been cut (federal program) and the station is slated to be discontinued at the end of 1994 water year. There are 79 years of record at this site and continued operation is needed. Water-supply wells were put into production upstream of the Makaha Stream station (16211600) in 1992. If pumping from these wells significantly affects streamflow, then the station will need to be removed from the long-term trend network and replaced with a similar site. The two long-term trend stations on Molokai remain free of significant regulation; however, only one of the stations (16400000) has more than 50 years of record. The two stations are in the eastern and southern areas of the island. A large part of the island is not covered by the current long-term trend network.

The five long-term trend stations on Maui provide reasonable coverage of the island. Three of the stations have at least 70 years of record. One limitation is the lack of a trend station in the southern and western areas of the island. The four long-term trend stations on Hawaii provide a reasonable coverage except in the western area of the island. Only one of the current stations has more than 50 years of record and the three remaining stations have an average of only 28 years of record. Funding for the Honolii Stream station (16717000) has been cut (federal program) and the station is slated to be discontinued at the end of the 1994 water year. Continued operation of this station is needed.

4. Identification of streams for protection.--Future goals associated with the issue of streams for protection can be partially met with the historical and current surface water data-collection program. Currently there is some debate as to which streams should be candidates for protection. It is clear, however, that for a goal of stream protection, a way to quantify what is being protected is needed. With regard to surface water this translates into the need to be able to describe the sources, sinks, and quantities of surface water in the system.

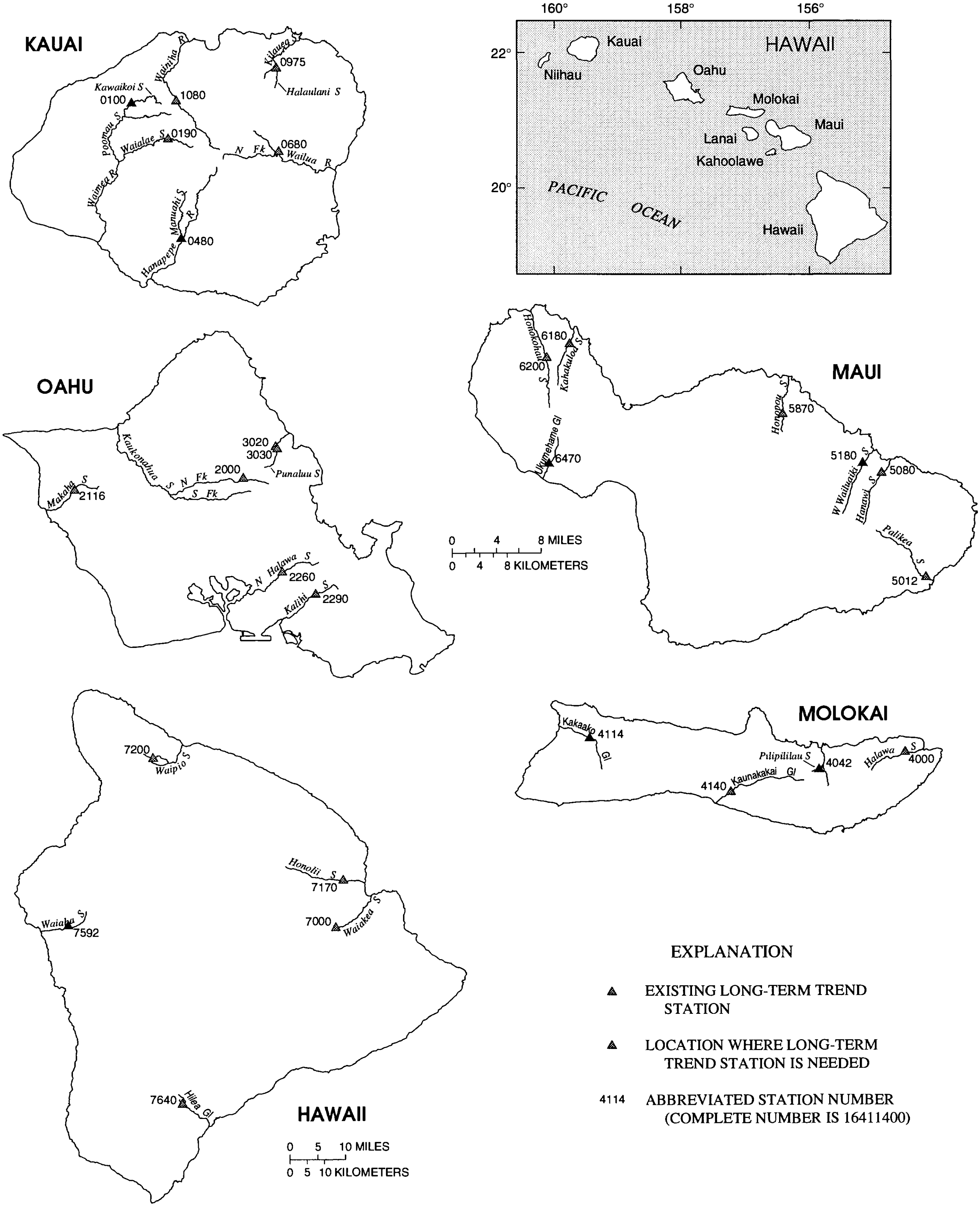

Figure 6. Existing and needed long-term trend stream-gaging stations, Hawaii, 1994.

A list of candidate streams for protection was given in the Hawaii Stream Assessment (Hawaii Commission on Water Resource Management, 1990b, p. 272). The 43 candidate streams are listed in table 17 along with a summary of the surface-water data-collection stations that have over time been operated in each of the stream watersheds. Currently, 89 of the 208 gages in operation in Hawaii are in the watersheds of candidate streams for protection. Historically, 191 gages have been or are currently being operated in the candidate watersheds. These gages represent a significant data base. No gages have been operated on Maunapuloa and Nualolo Streams on Kauai; Waialua Stream on Molokai; Piinaau and Manawainui Streams on Maui; and Halawa, Pololu, Lalakea, and Kolekole Streams on Hawaii. In addition, 10 of the 43 streams have only one gage and 19 of the 43 streams do not have an active gage of any kind. The existing gage network and data base can be used to provide streamflow characteristics at the gaged locations. In addition the existing data can be used to describe basinwide conditions for a select few of the candidate streams. Most gages were not operated specifically to describe the hydrology of the entire watershed. For these streams and those with little or no available data, alternatives need to be considered.

5. Identification of perennial stream reaches.--Future goals associated with the issue of identification of perennial stream reaches can only be minimally addressed with the existing surface-water data-collection program. The primary data-use category (table 6) applicable to this issue is hydrologic systems. The Hawaii Stream Assessment (Hawaii Commission on Water Resource Management, 1990b) represents the most thorough documentation of perennial streams in Hawaii to date. The assessment does not, however, identify the reaches of streams that are perennial; only the streams that have perennial reaches are identified. The current surface-water data-collection program primarily provides streamflow data at specific points. These data can be used to identify whether the flow is perennial, but only at the location of the gage. To identify perennial stream reaches the data collected at gaging stations need to be extrapolated in space over the entire stream segments in question. To date this has been done only on a very limited scale as part of seepage studies done for specific projects (Izuka, 1992).

6. Ground-water/surface-water interaction.--Future goals associated with the issue of ground-water/surface-water interaction can only be minimally addressed with the existing surface-water data-collection program. The current program is structured primarily to provide streamflow data at specific points. Streamflow data that describe the magnitude of changes in base flow (flow supplied by ground-water discharge to the stream) or data from seepage runs along stream reaches are required to address the issue of ground-water/surface-water interaction. Data requirements for this issue are almost the same as those described for the issue of identification of perennial stream reaches and the primary data-use category (table 6) applicable to this issue is hydrologic systems. Synoptic streamflow measurements along stream reaches are not routinely collected as part of the surface-water data-collection program. A limited number of studies have collected these types of data (Izuka, 1992: Izuka and others, 1993: and Takasaki and others, 1969). In addition a project, jointly funded by the Hawaii Department of Land and Natural Resources, Maui Department of Water Supply, and the USGS, has just started to investigate ground-water/surface-water interactions in northeast Maui.

7. Perennial stream data.--Future goals associated with the issue of perennial stream data are being partially met. As noted earlier in the discussion on the issue of surface-water availability, an extensive data base of information exists for perennial streams. A total of 139 of Hawaii's 376 perennial streams have been gaged. The primary data-use categories applicable to this issue are regional hydrology (low and peak flows) and hydrologic systems. The limitations noted for perennial streams in the discussion on the issue of surface-water availability are appropriate here as well. Alternatives need to be considered to address the issues of record lengths at gages, geographic distribution of available data, use of regional regression equations and partial-record gages, and data needs for regulated streams. Also, little is known about the flow variability along stream reaches.

8. Intermittent stream data.--Future goals associated with the issue of intermittent streams are being minimally met. Historically, 100 gages have been operated on streams classified as ephemeral (or intermittent) and 56 of these are crest-stage gages (tables 1–5). The primary data-use categories applicable to this issue are regional hydrology (low and peak flows) and hydrologic systems. Currently (1994) 56 gages are active on ephemeral streams, 47 of which are crest-stage gages (tables 1–5). At this time only flood-frequency characteristics are estimated at the crest-stage gages. Alternatives need to be considered to address needs for

Table 17. Candidate streams for protection and associated surface-water data-collection stations, Hawaii, 1994
[From Hawaii Department of Land and Natural Resources, 1990; --, no station; *, active as of 1994]

Stream	Station				
	Kauai				
Kalalau	16117000				
Hanakoa	16116000				
Hanakapiai	16115000				
Maunapuloa	--				
Wainiha	16108000*	16109000	16110000	16111000	16113000
Lumahai	16106000				
Waioli	16105000				
Hanalei	16100000	16101000	16102000	16103000*	16104000
	16104200*				
Wailua system	16056800	16057000	16058000	16058500	16060000*
	16061000	16061200*	16062000*	16063000	16064000
	16068000*	16068700	16069000*	16070000	16071000*
	16071500*	16071800*	16100000		
Huleia	16055000*				
Hanapepe	16039000	16042000	16043000	16044000	16045000
	16046000	16047000	16048000	16049000*	16050000
	16051000	16052000*			
Waimea system	16010000*	16011000	16012000	16013000	16014000
	16015000	16016000	16017000	16018000	16019000*
	16020000	16021000	16022000	16024000	16025000
	16027000	16028000	16029000	16029100	16029500
	16030000	16031000*	16032000	16033000	16034000
	16035000	16036000*	16037000	16037100	16038000*
Nualolo	--				
	Oahu				
Kahana	16295995	16296000	16296500*	16297000	
Maunawili	16249200	16249400	16249500*	16249600	16249800
	16249900*	16250000	16254000*	16256000	16257000
	16258000	16260000	16260500*	16261000	16262000
	16263000	16264100	16264400	16264500	16264800*
Halawa	16225800*	16226000*	16226200*	16227000	16227100*
Kaupuni	16211800*	16211850	16211900		
Makaleha	16211300*				
Kiikii system	16200000*	16201000	16203000	16204000	16206000
	16206500	16207000	16208000*	16208500	16209000
	16210500*	16210900	16211000	16211200*	
	Molokai				
Waihanau	16409000				
Waikolu	16405100*	16405500*	16406000	16408000*	
Pelekunu	16403400*	16403500*	16403600*	16403700*	16403800*
	16403900*	16404000	16404200*	16405000	
Wailau	16402000	16403000			
Halawa	16400000*				
Waialua	--				
	Maui				
Waihee	16612000	16613000	16613500	16614000*	
Waiehu	16608000	16609000	16609500	16610000	16611000
Iao	16604000	16604500*	16607000*		
Waikapu	16650000	16650500*			
Piinaau	--				
Waiohue	16515000				
Hanawi	16508000*	16509000*			
Oheo	16501000	16501200*			
Manawainui	--				
	Hawaii				
Halawa	--				
Pololu	--				
Honokane Nui	16747000	16747500	16748000	16749000	16749500
Waimanu	16737000	16737500*			
Wailoa-Waipio	16720000*	16720300*	16720500*	16721000	16721500
	16722000	16722300	16722600	16723000	16724000
	16724800*	16725000*	16726000*	16727000*	16728000
	16729000	16730000	16731000	16732000	16732100
	16732150	16732200			
Lalakea	--				
Kolekole	--				
Honolii	16716000	16717000*			
Wailuku	16701700	16701750	16701800	16703000	16704000*
	16709000	16710000	16713000*		

streamflow characteristics other than flood frequencies. In addition, needs to describe the variability of flow along intermittent stream reaches need to be considered.

9. Major streams and water-diversion systems.--Future goals associated with the issue of major streams and water-diversion systems are being partially met. In the Hawaii Stream Assessment (Hawaii Commission on Water Resource Management, 1990b, p. 55), 11 streams were classified as large. The streams (Wainiha, Lumahai, Hanalei, Wailua, Hanapepe, and Waimea on Kauai; Waihee and Iao on Maui; and Wailoa/Waipio, Honolii, and Wailuku on Hawaii) are also all classified as candidate streams for protection. As noted in table 17, at least one gage has been operated in each of the 11 large stream basins and all but Lumahai Stream on Kauai has at least one active gage. The primary data-use category (table 6) applicable to this issue is hydrologic systems. Hawaii Commission on Water Resource Management (1992c, app. D) provided flow charts of the major water-diversion systems in Hawaii along with average flow rates. These data provide a good baseline of information on the major streams and water-diversion systems. However, at least three topics need to be addressed in the future. First, significant changes are likely to take place in the future regarding use of diverted streamflows. An example would be those related to changes in the agricultural industry and the crops being planted. Existing information commonly is based on historical data that needs to be updated to reflect the changes in diversions and uses. Second, in many diversion systems only the total magnitudes of water withdrawn are known. Frequently water in these systems comes from multiple sources and withdrawals from individual streams are not known. Third, only three (Wailua, Waimea, and Wailoa/Waipio) of the 11 large stream systems have more than two active gages. The limited number of active gages will not be sufficient to quantify the sources and sinks of water in the major streams and water diversion systems. To address these topics, alternatives need to be considered.

10. Hydrologic hazards.--Future goals associated with the issue of hydrologic hazards related to streams can, with minor exceptions, be adequately met with the existing network. The primary data-use categories (table 6) applicable to this issue are regional hydrology (low and peak flows) and hydrologic forecasts. Alternatives to address the factors discussed below need to be considered. Peak-discharge data for streams in Hawaii are currently being collected at 89 continuous-record and 107 crest-stage gages. These gages provide a reasonable spatial and hydrologic sampling of the streams on the islands of Kauai, Oahu, Molokai, Maui, and Hawaii. Accurate estimates of flood frequencies can be made at existing sites when sufficient record length is available (fig. 2). Estimates of flood frequencies for ungaged sites on Oahu can be made by applying the techniques developed by Wong (1994). For example, using the techniques developed by Wong (1994, table 8), an estimate for the 10-year flood can be made for ungaged sites in leeward Oahu that is equivalent in accuracy to an estimate made for a gaged site with about 8 years of record. If estimates at ungaged sites with greater accuracy are required then alternatives need to be considered. Methods to estimate floods at ungaged sites on the islands of Kauai, Molokai, Maui, and Hawaii were last evaluated in 1972 (Yamanaga, 1972), and updating the flood-frequency studies for these islands could be considered. Little information is available concerning the effects of urbanization on flood peaks in Hawaii and the current network is not specifically designed to address this issue. Warnings related to flooding on streams are based primarily on rainfall data. How rainfall warning thresholds are related to actual stream response could be reviewed. Flooding is frequently aggravated by accumulations of debris in stream channels, yet little is known about the possible magnitudes of these effects.

Hydrologic hazards related to streams can also involve drought periods. Analyses of the response of streams to extend periods of deficient rainfall and their frequency of occurrence can be made at sites where continuous-record gages have been operated for some period of time. Methods to extend these data to ungaged locations have not been developed.

11. Land-use changes.--Future goals associated with the issue of land-use changes can be partially met with the existing surface-water data program. The primary data-use categories (table 6) applicable to this issue are regional hydrology (low and peak flows), hydrologic systems, and long-term trends. Surface-water data have been collected in a variety of land-use settings in Hawaii (plates 1–5). These data provide a base of information which can be used to evaluate runoff from a number of different environments. However, only infrequently have detailed land-use data been compiled for gaged watersheds specifically to correlate with the streamflow data. In addition, only a limited number of gage networks have been historically established specifically to evaluate land-use changes. A study currently in progress to evaluate the effects of constructing the

H-3 freeway is one of these (Wong and Hill, 1992). Perhaps the land-use changes of greatest significance in Hawaii presently are those related to the ongoing conversion of agricultural (sugarcane and pineapple) lands to alternative crops and other uses, including urbanization. Current gaging programs can not adequately address these issues and alternatives need to be considered.

12. Availability of data.--Future goals associated with the issue of availability of data are currently being partially met. Operational changes have already been made so that the goals will be completely met in the future. Surface-water data that are collected are published in a series of annual data reports. A target date to complete all computation and review steps and publish the report has been established to be 6 months after completion of each water year (by April 1). These data are also stored in electronic data bases and are available in a variety of formats and media including the Internet. In addition data will be computed in a provisional format when they come in from the field. Near real time, provisional releases of these data will be available as required by data users.

13. Purposes for operating individual gages.--Future goals associated with the issue of defining purposes for operating individual gages will be partially met with the continuation of the system now in place. Current practice dictates that the purposes for operating a station are defined when the station is established. This information is documented in the station description kept in the master file for each station. Purposes for operating existing gages were also defined and summarized as part of earlier (Yamanaga, 1972, and Matsuoka and others, 1985) and the current (tables 6–8) surface-water data-collection evaluations. To ensure that the future goal of defining purposes for operating individual gages is completely met, four changes need to be considered. First, purposes for operating individual gages need to include a narrative statement and not simply a summary table. Second, uses of data collected at gages change frequently and the narrative statements need to be reviewed frequently and updated. Third, purposes for operating gages also need to be prepared for crest-stage gages and low-flow partial-record gages. Fourth, criteria need to be established that can be used to identify the length of time the gage needs to be operated to meet the identified purposes.

14. Analysis of data collected.--Future goals associated with the issue of analysis of data are only being minimally addressed. Data collected as part of the surface-water program are routinely published and stored in electronic data bases, however only limited analyses of these data are done. There has only been one detailed summary of streamflow characteristics for Hawaii and the published reports (Matsuoka, 1981 and 1983) only contain data through 1979 water year. No updates have been prepared to include the last 15 years of data. As noted in figures 2 and 3, the accuracy of streamflow statistics can improve significantly with additional years of record or more base-flow measurements. Starting with the 1992 annual data report for Hawaii (Matsuoka and others, 1993) a limited number of statistical characteristics for active, continuous-record stations are provided. Statistical characteristics are provided for the current year and for the period of record. However, the existing statistical summary reports contain no interpretive analyses, such as frequency or trend studies. Also, important aspects such as land-use and water-use changes in the watersheds upstream of surface-water gages have received only limited attention to date. To meet the goals associated with the issue of analysis of data collected, alternatives need to be considered.

In this section of the report, the adequacy of Hawaii's current surface-water data-collection program for addressing 14 future issues was evaluated. Results of this evaluation are summarized in table 18. Only two of the 14 future issues can be adequately addressed with the existing data base. However, an additional eight issues are being partially addressed and only four were classified as being minimally met. Alternative data collection and analysis strategies that can be used to address limitations in the current surface-water program are discussed in the next section of the report.

Alternative Data-Collection Strategies

As noted in the previous section of the report (table 18) Hawaii's current (1994) surface-water, data-collection program will not adequately address all of the 14 future issues identified as part of this evaluation. If cost were not a factor, a simple alternative would be to establish continuous-record gages at all of the locations where data are required. However, not only is cost a factor but also data needs extend beyond simple site-specific considerations. Data are needed along entire stream reaches and over complex highly regulated watersheds and not just at specific points. Another key consideration involves data accuracy or the level of uncertainty (or error) that can be tolerated. Ultimately this is a decision the data users need to consider.

In this section of the report each of the 14 future issues will be considered individually. Where appropriate a list of possible alternatives will be developed for each issue. Alternatives that could be considered include (1) continuous-record gages, (2) partial-record gages, such as crest-stage and low-flow partial-record gages, (3) miscellaneous measurements, (4) synoptic surveys, (5) regional regression analyses, (6) statistical analyses of data, (7) hydrologic and hydraulic modeling, (8) and publication of reports. Estimates of expected accuracy associated with the alternatives will be given where possible. In table 20, streams where continuous-record gaging stations are needed and the future issues they can addressed are summarized.

1. Ground-water availability.--Future goals associated with the issue of ground-water availability are being partially met. As shown in table 14 there are several areas where surface runoff is not adequately described. To more completely address this issue several options can be considered. First, the regional regression equations developed by Yamanaga in 1972 to estimate mean annual discharge at ungaged sites can be updated. The data base of streamflow information available for such an analysis has expanded significantly in the last 20 plus years and improved methods of statistical analyses are available (Tasker and Stedinger, 1989). Lower standard errors for the new equations could be reasonably expected. Benson and Carter (1973, fig. 4) noted that, Nationwide, 27 states have regression equations for mean annual flow with standard errors that are equal to or less than that associated with a gage having 10 years of record. However, only three of the 27 states had equations with standard errors more than three percent lower than that for 10 years of record. Therefore, standard errors for updated regional equations would likely be equivalent to those for gages that were operated at least 5 but not more than 10 years, or 12 to 17 percent on average (fig. 2).

Second, to date no attempt has been made to use data from partial-record gages to estimate runoff. If estimates for runoff could be made using these data then the number of stations where runoff estimates could be made would be greatly expanded (plates 1–5). This could be significant, especially in areas where intermittent streams dominate and crest-stage gages are the primary type of station operated (Kahului-Makena area on Maui, for example). Low-flow partial-record stations should provide estimates of average runoff that are comparable in accuracy to estimates of median streamflows made for these sites. Fontaine (1992, p. 1) noted that, in general, estimates of median flow based on data from low-flow partial-record stations had smaller errors than those for regional regression equations.

Third, use of rainfall-runoff modeling could be explored. Using this option, rainfall-runoff models would be calibrated in watersheds where sufficient data exist. Calibrated model parameters would then be extrapolated to provide model estimates of runoff in ungaged watersheds where historical rainfall data are available to drive the model. No applications of this specific type

Table 18. Adequacy of Hawaii's current (1994) surface-water data collection program for addressing future issues and associated goals.

Issue		Goals	Remarks
1.	Ground-water availability	Partially met	
2.	Surface-water availability	Partially met	
3.	Long-term baseline information	Adequately met	Only minor exceptions remain to be addressed
4.	Streams for protection	Partially met	
5.	Identification of perennial stream reaches	Minimally met	
6.	Ground-water/surface-water interaction	Minimally met	
7.	Perennial streams	Partially met	
8.	Intermittent streams	Minimally met	
9.	Major streams and water diversion systems	Partially met	
10.	Hydrologic hazards	Adequately met	Only minor exceptions remain to be addressed
11.	Land-use changes	Partially met	
12.	Availability of data	Partially met	Changes already enacted to meet goal
13.	Purposes for operating individual gages	Partially met	
14.	Analysis of data collected	Minimally met	

have been made in Hawaii and therefore estimates of standard errors to be expected will not be given here. Nakama (1994, table 4) noted that calibrated rainfall-runoff models developed for watersheds on Guam provided estimates of annual runoff that were generally within 20 percent of the actual values.

Fourth, additional continuous-record gages could be considered. This method would ultimately provide estimates with the greatest accuracy. A significant benefit of additional gages is that they not only provide accurate estimates of runoff but they can also be used to define the division of flow between surface runoff and base flow. Also, estimates of other streamflow characteristics can be made at these gages. In figure 7, approximate locations where stream-gaging stations are needed to address the most significant data gaps identified for areas of increasing ground-water demands are shown.

*2. **Surface-water availability.***--Future goals associated with the issue of surface-water availability are being partially met. However, as noted in the previous section, only 139 of Hawaii's 376 perennial streams have been gaged at any time and few ephemeral streams have ever been gaged. Options to improve our understanding of surface-water availability include the following. First, methodologies outlined in the section on evaluation of the program, regarding the length of time a station should be operated, are good guidelines to follow. Operation of gages for a minimum number of years will dramatically increase the accuracy of estimated streamflow characteristics at the sites (fig. 2).

Second, existing regional regression equations can be updated and equations for new streamflow characteristics generated. Yamanaga (1972) developed regression equations for a number of streamflow characteristics, however only the flood-frequency equations for Oahu (Wong, 1994) have been updated in the past 20 plus years. The only new streamflow characteristic for which a regression equation has been developed since 1972 is median streamflow (Fontaine, 1992). Updating regression equations with the additional 20 plus years of record and using recently improved statistical methods can significantly improve results. For example, the standard error for estimates of the 10-year flood for leeward Oahu using the 1972 equations are 50 percent whereas those for the recently updated equations are 36 percent (Wong, 1994). Fifty and 36 percent represent accuracies equivalent to a gage with about 4 and 8 years of record (table 9). These findings support the results of Benson and Carter's (1973) Nationwide analysis which indicates that regional regression equations can approximate, but seldom significantly exceed, accuracies equivalent to about 10 years of gage record. The data in figure 2 and table 9 can be used to estimate the magnitudes of errors that could be expected using regional regression equations in Hawaii assuming equations approaching 10 years of equivalent gage record are obtained.

Third, for studies that are specific to certain stream reaches or regions, the density of gage data required likely will never be available. Alternatives in these situations are to use hydrologic models to expand the available data base in terms of time or in terms of distance along stream reaches. Examples of models that could provide these capabilities are rainfall-runoff models that use rainfall data to extend streamflow records (Leavesley and others, 1983) or streamflow-routing models that translate data along stream reaches (Jobson, 1989). Hydrologic models can provide valuable data in areas where little or none exist; however, the models will not produce streamflow records that are equivalent in accuracy to those collected at gaging stations.

Fourth, partial-record stations such as crest-stage and low-flow partial-record gages can be operated for a fraction of the cost of a continuous-record gage and cost little or nothing to install. Crest-stage gages can provide flood-frequency data that are equivalent in accuracy to data from a continuous-record station. Low-flow partial-record stations can be used to provide estimates of low-flow characteristics that are generally more accurate than those from regional regression equations but not equivalent in accuracy to data from a continuous-record station (Fontaine, 1992, p. 1). Alternatives that include use of partial-record stations, where appropriate, need to be considered, especially in areas where monitoring of streamflow at a large number of sites would be required. These types of networks would be designed on an as needed basis.

Fifth is the method that would ultimately provide estimates with the greatest accuracy: additional continuous-record gages. Note that when a continuous record is available at a site, all of the required streamflow characteristics can be computed. A program of annually reviewing the purposes for which existing gages are operated and discontinuing those no longer needed (for

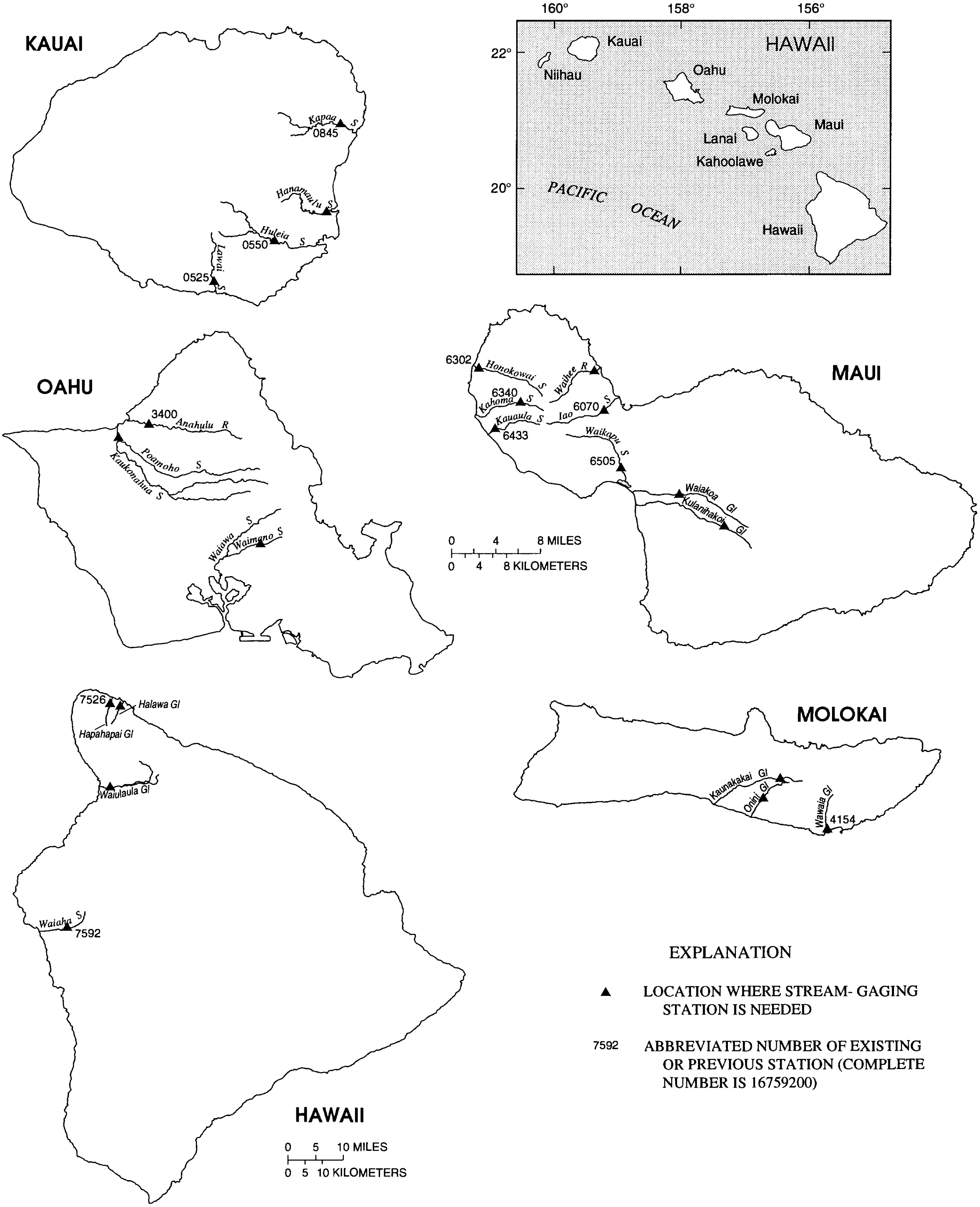

Figure 7. Approximate locations where stream-gaging stations are needed to provide estimates of runoff in areas of increasing ground-water demand, Hawaii, 1994.

example, table 10) would free resources that could be used to establish new stations. In figure 8 approximate locations for gaging stations that could be used to address the most significant data gaps identified in the previous section for the issue of surface-water availability are shown.

3. Long-term baseline data-collection and trends.--Future goals associated with the issue of long-term baseline information are being adequately met, with minor exceptions. Simple alternatives to address all the minor exceptions can be considered. First, all the stations listed in table 16 need to be clearly designated as long-term baseline stations and they need to remain in operation as long as they are free of significant artificial influences. Second, funding for stations 16229000, Kalihi Stream on Oahu, and 16717000, Honolii Stream on Hawaii, has been cut (federal program). Both stations are valuable long-term baseline sites and new funding needs to be provided to continue their operation. Third, when sufficient data are available, the effect on streamflow at station 16211600, Makaha Stream on Oahu, from the new upstream water-supply wells needs to be determined. If streamflow is affected, then a new long-term baseline station in the area needs to be established. Two possible replacement sites include stations at Mailiilii and Nanakuli Streams identified as part of the alternatives developed for the issue of surface-water availability (fig. 8). Fourth, new stations need to be established to meet the deficiencies in geographic and hydrologic coverage noted for the islands of Kauai, Molokai, Maui, and Hawaii. Possible locations for stations are identified in figure 6. The stations, listed in table 19, include four active sites where a simple change in identified station use is all that is needed. Three of the stations are inactive gages that need to be reestablished. Including stations 16010000 and 16518000 as long-term trend stations may be slightly redundant because similar stations are nearby. However, the unaltered condition of the watersheds and their length of available record (77 and 75 years) make these stations extremely valuable.

4. Identification of streams for protection.--Future goals associated with the issue of streams for protection are being partially met. Selection of the streams for protection is presently (1994) subject to debate (Stream Protection and Management Task Force, 1994). Therefore, no alternatives will be presented here. However, most of the selected streams will probably come from the list of candidate streams for protection identified in table 17. Note that stream-gaging alternatives identified for the three previous issues (figs. 6–8) include stations for the following candidate streams for protection, Huleia, Hanapepe, and Nualolo Streams on Kauai; Kiikii Stream on Oahu; Waihanau and Waialua Streams on Molokai; Waihee, Iao, and Waikapu Streams on Maui; and Halawa, Waimanu, Kolekole, and Honolii Streams on Hawaii. No continuous-record gages were currently active on Huleia, Nualolo, Waialua, Waikapu, Halawa, and Kolekole Streams. Even without specific alternatives, responses to other issues could provide some level of new action in the area of streams for protection. In the future, as streams for protection are identified, unmet data needs can be identified and appropriate plans for action implemented.

5. Identification of perennial stream reaches.--Future goals associated with the issue identification of perennial stream reaches are being minimally addressed. The Hawaii Stream Assessment report (Hawaii Commission on Water Resource Management, 1990b) represents an excellent reference identifying streams that have perennial reaches. These data need to be updated and revised as new data becomes available. Geo-

Table 19. Possible continuous-record stream-gaging stations to be added to the long-term trend data network, Hawaii, 1994
[P, station in operation as of water year 1994]

Station number	Station name	Current status	Period of continuous record	Years of record
16010000	Kawaikoi Stream near Waimea, Kauai	active	1909–16, 1919–P	77
16048000	Manuahi Stream at Koula near Eleele, Kauai	inactive	1917–20	3
16404200	Pilipililau Stream near Pelekunu, Molokai	active	1968–P	25
16411400	Kakaako Gulch near Mauna Loa, Molokai	active[1]	1963–72	9
16518000	West Wailuaiki Stream near Keanae, Maui	active	1914–15, 1916–17 1921–P	75
16647000	Ukumehame Gulch near Olowalu, Maui	inactive	1911–12, 1913–16 1916–19	6
16759200	Right Branch Waiaha Stream near Holualoa, Hawaii	inactive	1960–82	24

[1] Since 1972 operated as a crest-stage gage

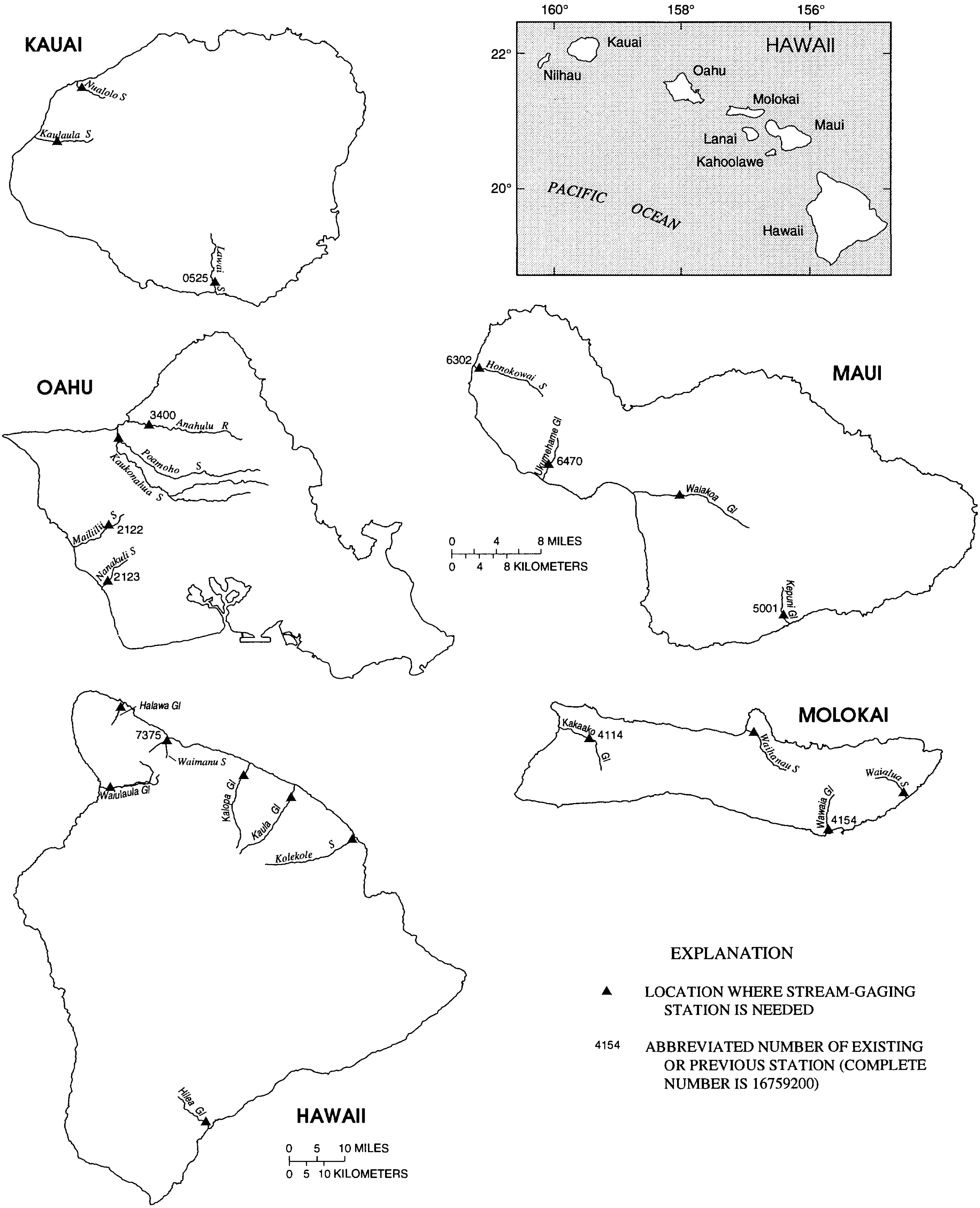

Figure 8. Approximate locations where stream-gaging stations are needed for surface-water availability data, Hawaii, 1994.

graphic information system (GIS) technology could be used to translate the existing information into a spatial data base with the actual reaches where flow is perennial identified. Existing information from seepage runs and ongoing ground-water/surface-water interaction studies (northeast Maui) will provide some of the data required and needs to be incorporated into the data base of perennial stream reaches. Stream biological data available from sources such as the Hawaii Division of Aquatic Resources and the U.S. Fish and Wildlife Service and streamflow diversion data available from the Hawaii Department of Land and Natural Resources can also provide additional information. Several stream reaches on otherwise perennial streams are actually intermittent as a result of water diversions. This diversion data, for the most part, exists and needs to be incorporated into the data base. The primary alternative to address the gaps that still exist in the data base on perennial stream reaches are seepage runs along stream reaches during periods when low base-flow conditions exist. Data from the existing network of continuous-record gages and the long-term baseline stations can be used to identify when these periods of low base flow are taking place.

6. Ground-water/surface-water interaction.--Future goals associated with the issue of ground-water/surface-water interaction are being minimally addressed. As noted earlier, the current surface-water data-collection program is structured primarily to provide data at specific locations on streams. To address the issue of ground-water/surface-water interactions, data describing the variability of base flow along stream reaches are required. These data requirements are stream specific and require intensive measurements of flow along the stream. The number of options that can be used to more completely address this issue are limited. Options that would support these stream-specific studies include the following. First, a network of continuous-record gages are required so that periods of base flow in the areas in question can be identified. Data from the existing network, augmented by the needed perennial stream stations indicated in figures 6–8, are probably adequate, at most sites, for identifying periods of base flow. Second, streamflow measurements made as part of seepage runs are generally considered miscellaneous measurements and are commonly not stored in any data base. A consolidation of data collected as part of seepage runs would be valuable. Included in the data base would be the identification of stream reaches, dates, locations where measurements were made, measured discharges, geologic and streambed characteristics, and descriptions of hydrologic conditions before and during the seepage runs.

7. Perennial stream data.--Future goals associated with the issue of perennial streams are being partially met. Limitations in our understanding of perennial streams are essentially the same as those noted for the issue of surface-water availability. Earlier five possible alternatives to address limitations associated with the issue of surface-water availability were discussed, including the identification of possible locations for new gages (fig. 8). These same five alternatives are appropriate for the issue of perennial streams and will not be repeated here. One exception is that needed gages on Kakaako Gulch on Molokai, Waiakoa and Kepuni Gulches on Maui, and Waiulaula and Hilea Gulches on Hawaii (fig. 8) are located on intermittent streams and would not be appropriate for addressing the issue of perennial streams.

8. Intermittent stream data.--Future goals associated with the issue of intermittent streams are being minimally met. The following alternatives have the potential to significantly increase our understanding of the hydrology of intermittent streams in Hawaii. First, a significant source of information on intermittent streams are the numerous crest-stage gages that have been operated. Currently data from crest-stage gages are used only to estimate flood-frequency characteristics and no attempts have been made to use these data to estimate other streamflow characteristics. The feasibility of estimating additional characteristics, such as average runoff, at crest-stage gages needs to be explored. Second, as noted earlier, regional regression equations have in general not been updated for more than 20 years. Possible uses of regional estimating equations for ungaged sites on intermittent streams need to be explored. Third, significant volumes of ground-water recharge likely takes place along intermittent stream channels. To evaluate this factor, locating multiple gages along intermittent streams would be of use. Potential streams where additional gages could provide this recharge information include Kaunakakai Stream on Molokai, Waiakoa and Kulanihakoi Gulches on Maui, and Waiaha Stream and Hilea Gulch on Hawaii (fig. 9). Fourth, intermittent streams need to be included in the network of long-term trend stations. Possible stations would include needed gages on Kakaako Gulch on Molokai and Waiaha Stream on Hawaii (fig. 6). Fifth, gages on intermittent streams would provide the highest

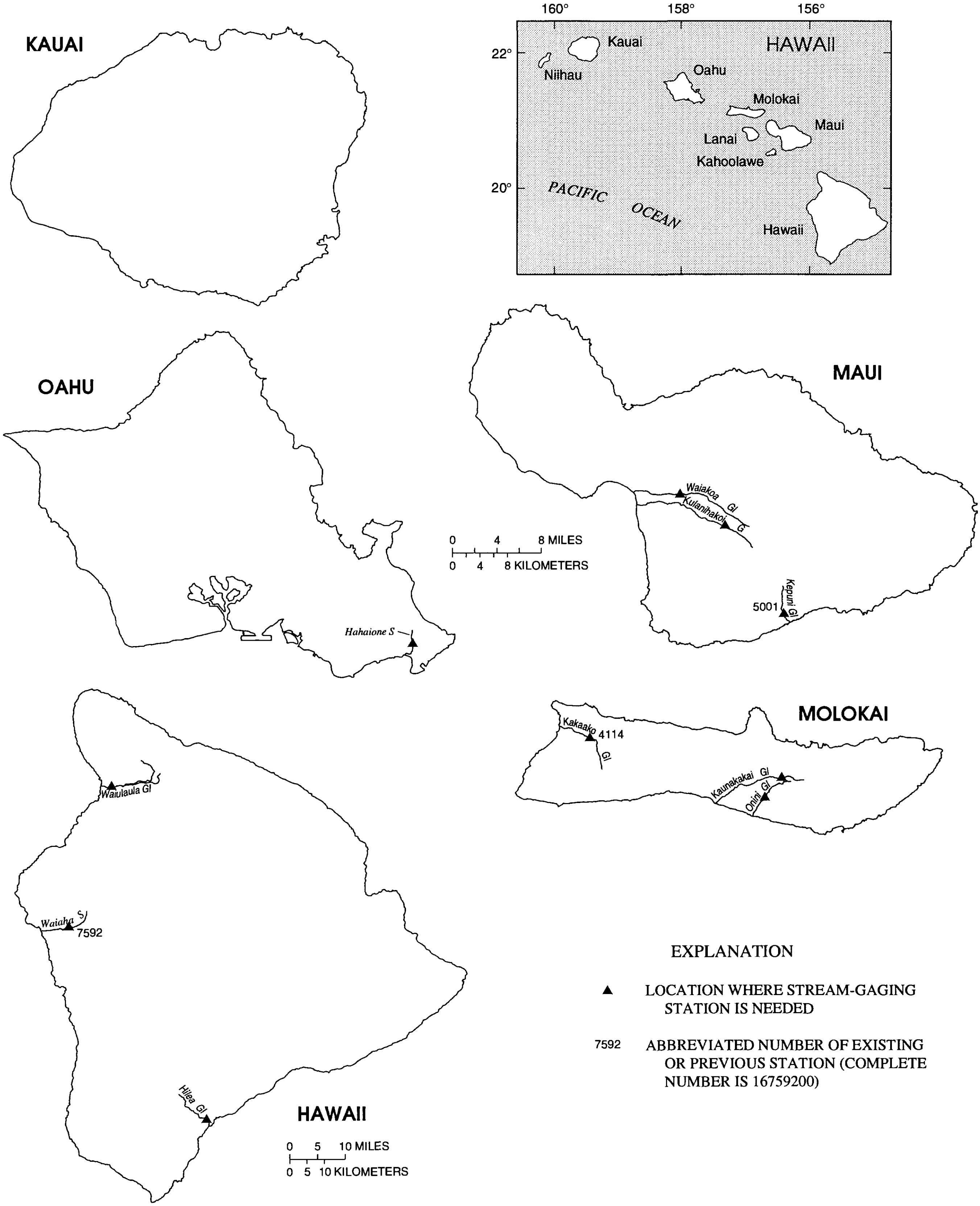

Figure 9. Approximate locations where stream-gaging stations are needed for intermittent stream data, Hawaii, 1994.

level of information at the locations of gages. Possible locations where continuous-record gages on intermittent streams would be of benefit are shown in figure 9.

9. Major streams and water-diversion systems.--Future goals associated with the issue of major streams and water-diversion systems are being partially met. In the section of the report on the evaluation of future goals, three topics that need to be considered were identified. These topics included (1) changes in the use of water in diversion systems, (2) quantification of water sources along multiple-source diversions, and (3) lack of active gages on major streams. Alternatives to address these three topics need to include some degree of gaging activity. Most major streams and all diversion systems are highly regulated. Previous study has indicated that extrapolation of data to ungaged sites or partial-record sites in regulated stream systems requires the existence of continuous-record data in the system (Fontaine, 1992). To address the first topic, new continuous-record gages should be established along major diversion systems where changes in magnitudes of water use are being considered. A less expensive alternative would be to establish partial-record sites on the diversion systems. Along most diversions the primary data required are some measures of total water use. To meet this requirement estimates of monthly and annual mean flows would be sufficient. Ries (1990) documented the application of a method that used individual discharge measurements to estimate monthly mean flows. Riggs (1969) and Parrett and Hull (1986) report that the annual mean discharge, produced by summing and averaging the estimated monthly means, can be within about 10 percent of actual, on average. To address the second topic, synoptic measurements of flow along diversion systems need to be done. These synoptic measurement programs could be used to identify magnitudes of water gains or losses along the diversion systems and where they take place. To address the third topic, attempts need to be made to establish additional continuous-record gages. Possible locations where continuous-record gages on major streams would be of benefit are shown in figure 10.

10. Hydrologic hazards.--Future goals associated with the issue of hydrologic hazards are being adequately met, with minor exceptions. Six alternatives to address some of these exceptions could be considered. First, Wong (1994) has developed regional regression equations that can be used to provide estimates of the magnitude and frequency of floods on ungaged streams on Oahu. Wong (1994) also updated flood-frequency estimates for gaged locations on Oahu. Regional regression analyses could be done using existing data for the islands of Kauai, Molokai, Maui, and Hawaii. Second, as noted in table 11, a total of 48 crest-stage gages have close to 40 years of record. In the near future some of these gages could be discontinued and relocated to basins where the degree of urban development is significant or increasing. Third, to refine flood warning systems, stream response to periods of intense rainfall needs to be evaluated. Possible options include the analysis of rainfall/peak-runoff relations in gaged watersheds or the use of rainfall-runoff models to simulate them (Shade, 1984). Watersheds such as North Halawa and Moanalua valleys on Oahu have extensive rainfall and runoff data available for such analyses. Fourth, accumulations of woody debris, particularly at bridges, often aggravates flood hazards. To address this problem, data needs to be collected so that correlations between magnitudes of flood peaks and relative degrees of debris accumulations can be established. These data can be used to identify sites where debris accumulation is common. Hydraulic models (Shearman, 1990) could then be used to establish the different stream responses at the problem sites during floods if varying magnitudes of debris accumulated. These data would aid in the design of stream crossings and could be used to more accurately identify high-risk flood hazard areas. Fifth, attempts need to be made to document the magnitudes of extreme floods at all inactive gages in flood-affected areas. Cohn and Stedinger (1987) have demonstrated that information obtained for extreme floods outside the period of systematic data collection can be used to significantly improve flood-frequency estimates. Sixth, regional regression analyses needs to be undertaken to evaluate the responses of both gaged and ungaged streams to periods of drought.

11. Land-use changes.--Future goals associated with the issue of land-use changes are being partially met. To address this issue more completely, several options can be considered. First, land uses within gaged watersheds need to be documented and updated regularly. Second, as noted in the previous section, some of the crest-stage gages need to be relocated to basins where the degree of urban development is significant or is increasing. Third, continuous-record gages need to be located in watersheds where significant changes in agricultural practices are anticipated. Possible examples

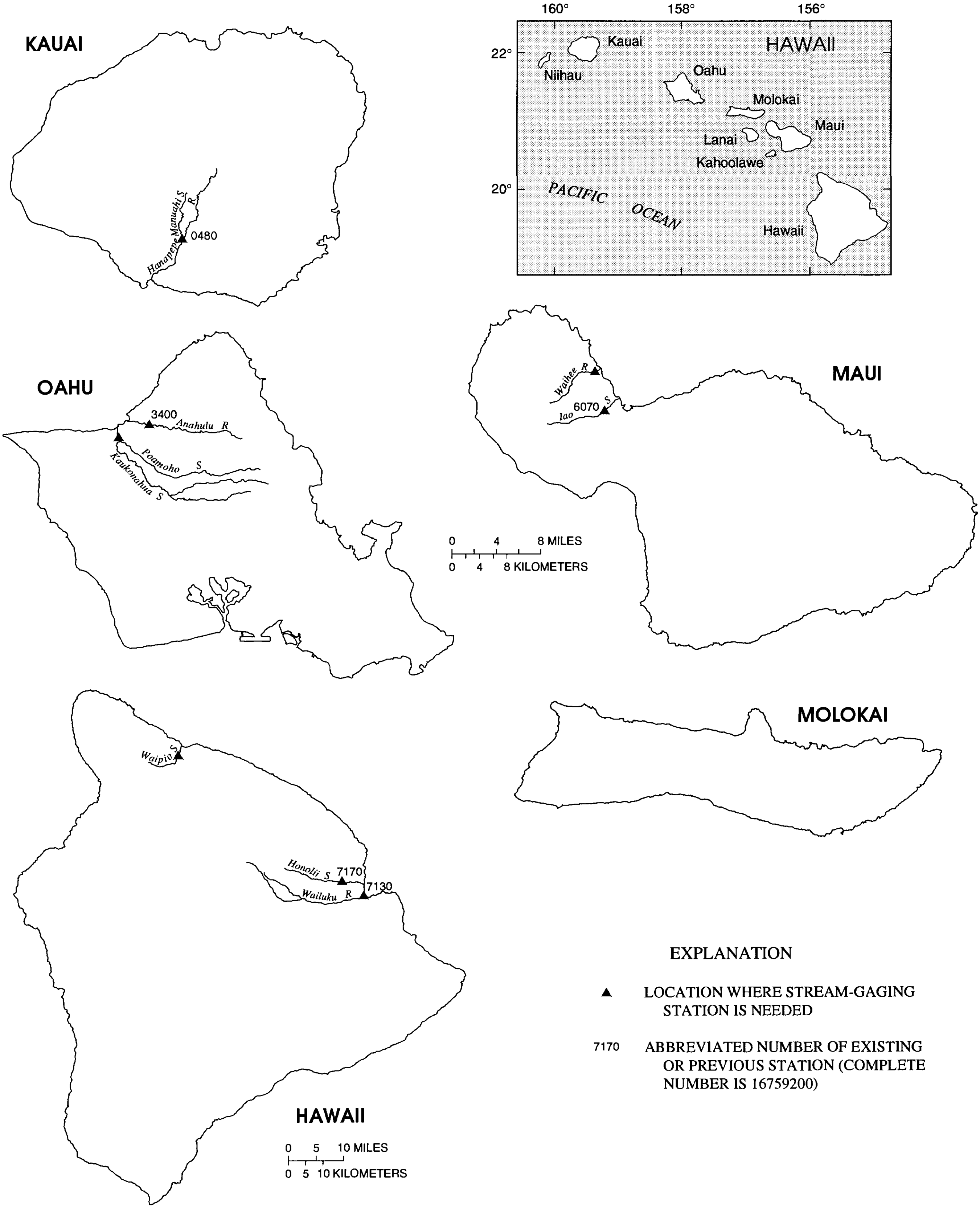

Figure 10. Approximate locations where stream-gaging stations are needed for major stream and water-diversion system data, Hawaii, 1994.

would be the Waialua area on Oahu and the Hamakua coast on Hawaii. Data from these possible continuous-record gages could also support any analyses of water quality and sediment that might be called for in these areas. Fourth, analyses of existing data bases need to be undertaken to determine to what degree, if any, past land-use changes within watersheds have affected rainfall-runoff relations. Such analyses could also be conducted on multiple watersheds with differing land uses.

12. Availability of data.--Future goals associated with the issue of availability of data are currently being partially met. As noted in the previous section, operational changes have already been made to meet this goal. Changes primarily involve timeliness of data collection, analyses, and publication and the availability of data in a variety of electronic formats.

13. Purposes for operating individual stations.--Future goals associated with the issue purposes for operating individual gages are currently being partially met. Four changes were discussed in the previous section that, when made, would allow the goals associated with this issue to be completely met in the future. The proposed changes call for the following actions. First, narrative statements describing why gages are operated need to be written. The narratives are expansions of the information summarized in table 6. Second, the narrative statements need to be updated on a regular basis. Third, narrative statements describing why gages are operated need to be prepared for crest-stage gages and low-flow partial-record gages as well (tables 7–8). Fourth, the length of time individual gages should be operated needs to be estimated. The period of operation is based on the established purposes for operating the station and is determined using the methodology described in this report to evaluate the current program. Desired periods of operation may change as purposes for operating the station change, therefore regular updates are needed.

14. Analysis of data collected.--Future goals associated with the issue of analysis of data collected are being minimally met. The inclusion of a limited number of statistical characteristics in annual data reports, starting with the 1992 water year, was a step forward. A simple alternative to more completely address this issue would be to publish reports that provide statistical summaries and interpretive analyses of the data collected and descriptions of watershed characteristics. Analyses for stations where additional data are available need to be updated as often as every five years. Information that could be included as part of these reports would be the following:

1. Drainage area;
2. Period of record of station;
3. Summaries of watershed characteristics such as topography, vegetation, rock types, land use, and channel slopes;
4. Artificial influences, such as diversions;
5. Dates when significant watershed changes took place;
6. Statistical summaries such as flow-duration curves, average discharge, annual mean discharges, streamflow characteristics by month, and n-day high- and low-flow analyses;
7. Interpretive analyses such as flood frequency, trend analyses (especially for long-term trend stations), base-flow separations, and computations of runoff ratios;
8. Analyses of flood data at crest-stage gages; and
9. Analyses of streamflow characteristics at low-flow partial-record stations.

In this section of the report alternative data collection strategies that could be used to address each of the identified 14 future issues were discussed. Multiple alternatives are worth considering. For most of the issues the most accurate alternatives would be those that included operation of additional continuous-record gaging stations. In table 20 streams where continuous-record gaging stations have been proposed and the future issues they can address are summarized.

SURFACE-WATER QUALITY DATA-COLLECTION PROGRAM

Unlike data on surface-water quantity, collection and analysis of data on surface-water quality in Hawaii is spread among several diverse private groups, local, county, state, and federal agencies, and universities. It is probably fair to say that no systematic, Statewide, baseline surface-water quality monitoring program currently exists in Hawaii. Most of the data-collection activities being conducted by the various groups are area or project specific and primarily are associated with ground-water issues.

Table 20. Summary of streams where gaging stations are needed to further address selected future issues, Hawaii, 1994

[x, gage is needed; --, gage is not needed]

Stream	Future issues: Ground-water availability	Surface-water availability	Long-term baseline information	Streams for protection	Perennial streams	Intermittent streams	Major streams and water-diversion systems
Kauai							
Kawaikoi Stream	--	--	X	--	--	--	--
Manuahi Stream	--	--	X	--	X	--	X
Kapaa Stream	X	--	--	--	--	--	--
Hanamaulu Stream	X	--	--	--	--	--	--
Huleia Stream	X	--	--	X	--	--	--
Lawai Stream	X	X	--	--	X	--	--
Nualolo Stream	--	X	--	X	X	--	--
Kaulaula Stream	--	X	--	--	X	--	--
Oahu							
Kalihi Stream	--	--	X	--	--	--	--
Anahulu River	X	X	--	--	X	--	X
Kiikii Stream	X	X	--	X	X	--	X
Waimano Stream	X	--	--	--	--	--	--
Mailiilii Stream	--	X	--	--	X	--	--
Nanakuli Stream	--	X	--	--	X	--	--
Hahaione Stream	--	--	--	--	--	X	--
Molokai							
Kakaako Gulch	--	X	X	--	--	X	--
Pilipililau Stream	--	--	X	--	--	--	--
Onini Gulch	X	--	--	--	--	X	--
South Fork	--	--	--	--	--	--	--
Kaunakakai Gulch	X	--	--	--	--	X	--
Wawaia Gulch	X	X	--	--	X	--	--
Waialua Stream	--	X	--	X	X	--	--
Waihanau Stream	--	X	--	X	X	--	--
Maui							
West Wailuaiki Stream	--	--	X	--	--	--	--
Ukumehame Gulch	--	X	X	--	X	--	--
Waihee River	X	--	--	X	--	--	X
Iao Stream	X	--	--	X	--	--	X
Honokowai Stream	X	X	--	--	X	--	--
Kahoma Stream	X	--	--	--	--	--	--
Waikapu Stream	X	--	--	X	--	--	--
Waiakoa Gulch	X	X	--	--	--	X	--
Kulanihakoi Gulch	X	--	--	--	--	X	--
Kauaula Stream	X	--	--	--	--	--	--
Kepuni Gulch	--	X	--	--	--	X	--

Table 20. Summary of streams where gaging stations are needed to further address selected future issues, Hawaii, 1994--Continued

Stream	Future issues						
	Ground-water availability	Surface-water availability	Long-term baseline information	Streams for protection	Perennial streams	Intermittent streams	Major streams and water-diversion systems
Hawaii							
Honolii Stream	--	--	X	X	--	--	X
Wailuku River	--	--	--	X	--	--	X
Right Branch	--	--	--	--	--	--	--
Waiaha Stream	X	--	X	--	--	X	--
Hapahapai Gulch	X	--	--	--	--	--	--
Halawa Guclh	X	X	--	X	X	--	--
Waiulaula Gulch	X	X	--	--	--	X	--
Waimanu Stream	--	X	--	X	X	--	--
Kalopa Gulch	--	X	--	X	--	--	--
Kaula Gulch	--	X	--	X	--	--	--
Kolekole Stream	--	X	--	X	X	--	--
Hilea Gulch	--	X	--	--	--	X	--
Waipio Stream	--	--	--	--	--	--	X

The USGS does not have an ongoing program to collect surface-water quality data in cooperation with the Hawaii Department of Land and Natural Resources (DLNR). As a result no specific evaluation of the surface-water quality data-collection programs will be undertaken as part of this study. The USGS does, however, collect surface-water quality data in Hawaii. A description of these historical and current data collection activities will be given here along with information regarding the availability and published analyses of these data and a summary of data limitations.

Historical Program

The systematic collection of surface-water quality data by the USGS in Hawaii did not begin until the late 1960's. Some of the first surface-water quality data were collected as part of two Nationwide programs operated by USGS, the National Stream Quality Accounting Network (NASQAN), and the Hydrologic Bench-Mark Network (HBM). The NASQAN program is a Nationwide data-collection network designed to meet many of the information needs of government agencies and others involved in water-quality planning and management (Matsuoka and others, 1993, p. 4). The HBM program currently includes a Nationwide network of 58 data-collection sites operated with the objectives of documenting the hydrologic characteristics of representative, undeveloped watersheds nationwide and providing a comparative base for studying artificial effects on the hydrologic environment (Lawrence, 1987, p. 1). The first NASQAN stations in Hawaii were established in the late 1960's and by 1977 a total of six stations were in operation. The six NASQAN stations in Hawaii included 16031000 on the Waimea River on Kauai; 16213000 on Waikele and 16229300 on Kalihi Streams on Oahu; 16400000 on Halawa Stream on Molokai; 16618000 on Kahakuloa Stream on Maui; and 16713000 on Wailuku River on Hawaii. A HBM station was established on Honolii Stream on Hawaii (station 16717000) in 1969. Water-quality data collected at the NASQAN and HBM stations included physical properties, sediment data, common ions, metals, general organic properties, biological properties, phytoplankton data, pesticides, and sometimes continuous records of specific conductance, suspended-sediment discharge, and water temperature.

In the early 1970's a regular program was established in which limited analyses of physical properties, common ions, and nutrients were conducted on a regular basis at active, continuous-record stream gages. These analyses were gradually phased out and by 1989 were discontinued completely. In addition to the above programs the USGS has also been involved in special studies that have extensive surface-water quality components. The most significant of these special projects are those done on Moanalua Stream, North Halawa Stream, and windward streams in association with construction of the H-3 freeway.

A listing of stations where surface-water quality data has been collected by the USGS along with a summary of the types of data collected and periods of available record are provided in tables 21 through 25 (at end of report). Historically, data has been collected at 30 sites on Kauai, 75 sites on Oahu, 12 sites on Molokai, 24 sites on Maui, and 30 sites on Hawaii. Locations of these sites are summarized on figures 11 through 15.

Current Program

Currently (1994) surface-water quality data are being collected at two sites on Maui, 14 sites on Oahu, one site on Molokai, one site on Maui, and one site on Hawaii (tables 21–25). The NASQAN program now includes data collection at only three stations in Hawaii: Waimea River on Kauai, Waikele Stream on Oahu, and Halawa Stream on Molokai. Further reductions in the NASQAN program are being considered. The HBM station on Honolii Stream on Hawaii has been inactivated and the former NASQAN station on Kahakuloa Stream on Maui has replaced it. Thirteen of the active stations remaining are operated as part of the H-3 freeway project on Oahu. This project will likely end shortly after the completion of the freeway.

A third, Nationwide water-quality program was recently initiated by the USGS (Leahy and others, 1990). However, currently (1994) no data collection as part of this program, titled the National Water Quality Assessment (NAWQA) has taken place in Hawaii. A possible starting date of 1996 is scheduled.

Funding for the NASQAN and HBM stations is provided as part of the federal program. Funding for the H-3 project stations is provided by the Hawaii Department of Transportation.

Availability and Analyses of Data

Most surface-water quality data being collected in Hawaii by the USGS are published in the series of annual data reports (Matsuoka and others, 1993). Beginning with the 1990 water year, all annual data reports for a given year, are reproduced on a CD-ROM disc that is available to data users. Selected water-quality data are also published in reports that are prepared to document results of special projects (Izuka and others, 1993; Wong and Hill, 1992).

Water-quality data collected by the USGS are also stored in the WATSTORE computer system (Hutchinson, 1975). As with surface-water quantity data a variety of useful products, ranging from data tables to complex statistical analyses, can be produced using WATSTORE. Water-quality data are also transferred into the U.S. Environmental Protection Agency STORET system.

A limited number of reports have been prepared that provide statistical summaries or analyses of surface-water quality data. Matsuoka (1981) provided statistical summaries of data collected through the 1979 water year. Included were listings of data collected and the mean, standard deviation, minimum, and maximum values for the various properties and characteristics for which analyses had been done. Wong and Hill (1992) provided a summary of water-quality data collected as part of the H-3 freeway project for water years 1983-89. They provided maximum, minimum, and average values for each property for which analyses had been conducted. In addition they provided selected concentration-nonexceedence data points. Yee and Lum (1993) summarized concentrations and trends of selected water property for the NASQAN and HBM stations in Hawaii. Nationwide analyses of data collected as part of the NASQAN and HBM programs have been published by Smith and others (1987 and 1993).

Limitations of the Program

The surface-water quality data-collection programs operated by the USGS in Hawaii, to date, provide a basic level of background data. The data collected do not represent results from a well designed network established to address significant Statewide issues in Hawaii. Data have been collected primarily to address three specific issues: (1) Nationwide programs (NASQAN and HBM stations), (2) special studies (H-3 freeway), and (3) basic analyses at sites where surface-water quantity stations have been operated.

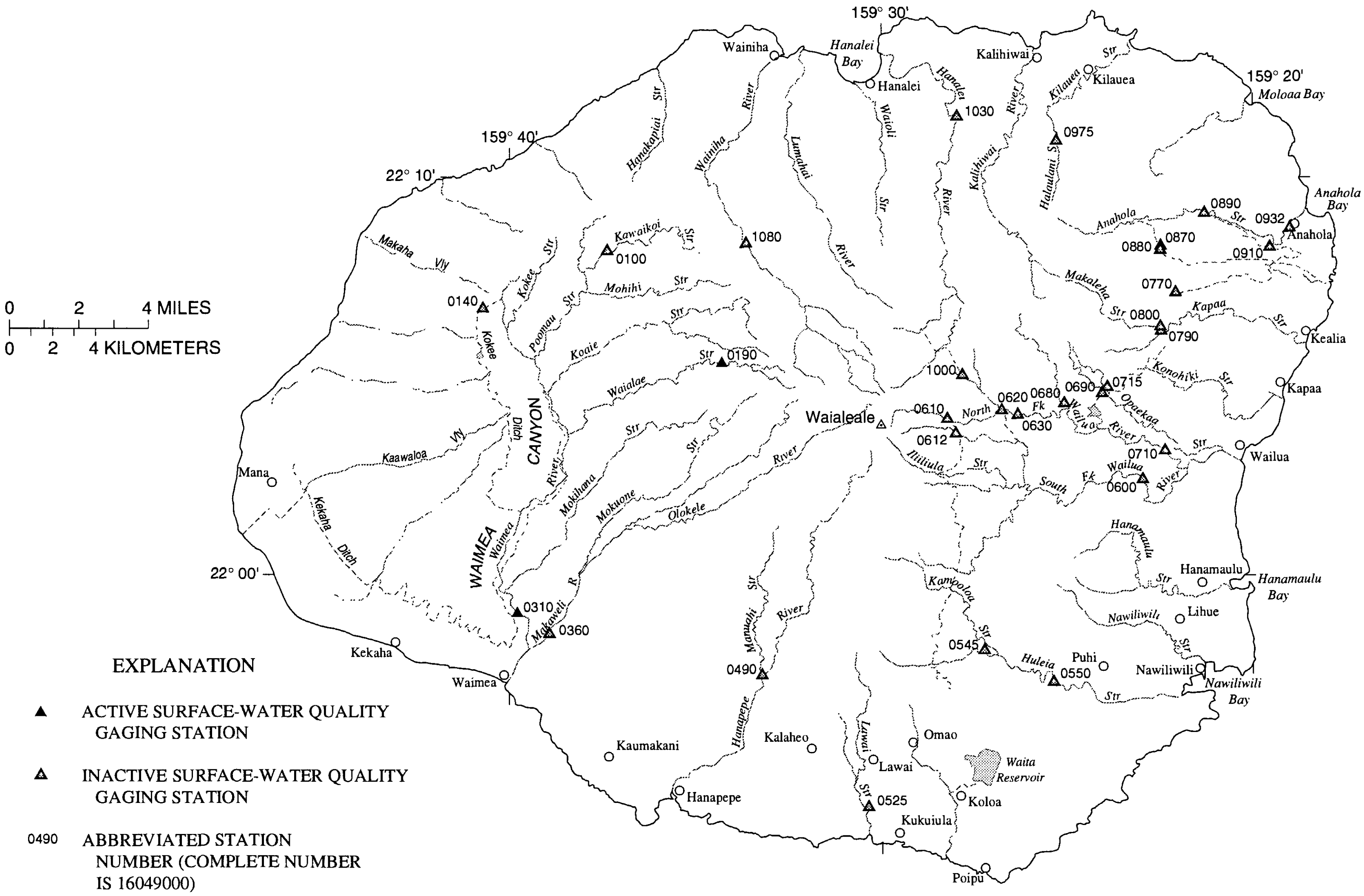

Figure 11. Surface-water quality gaging stations, island of Kauai, Hawaii, 1994.

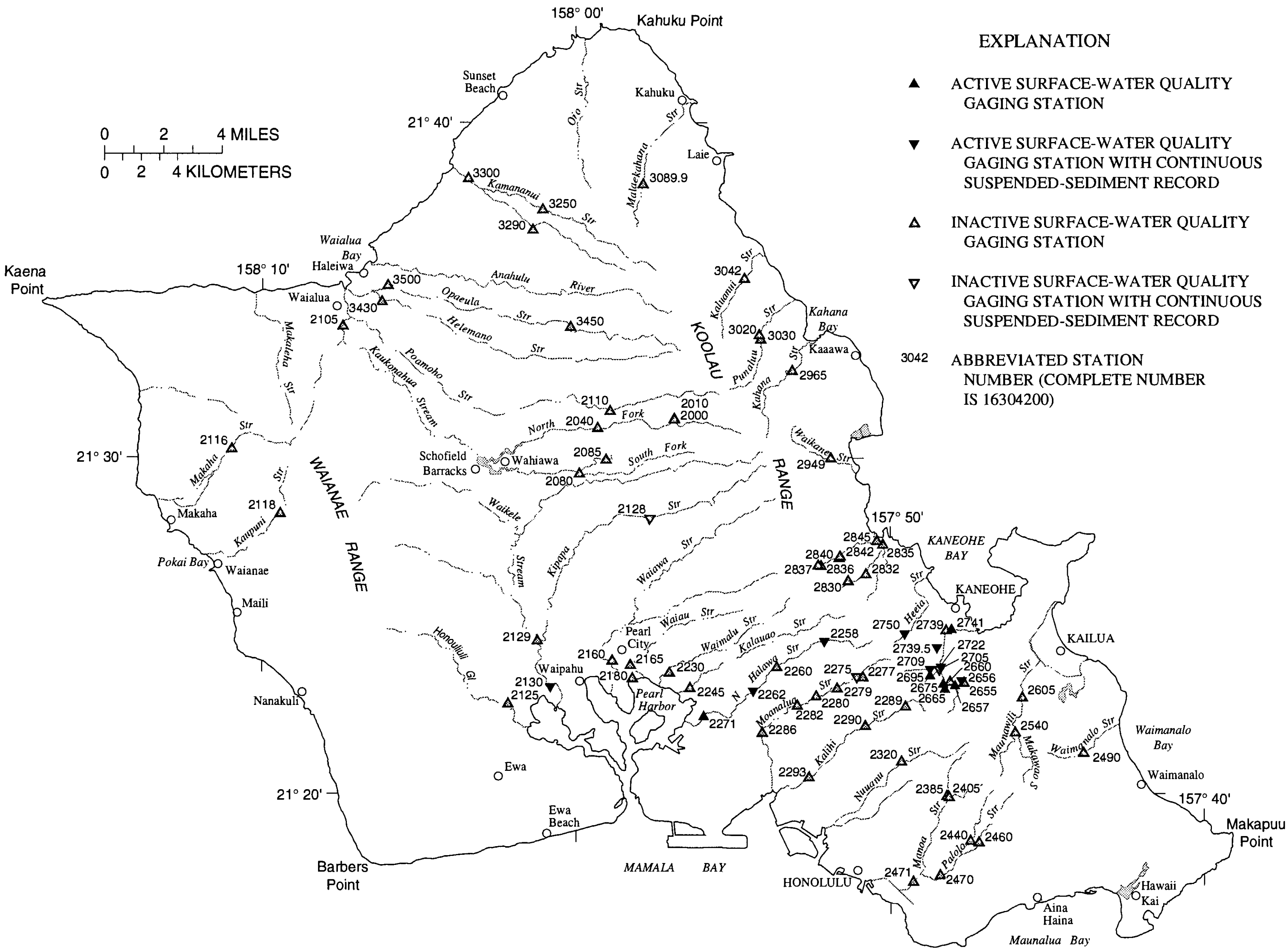

Figure 12. Surface-water quality gaging stations, island of Oahu, Hawaii, 1994.

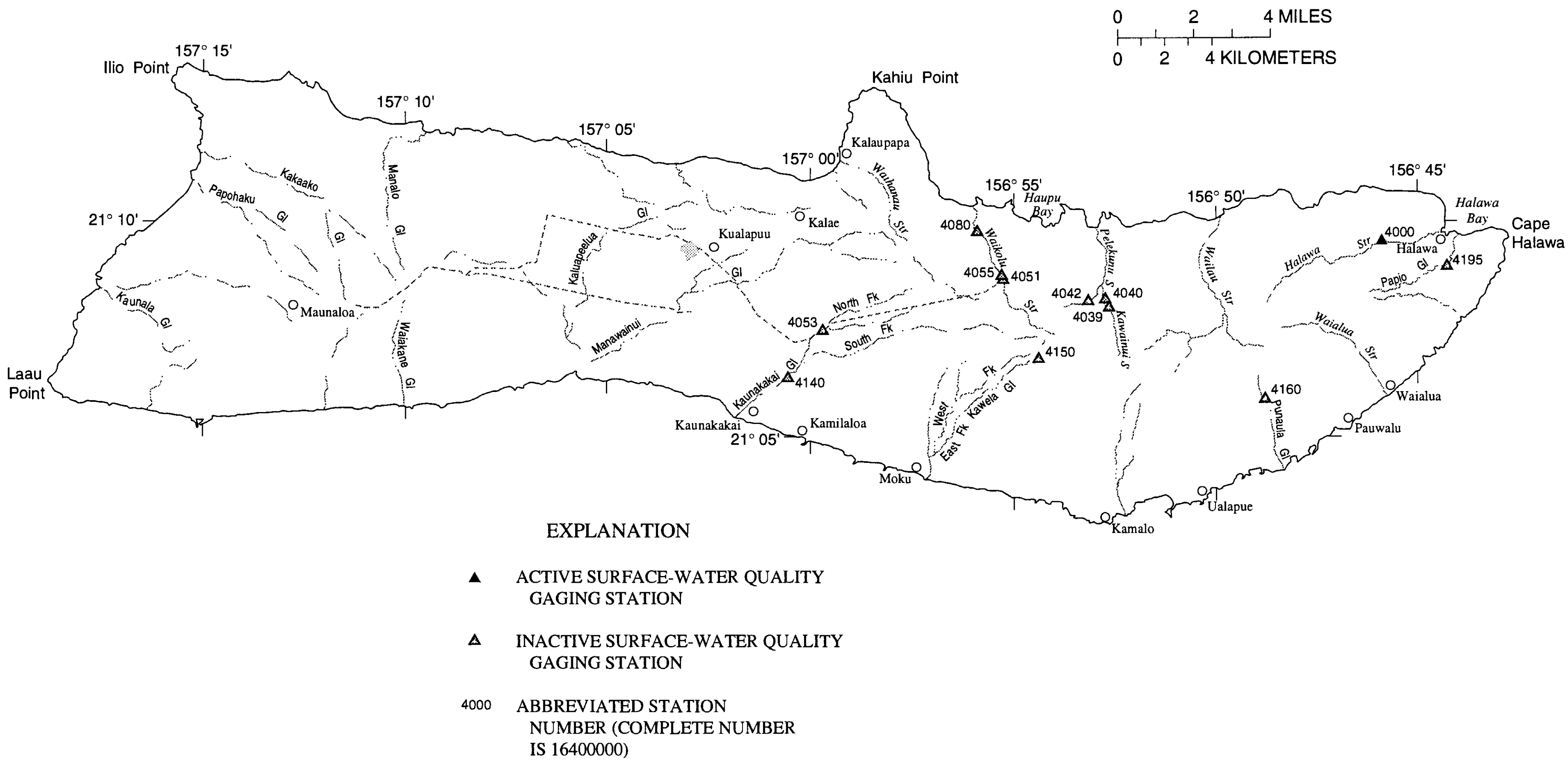

Figure 13. Surface-water quality gaging stations, island of Molokai, Hawaii, 1994.

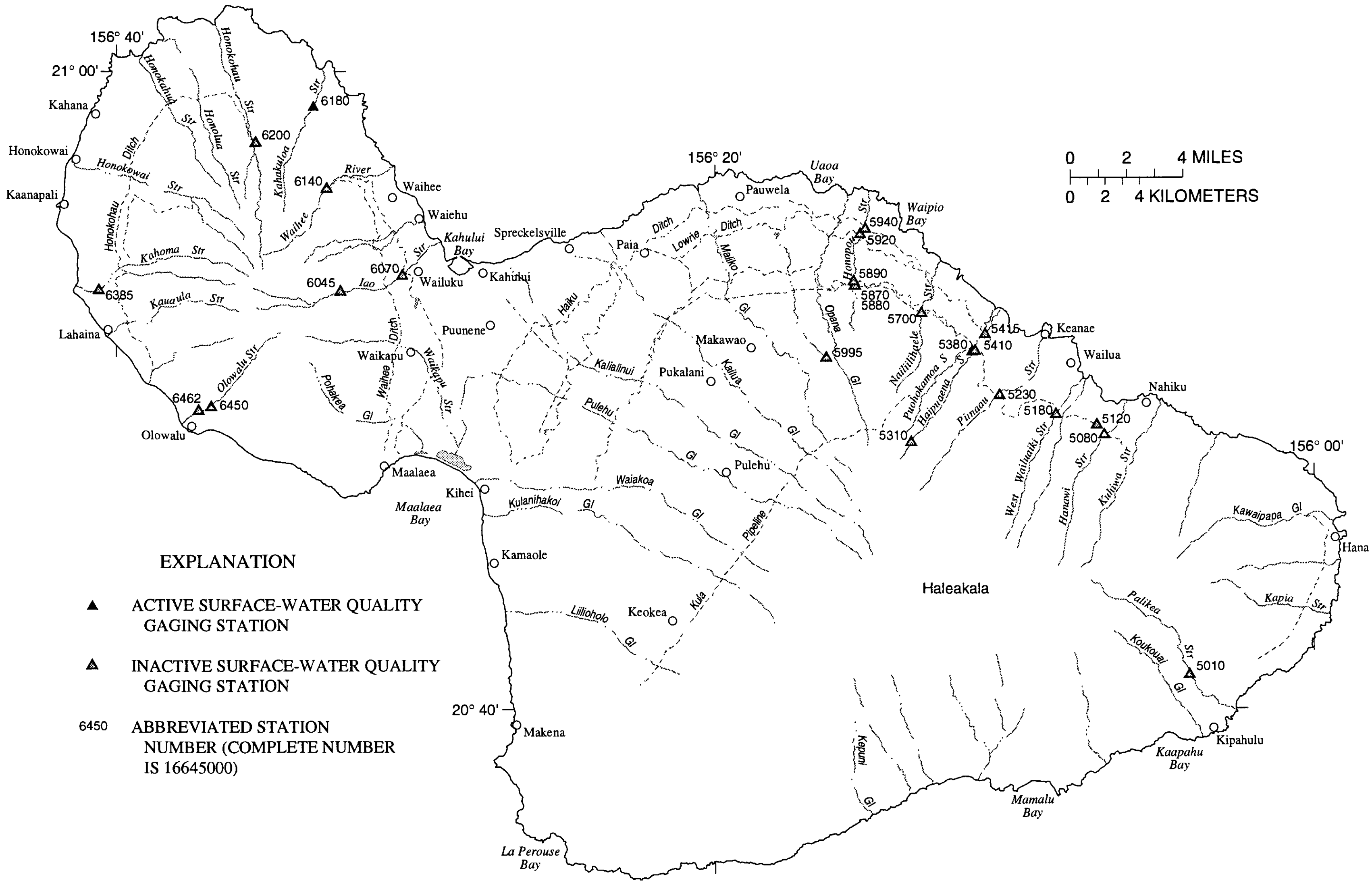

Figure 14. Surface-water quality gaging stations, island of Maui, Hawaii, 1994.

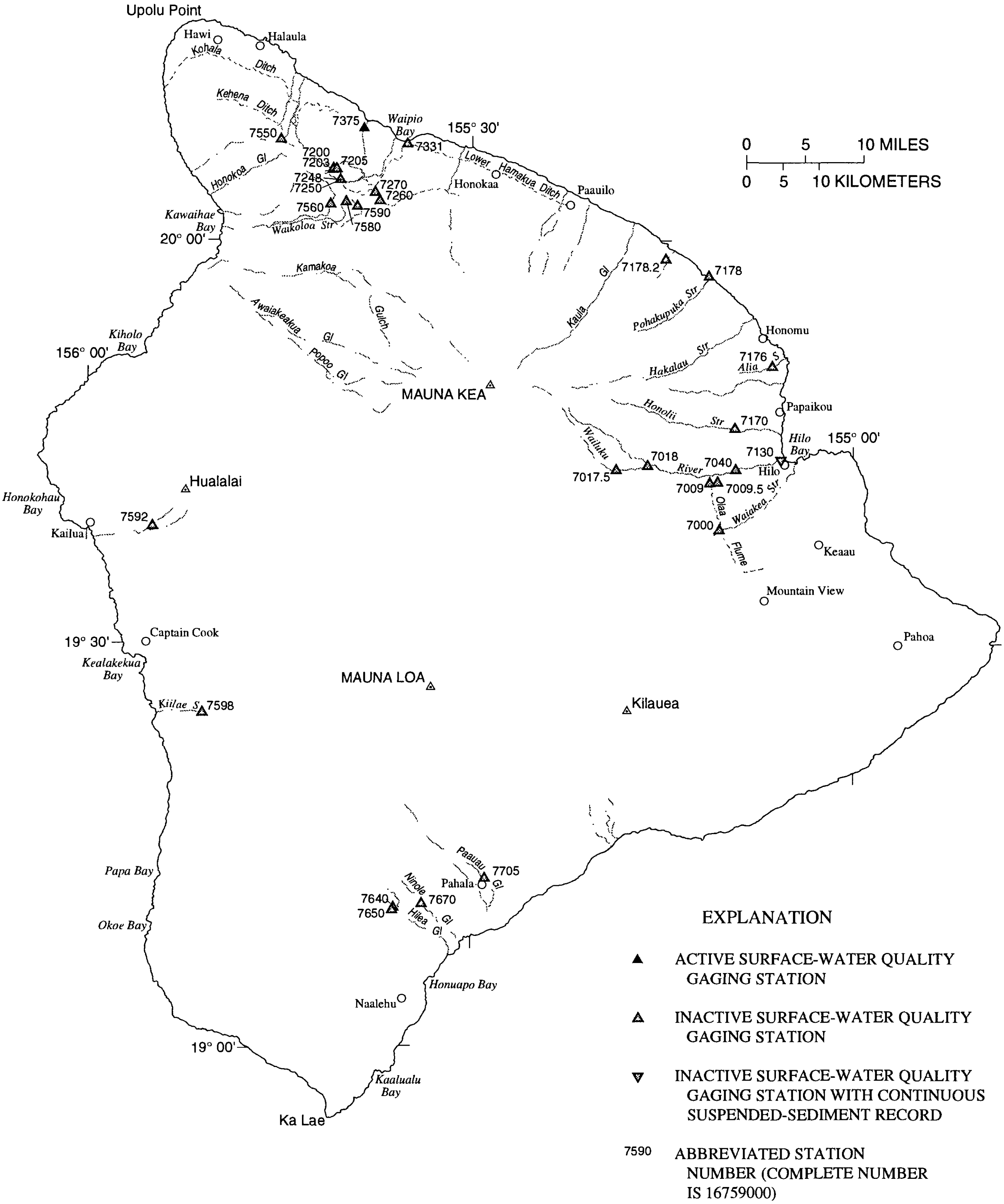

Figure 15. Surface-water quality gaging stations, island of Hawaii, Hawaii, 1994.

Some of the most significant limitations in Hawaii surface-water quality data programs involve the following topics. First, only limited numbers of continuous, suspended-sediment discharge stations have been operated in Hawaii and most of these have been on the island of Oahu (tables 21–25). No continuous-record, suspended-sediment stations have been operated on the islands of Kauai, Molokai, and Maui and only one station has been operated on the island of Hawaii. Second, no systematic program of collecting water-quality data related to specific land-use practices has been undertaken. Third, no systematic, Statewide program of monitoring the quality of surface-water discharges to the ocean has been operated. Fourth, no systematic, Statewide program to establish background water quality of streams in Hawaii exists. Fifth, more data are required to evaluate the effects of nonpoint sources on receiving water bodies. Sixth, only a limited amount of coordination exists between the broad variety of organizations that collect surface-water quality data in Hawaii. As noted in a recent national water-quality monitoring report (Intergovernmental Task Force on Monitoring Water Quality, 1992) greater coordination, consistency, and collaboration among the various agencies involved with water-quality data-collection issues is critical.

In the Hawaii water-quality plan (Hawaii Commission on Water Resource Management, 1990a, p. II-7) three specific surface-water quality issues were raised. The issues include (1) reduction of nonpoint source discharges, (2) control of feral animal populations to minimize contamination in surface water and to improve vegetal cover in watershed areas, and (3) enforce sanitary conditions and good drainage in streams and canals. No Statewide data collection programs are in place to address these issues.

RAINFALL DATA-COLLECTION PROGRAM

Goals of the Program

The goals for the rainfall data-collection program in many ways parallel the data-use categories described for the current surface-water quantity data-collection program. In general, the overall objective is to be able to provide information on rainfall characteristics for any area in Hawaii. If this general objective can be met then most of the specific goals, which are described below, can be addressed. In keeping with the format used to describe data-use classes for the surface-water quantity program, goals for the rainfall program will be discussed as either regional, systems related, current needs, forecasting, water quality, or trend analysis goals. A common, unifying theme for this discussion is the need to make both site-specific and extrapolated information available through established data bases and published reports.

Regional goals are necessary because it is not feasible to collect data at all points of interest. Data, therefore, need to be collected at a sufficient frequency and number of locations so that it can be extrapolated with respect to both time and location. The adequacy of the rainfall data-collection program with respect to regional goals can be evaluated by assessing how accurately rainfall characteristics can be estimated for ungaged areas. The goal is to provide the following statistical characteristics on a regional basis: (1) daily, monthly, and annual totals, (2) long-term mean and median monthly and annual values, (3) storm totals for short durations and entire storms, (4) frequency analyses for storm data which include durations ranging from 30 minutes or less to 24 hours and recurrence intervals from 1 through 100 years, (5) totals over extended periods of deficient rainfall or droughts, and (6) frequency analyses for periods of deficient rainfall which include durations ranging from 3 to 12 months and recurrence intervals from 5 through 100 years. These statistical characteristics are needed for locations that range in scale from specific rain-gage sites to entire islands.

Systems-related goals are based on the need to account for water movement or availability in specific networks or regions and to describe current hydrologic conditions. In Hawaii, systems goals relate to three primary objectives (1) to provide rainfall data used as part of mass-balance calculations to determine recharge and therefore water availability in aquifer systems Statewide, (2) to provide background rainfall data that are used to determine when and how much to irrigate crops, and (3) to describe current hydrologic conditions and to determine the existence, areal extent, and severity of deficient or drought conditions. To meet the first objective the goal is to provide long-term estimates of mean monthly and mean annual rainfall values for entire aquifer areas. To meet the second objective the goal is to provide rainfall totals in a rapid-reporting, real-time basis, that are representative of what fell over a specific area. To meet the third objective the goal is to provide daily rainfall totals, in a near real-time basis, from a network of rain gages that are representative of the general climatic variability which exists in the State.

Current-needs goals are based on the need to provide specific rainfall information at certain, predetermined locations. Current needs are therefore both site and data specific and goals for these types of rainfall data-collection sites cannot be generalized in advance. Current needs goals need to be developed on a case by case basis. Examples of current needs are (1) research projects such as hillslope-stability studies that need near real-time, recording rain gages that provide storm data at intervals on the order of minutes, (2) rainfall-runoff modeling studies that need to define the distribution of rainfall over specific watersheds, and (3) planning and design of rain catchment systems to provide alternative sources of water supply. Rainfall data collection efforts to meet current needs are typically short term in nature and frequently data collection is terminated when the project is completed.

Forecasting goals are based on the need to provide advance warning for possible catastrophic or life-threatening events. An obvious example of forecasting is the work of the National Weather Service (NWS) related to possible flood conditions. To meet forecasting objectives, the goals of the rainfall data-collection program are to provide real-time rainfall information from a network of stations that provides adequate areal coverage of watersheds where flood potential exists. A goal would be to establish real-time recording rain gages in high-rainfall, upland areas. Rainfall data from these sites would provide the greatest amount of time to respond before water levels in streams rose to dangerous levels. Although not currently operational in Hawaii, forecasts related to potential for debris flows based on rainfall are also a possibility. Again, strategically located, real-time data-collection rain gages are required for this forecasting. The NWS plans to install the NEXRAD radar system in Hawaii by 1995. A forecasting goal for the rainfall data-collection program at that time would be to provide a baseline of ground-truth data which can be used to calibrate and verify the performance of the NEXRAD system.

Water-quality goals associated with rainfall data programs focus primarily on evaluating wet atmospheric deposition and the chemical quality of rain. Sources of depositional materials associated with rain include global-scale emissions, localized volcanic emissions, and the surrounding oceans. Specific goals include use of rain water-quality data to (1) determine the acidity of rain associated with volcanic activity on the island of Hawaii, (2) determine the significance of rain water as a source of chlorides, and (3) determine the concentrations of stable isotopes in rain as a first step in evaluating flow paths of water in hydrologic systems.

Trend-related goals are based on the need to evaluate the statistical structure of rainfall time-series data. Statistical characteristics, such as mean annual rainfall, are generally based on short-term data sets or on selected base periods that are assumed to be representative of average or long-term conditions. The objective is therefore to maintain rainfall data-collection operations at selected sites where long-term data are available. The selected sites need to be clearly identified as being operated specifically to determine long-term trends and they need to provide adequate areal coverage on each of the islands. Rainfall data from long-term sites can be used to (1) test the representative nature of short-term data sets, (2) adjust short-term records to more accurately represent long-term conditions, (3) determine the existence of longer-term trends such as those associated with possible global climate change, and (4) determine the existence of short-term or cyclic trends such as those associated with El Ninos or volcanic activity.

Description of the Program

The density of rain gages in the Hawaii program is one of the highest in the world. By 1976, rainfall data had been collected at a total of 1,985 sites in the State (Schroeder, 1981). This number has likely increased since then. This dense network of rain gages developed primarily for two reasons. First, rainfall data are needed by a diversity of organizations to make important water-related decisions on an ongoing basis. Second, rainfall in Hawaii exhibits extreme spatial variability.

Plantation agriculture (primarily sugarcane and pineapple) and large ranches have been a significant part of the Hawaiian economy for more than 100 years. The plantations and ranches depend on detailed information regarding water availability to manage their operations. Rainfall data is a significant factor in evaluating water availability. As a result, dense networks of gages were established in areas where plantations and ranches operate. Almost all of the earliest rainfall data-collection sites in Hawaii were operated by either the plantations or the ranches. To date, plantations and ranches have probably operated as many rain gages as all the other groups in the State combined.

Population growth and related urban and residential development have significantly increased domestic water demands in the State. Water distributors, such as the Honolulu Board of Water Supply, established rain-gage networks to address their needs regarding water-supply issues. The National Weather Service (NWS) mission of forecasting and providing climatologic data called for further expansions of the rain-gage program. Scientific and regulatory interest regarding water-related issues continued to grow and agencies such as the USGS and the Hawaii Department of Land and Natural Resources (DLNR) and scientists at the University of Hawaii required and collected more rainfall data. Agencies such as the NWS and DLNR have made extensive use of private citizens to collect these data.

As noted earlier, dense networks of rain gages were established partly because of the extreme spatial variability of rainfall in Hawaii. Gradients of average rainfall in Hawaii are some of the steepest in the world. Giambelluca and others (1986, p. 2) noted that average rainfall on Kauai increases from about 20 in. near Kekaha to more than 433 in. on the summit of Mount Waialeale. This results in an average gradient of about 26.6 in. of rain per mile. Although not as extreme, large spatial variability of rainfall also exists on the islands of Oahu, Molokai, Maui, and Hawaii. None of the other states in the U.S. have this degree of spatial variability in precipitation.

Rain gages in Hawaii have been operated by a broad variety of groups and individuals and for a variety of purposes. Undoubtedly this diversity has played a large role in developing the dense network of rain gages that exists. A negative aspect of this diversity has been lack of uniform data-collection standards and data-storage and publication policies. These factors have frequently made simple analyses of available data difficult.

One of the first summaries of rain gages in Hawaii was published by Leopold and others (1948) under the joint auspices of the Hawaiian Sugar Planters Association and the Pineapple Research Institute. They noted that a large organizational job was necessary before the available data on daily rainfall values could be analyzed. Leopold and others (1948) attempted to resolve differences and summarize station names, locations, altitudes, and lengths of record for all gages in operation as of 1948. Significant contributions made by this documentation included: (1) establishing a Statewide numbering system for rain gages that was later adopted as the official state identification system (presently referred to as State key numbers), (2) establishing the Weather Bureau standard as the method used to operate and date records from non-recording, daily gages, and (3) listing operational rain gages in the State.

In 1961, the U.S. Weather Bureau published a report (Taliaferro, 1961) updating and expanding the earlier summary by Leopold and others (1948). The report included sites where other climatologic data, in addition to rainfall, were collected. Also, the report included a summary of all the sites where data had been collected, not just those that were active. One of the first rainfall data-collection efforts in Hawaii noted by Taliaferro (1961, p. 70) was that of a Dr. Rooke in 1837, in Honolulu, at State key station number 705.9.

The most recent listing of sites where rainfall data have been collected was published by the Hawaii Division of Water and Land Development (1973). In this update a total of 3,402 sites where climatologic data have been collected are listed. Rainfall data are not available for all the sites.

Currently, most rain gages operated in Hawaii are included in one of two principal networks. These networks are coordinated by the NWS and DLNR. Both the NWS and DLNR maintain files that include listings of active gages. A list of the active rain gages (as of March 1993) on the islands of Kauai, Oahu, Molokai, Maui, and Hawaii, included in the NWS and DLNR networks, is given in tables 26 through 30 (at end of report). The locations of these gages are shown in plate 6. As of March 1993 there were 92, 150, 15, 123, and 148 active rain gages on Kauai, Oahu, Molokai, Maui, and Hawaii, respectively.

Availability and Analyses of Data

In the preceding section on goals of the program, the importance of making data available through established data bases and published reports was stressed. As noted by Leopold and others (1948, p. 210) only some of the rainfall data is published and most exists only in paper files. In the most recently published summary of historical, rainfall data-collection sites (Hawaii Division of Water and Land Development, 1973), sources for the data collected were identified. Sources included the U.S. Weather Bureau (currently referred to as the National Weather Service), Hawaii Division of Water and Land Development, Hawaii Sugar Planters Association, observers, and other. The category "other" could include miscellaneous sources such as the Pineapple Research Institute, Hawaii Water Authority, Honolulu Board of Water Supply, the U.S. military, or the USGS. Taliaferro (1961) also identified, where appropriate, publications where the data could be found. A variety of publications include rainfall data, however, the largest single source of data are the reports of the NWS. The NWS data are currently published by their parent agency the National Oceanic and Atmospheric Administration (NOAA). NOAA publishes the data in three principal formats. First, available hourly rainfall data have been published on a monthly basis since 1965 (for example see NOAA, 1991a). Also included in these reports are monthly maxima and time of occurrence for time intervals ranging from 15 minutes to 24 hours. Second, available daily rainfall data have been published on a monthly basis since 1905 (for example see NOAA, 1991b). Also included in these reports are monthly totals and departures from normal. Third, monthly and annual totals and departures from normal are summarized in annual reports that have been published since 1905 (for example see NOAA, 1991c). The rainfall data are available in data bases at the NOAA National Climatic Data Center in Asheville, North Carolina. Rainfall data included as part of the DLNR program are available in their files and are not routinely published.

Some of the rainfall data collected by the Honolulu Board of Water Supply are published in their series of annual reports (for example see Honolulu Board of Water Supply, 1986). These reports were published biennially from 1925 through 1959 and annually from 1959 to present. The USGS has published rainfall data in a variety of reports. Starting with the data report for 1993 water year, these data will be published on an annual basis and daily values stored in an electronic data base. Data for 45 sites were included in the 1993 USGS annual data report (Matsuoka and others, 1994).

Numerous analyses of mean and median monthly and annual rainfall data have been done for Hawaii. The most important studies are summarized in table 31. The most recent and perhaps one of the most comprehensive summaries of mean and median rainfall data in Hawaii is Giambelluca and others (1986). in which more than 1,200 gages, updated through 1983, were adjusted to a common base period, by island. The base period for Kauai, Oahu, Maui, and Hawaii was 1916 through 1983. The base period for Molokai was 1931 through 1983. These data were then used to generate maps describing the distribution of median and mean monthly and annual rainfall in Hawaii.

The U.S. Weather Bureau (1962) compiled the first detailed analysis of high rainfall-frequency relations for the Hawaiian islands. The analysis included areas up to 200 mi^2, durations from 30 minutes to 24 hours, and return periods from 1 to 100 years. Included were analyses for each of the major islands discussed in this report (Kauai, Oahu, Molokai, Maui, and Hawaii) using data available through 1959. Results of the

Table 31. List of previous rainfall maps of Hawaii [modified from Giambelluca and others, 1986, table 1, p.3]

Year published	Author	Description
1929	J.F. Voorhees	Mean annual rainfall of Oahu
1933	W.T. Nakamura	Mean annual rainfall of Oahu
1939	W.R. Feldwisch	Mean annual rainfall of major islands[1]
1942	H.T. Stearns, G.A. Macdonald	Mean annual rainfall of Maui
1948	M.H. Halstead, L.B. Leopold	Median monthly rainfall of Oahu
1949	L.B. Leopold	Mean annual rainfall of East Maui
1951	C.K. Stidd, L.B. Leopold	Mean annual rainfall of major islands[1]
1955	W.A. Mordy, Saul Price	Monthly and annual mean rainfall of major islands[1]
1959	W.J. Taliaferro	Monthly and annual median rainfall of major islands[1]
1967	D.I. Blumenstock, Saul Price	Mean annual rainfall of major islands[1]
1973	Division of Water and Land Development	Median annual rainfall of major islands[1]
1982	Division of Water and Land Development	Median annual rainfall of major islands[1]
1986	T.W. Giambelluca, M.A. Nullet, T.A. Schroeder	Median and mean monthly and annual rainfall of major islands[1]

[1] Includes islands of Kauai, Oahu, Molokai, Lanai, Maui, and Hawaii

Weather Bureau study were updated for the island of Oahu using data available through 1982 by Giambelluca and others (1984). The updated study included frequency maps showing the distribution of high rainfall for durations of 1, 6, and 24-hours and return periods of 2, 10, 50, and 100 years.

Although several studies of specific drought periods in Hawaii have been published, few studies if any have considered long-term, low-rainfall frequency distributions. In 1991, Giambelluca and others, using a network of long-term rainfall stations and data through 1986, published a detailed analysis of low-rainfall (drought) distributions. Included as results of the study were maps of Kauai, Oahu, Molokai, Lanai, Maui, and Hawaii showing the distributions of 3-, 6-, 9-, and 12-month low-rainfalls with return periods of 2 through 200 years. No additional updates of Statewide, rainfall characteristics have been published for Hawaii.

Evaluation of the Program and Alternatives

In the previous sections, goals for the rainfall data-collection program were discussed, the current and historical data programs were described, and availability and analyses of data summarized. In this section each of the goals for the rainfall data-collection program will be discussed individually in terms of how adequately they are being addressed by available data and analysis. Alternative data collection and analysis strategies will be proposed where appropriate.

Regional goals associated with the rainfall data-collection program are being partially met. Hawaii historically and currently has as dense a network of rain gages as exists in the world. However, even this dense network cannot adequately sample rainfall at all locations. In figure 16 areas where few, if any, gages are being operated, as of March 1993, are identified. In general, gages are lacking in areas of high rainfall and in several areas where neither residential development or agriculture is prevalent. The lack of active gages in areas of high rainfall is further demonstrated by the data summarized in table 32. On Oahu, for example, 103 of the 150 active gages are located in areas receiving less than an average of 80 in. of rain annually. In table 33 the distribution of active rain gages by altitude is summarized. Altitude is a significant factor affecting the distribution of rainfall in Hawaii. As shown in table 33, most active gages are located at lower altitudes. On Oahu, 145 of the 150 active gages are at altitudes below 2,000 ft. Another way to look at the distribution of rain gages is to determine the percentage of gages located in selected areas. Geographic information systems (GIS) technology makes such analyses relatively straightforward. Such an analysis was done for the island of Hawaii where it was noted that 39 percent of the island receives less than an average of 40 in. of rain annually yet only 14 percent of the active gages are located in those areas. Thirty-two percent of the island receives an average of between 60 to 160 in. of rain annually yet 59 percent of active gages are located in these areas. To improve the current rainfall data-collection program, consideration

Table 32. Distribution of active rain gages by mean annual rainfall, Hawaii, March 1993.

Island	Maximum mean annual rainfall isohyet (inches)	Number of gages by range in mean annual rainfall (inches)					
		0–40	40–80	80–120	120–160	160–200	>200
Kauai	435	20	42	16	7	5	2
Oahu	275	50	53	24	13	5	5
Molokai	160	10	2	3	0	0	0
Maui	355	57	43	8	3	4	8
Hawaii	235	21	60	33	23	7	4

Table 33. Distribution of active rain gages by altitude, Hawaii, March 1993.
[--, not applicable]

Island	Maximum altitude (feet)	Number of gages by range in altitude (feet)				
		0–2,000	2,000–4,000	4,000–6,000	>6,000	Total
Kauai	5,243	80	8	4	--	92
Oahu	4,020	145	4	1	--	150
Molokai	4,970	14	1	0	--	15
Maui	10,023	93	19	6	5	123
Hawaii	13,796	99	33	10	6	148

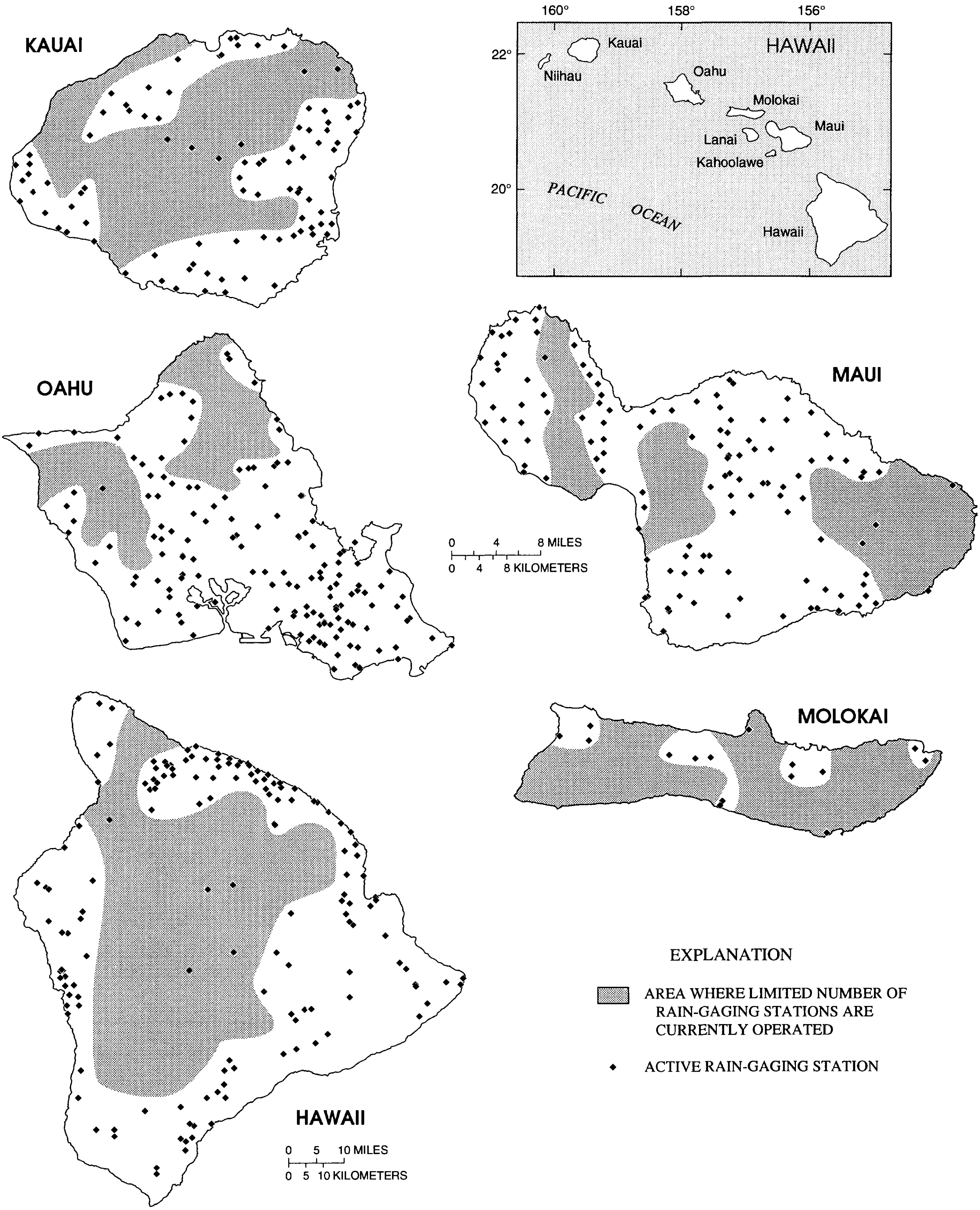

Figure 16. Areas where limited numbers of rain-gaging stations are operated, Hawaii, March 1993.

needs to be given to locating new gages in areas where current coverage is limited.

Length of available record is a significant factor affecting the accuracy of statistical characteristics computed using rain gage data. In table 34 the distribution of active rain gages by length of record is summarized. Note that 201 of the active rain gages have at least 60 years of record and 23 of these have more than 100 years of record. A significant strength of Hawaii's rainfall program is that such a long-term data base exists. Emphasis on the collection of long-term data needs to be continued.

Several analyses have been published that can be used to extend rainfall statistical characteristics to ungaged areas. Reports describing mean and median monthly and annual values have been updated regularly. One rainfall characteristic that is in significant need of analysis is that of storm-frequency data. The most recent analysis of storm-frequency data for Hawaii (with the exception of Oahu, see Giambelluca and others, 1984) was published in 1962 (U.S. Weather Bureau, 1962). Consideration needs to be given to updating the storm frequency report for the remaining islands.

In previous studies of storm-frequency data a significant problem was the lack of recording rain gages. Significant strides have been made to improve this situation. In table 35 the number of active recording and real-time rain gages in Hawaii is summarized. A total of 130 gages, 25 percent of the total number of active gages, are recording. The distribution of the recording gages (plate 6) however, is similar to that of rain gages in general (fig. 16). Overall areas of high rainfall are inadequately gaged as are several additional geographic regions, as indicated in figure 16. A significant number of the rain gages with recording capabilities are also real-time data sites that are being operated primarily to provide flood warnings. Most of the data collected at these real-time gages is not currently being stored and/or published. Consideration needs to be given to correcting this limitation.

Systems-related goals associated with the rainfall data-collection program generally are being adequately met. Historically the needs for rainfall data related to agricultural interest have been met by the plantations and ranches, which have operated a significant number of the rain gages Statewide. As of 1993 the plantations and ranches operate 70 percent of the active rain gages on Kauai, 26 percent on Oahu, 27 percent on Molokai, 60 percent on Maui, and 46 percent on Hawaii. Two additional systems-related goals involve the need to describe water availability in ground-water systems and current hydrologic conditions. For both goals rainfall data play a critical role. The lack of rain gages in the areas identified in figure 16 limits the accuracy of analyses of water availability and current hydrologic conditions that can be undertaken. Where possible, consideration needs to be given to locating new rain gages in these areas.

Current-needs goals are typically site and project specific. In general it is neither possible nor even desir-

Table 34. Distribution of active rain gages by length of record, Hawaii, March 1993.

Island	Total	Number of gages by length of record (years)					
		0–20	21–40	41–60	61–80	81–100	>100
Kauai	92	10	14	23	16	24	5
Oahu	150	20	51	26	39	10	4
Molokai	15	3	5	4	2	1	0
Maui	123	13	21	36	21	30	2
Hawaii	148	24	49	28	13	22	12
Total	528	70	140	117	91	87	23

Table 35. Distribution of active recording and real-time rain-gages, Hawaii, March 1993

Island	Total	Real time	Recording
Kauai	92	10	25
Oahu	150	25	46
Molokai	15	2	5
Maui	123	10	23
Hawaii	148	16	31
Total	528	63	130

able to plan for these needs in advance as part of the operation of the rainfall data-collection program. Therefore current-needs goals should continue to be addressed on a case by case basis by the specific groups involved with the projects or current needs in question.

Forecasting goals associated with the rainfall data-collection program are being partially met. In response to recent floods, notably the December 1991 flood on Kauai, the NWS and DLNR have both attempted to expand their real-time rainfall-monitoring programs. As noted in table 35, as of March 1993 a total of 63 real-time rainfall gages were in operation in Hawaii. Locations of these 63 gages are identified on plate 6. The installation of real-time gages needs to take into account several variables in addition to rainfall variability. An example is the distribution of flood-prone areas where warnings are critical. However, the distribution of real-time gages in Hawaii has the same types of problems associated with the rain-gaging program in general. Several of the high-rainfall areas (fig. 16) lack data. Where possible, expansion of the real-time data-collection program in these areas needs to be considered.

As early as 1976 Schroeder noted that the installation of a meteorological radar system is the only viable solution to the problem of early detection of flash-flood potential (Schroeder, 1976, p. iii). The NWS plans to install such a NEXRAD system in Hawaii by 1995. The system, commonly referred to as WSR-88D, is based on integrating Doppler radar capabilities, real-time signal-processing techniques, meteorological and hydrological algorithms, and automated product-processing programs. The NEXRAD system can provide products such as areal rainfall intensities and storm totals updated every 5 to 10 minutes (Klazura and others, 1992, and Shedd and others, 1992). Certainly these new radar-based systems have the potential to dramatically increase the accuracy and areal coverage of rainfall forecasting in Hawaii. The current program of recording rain gages in Hawaii needs to be expanded, at least initially, to provide the ground-truth data required to calibrate and verify the NEXRAD system.

Water-quality goals associated with the rainfall data-collection program are being minimally met. Presently (1994) no systematic program to sample the water quality of rainfall exists in Hawaii. Consideration need to be given to establishing a baseline monitoring program for each of the islands that as a minimum measures the acidity and chloride concentrations in rain from a variety of storm types.

Trend-related goals associated with the rainfall data-collection program are being partially met. As noted in table 34, a significant number of gages have been operated for at least 80 years. These data have been used in studies such as those by Giambelluca and others (1986) to adjust short-term records to long-term base periods. Long-term records are also critical in any attempts to quantify if long-term or ongoing changes in the rainfall regime of the Hawaiian islands are taking place. As noted in table 36, only 22 of the rain gages that have been in operation for more than 80 years are currently recording gages. Most of the long-term gages (92 out of 110) are operated by plantations or ranches. This factor is of concern for two reasons. First, many plantations are being closed and continued operation of the associated long-term rain gages is uncertain. Second, because most long-term rain gages have been operated by plantations or ranches, their geographic distribution is limited primarily to agricultural areas. This limited geographic distribution of long-term trend gages is illustrated in figure 17. To address these concerns, consideration needs to be given to identifying a network of recording gages that is planned to remain in operation as long as possible. Where possible this network should include existing sites with long-term data that provide a representative sampling of the diverse geography and rainfall that exists on each of the islands. Continued op-

Table 36. Number of active rain gages with greater than 80 years of record by type and observer, Hawaii, March 1993.

			Observer			
Island	**Number of gages**	**Recording**	**Plantation or ranch**	**Federal agency**	**State or county agency**	**Other**
Kauai	29	4	21	6	0	2
Oahu	14	4	10	0	3	1
Molokai	1	1	1	0	0	0
Maui	32	6	31	0	1	0
Hawaii	34	7	29	1	1	3
Total	110	22	92	7	5	6

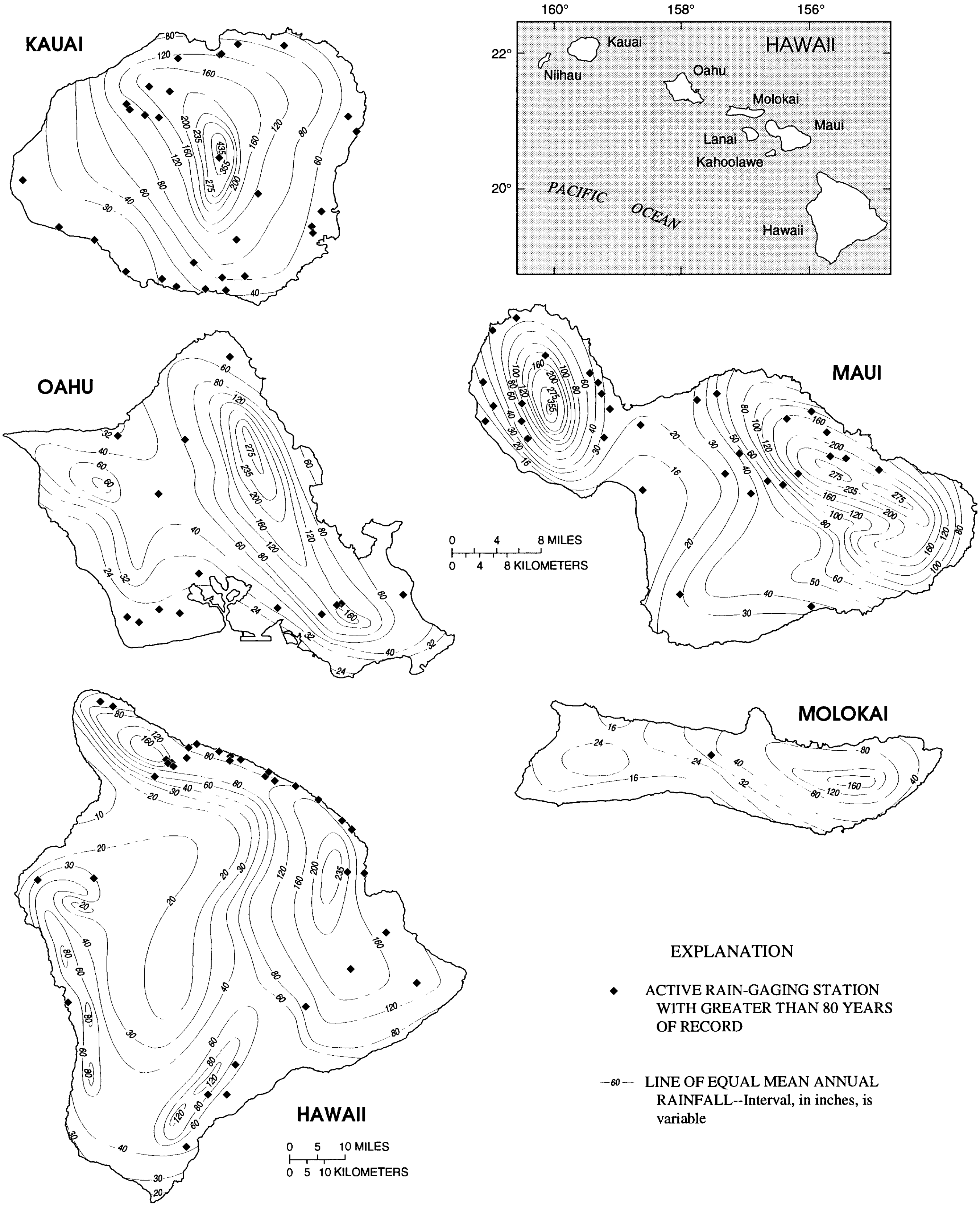

Figure 17. Active (1993) rain-gaging stations with greater than 80 years of record and lines of mean annual rainfall, Hawaii (rainfall contours modified from Giambelluca and others, 1986).

eration of selected rain gages currently maintained by plantations and ranches that may close in the future needs to be a part of the plan. To supplement this plan, consideration needs to be given to operating at least one recording rain gage in the watersheds of the identified long-term surface-water-quantity trend stations (fig. 6). This would allow comparison of long-term rainfall and runoff data. In figure 18 the location of the watersheds of existing and needed long-term surface-water trend stations and nearby, active rainfall gages are shown. Currently, no rain gages are operated in the watersheds of long-term surface-water trend stations 16048000, 16068000, 16097500, and 16108000 on Kauai, station 16200000 on Oahu, station 16400000 on Molokai, stations 16501200 and 16647000 on Maui, and station 16717000 on Hawaii. In addition only 10 of the 27 watersheds currently have recording rain gages.

The rainfall data-collection program is made up of a variety of groups, individuals, and government agencies who collect and store the data. Attempts need to be made to regularly update the summary of sites where data are collected. Such information could be readily incorporated into GIS data bases and in turn provide valuable information for additional analyses. A summary of the rainfall data-collection program for all historical and active sites was last published in 1973 (Hawaii Division of Water and Land Development, 1973) and an update is needed. As noted above, a significant number of real-time rain gages are being operated for which data are collected but not stored. These data are extremely valuable and consideration needs to be given to a remedy for this limitation. Summarizing available information and making it available through established data bases and published reports is a function that needs to be continuously stressed.

SUMMARY AND CONCLUSIONS

On the basis of information from State, county, local, and federal agencies, universities, major water users, and environmental groups, 14 specific issues and related goals for the surface-water quantity data-collection programs in Hawaii were identified. These issues include problems related to availability, interaction between ground water and surface water, streams for protection, hydrologic hazards, and availability and analyses of data.

To aid in the evaluation, a geographic information system (GIS) data base was developed that includes information regarding all surface-water stream gages that have been operated in Hawaii by the USGS. Information for a total of 668 continuous record, crest-stage, and low-flow partial-record gages are included in the data base. Evaluation of the current surface-water quantity data-collection program indicated that changes in status need to be considered at 25 continuous-record gages, 5 crest-stage gages, and 12 low-flow partial-record gages. Possible changes in status are summarized and include discontinuing several of these gages.

The existing surface-water quantity data base was determined to be adequate to address only 2 of the 14 specific issues and future goals identified for the program. Alternatives were identified to address the areas where future issues and goals could not be adequately addressed. Options include new and expanded data collection, use of regional regression analyses, hydrologic and hydraulic modeling, and analysis and publication of existing data. A total of 47 streams were identified where additional stream-gaging stations are needed.

Analysis of the surface-water quality programs in Hawaii was limited to a description of the USGS's historical and existing programs and a summary of how these data have been analyzed and made available. Historically surface-water quality data have been collected at 30 gages on Kauai, 75 gages on Oahu, 12 gages on Molokai, 24 gages on Maui, and 30 gages on Hawaii. Limitations of the existing program were identified and include: (1) limited continuous records of suspended sediment have been collected, (2) systematic programs to collect water-quality data related to land use, surface-water discharge to oceans, general background water quality, and nonpoint-source effects are lacking, and (3) coordination between the numerous agencies in Hawaii involved with surface-water quality issues could be improved.

The density of rain gages in Hawaii is one of the highest in the world. Future goals identified for the rainfall data-collection program were discussed as either regional, systems related, current needs, forecasting, water quality, or trend analysis related. Description of the program noted that close to 2,000 rain gages have been operated at one time in Hawaii. As of March 1993 there were 528 active gages on the islands of Kauai, Oahu, Molokai, Maui, and Hawaii.

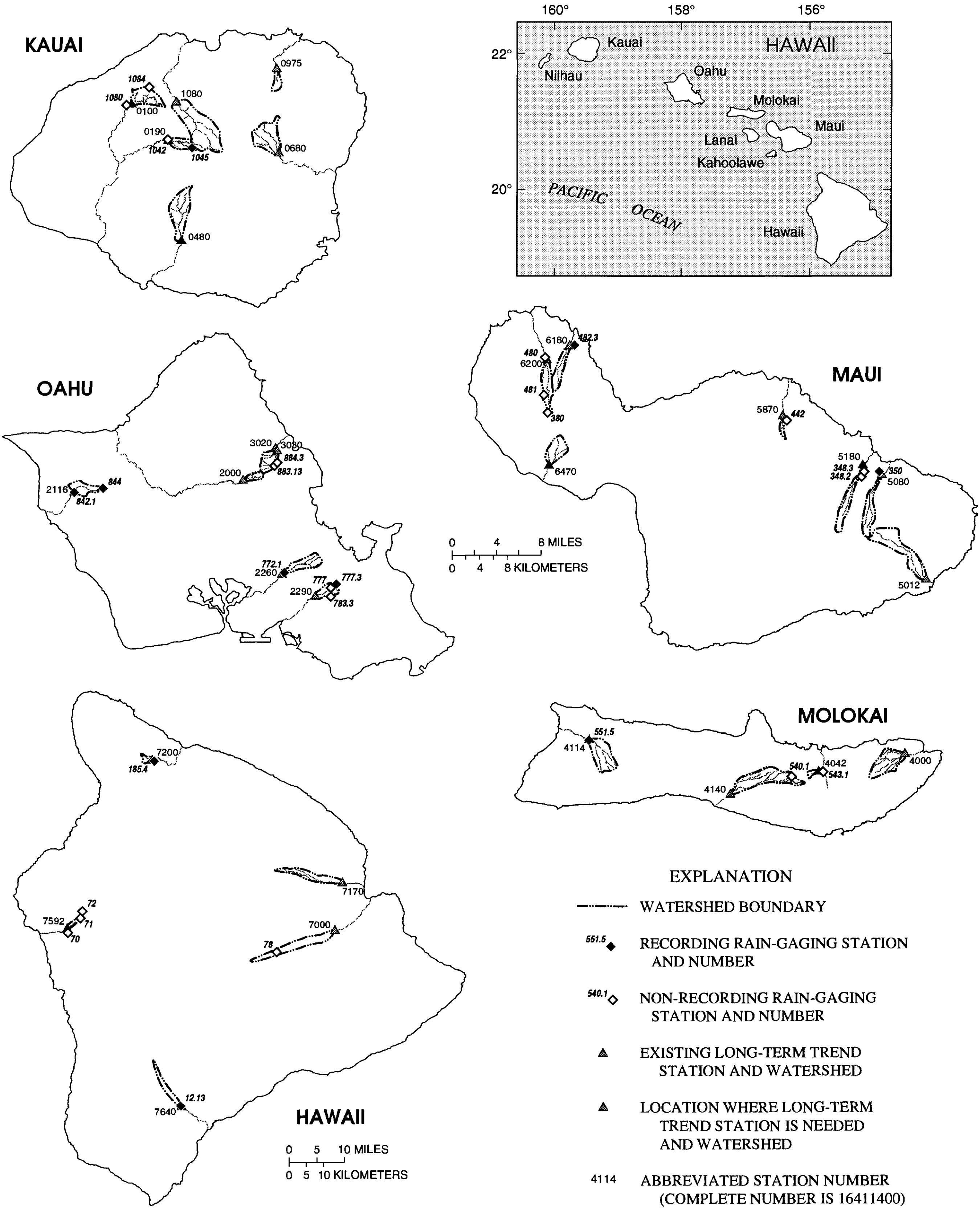

Figure 18. Active rain-gaging stations located within or adjacent to watersheds of existing and needed long-term surface-water quantity trend stations, Hawaii, 1994.

Evaluation of the rainfall data-collection program indicated that, in general, future goals could only be partially met. Gages are lacking in areas of high rainfall and areas where neither residential development nor agriculture is prevalent. Additional recording, and in some areas real-time, rain gages are needed. A majority of the long-term rain gages in Hawaii (92 out of 110) are operated by plantations and ranches. A significant issue involves the potential closure of several plantations so that continued operation of many of these long-term rain gages uncertain. Available analyses of storm-frequency data for the islands of Kauai, Molokai, Maui, and Hawaii need to be updated.

Evaluation of data-collection programs in Hawaii needs to be an ongoing process. Goals are constantly evolving and programs need to be flexible enough to meet them. Summarizing available information and making it available through data bases and published reports is a function that needs to be continuously stressed. The need for coordination between the numerous agencies involved with data-collection activities in Hawaii needs continued emphasis.

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Table 1. Surface-water gaging stations, island of Kauai, Hawaii, through 1994

[P, in operation 1994 water year; makai, oceanside; mauka, mountainside; -- less than 1 complete year of record]

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16010000*	Kawaikoi Stream near Waimea	SW	1909–16 1919–P	77-SW	no	no	continuous
16011000	Waikoali Stream near Waimea	SW SW-LF SW SW-LF	1909–13 1914–17 1919–25 1961–62 1964 1966–70 1972–85	5-SW 26-LF	no	no	continuous
16012000	Kauaikinana Stream near Waimea	SW-LF SW SW-LF	1911–13 1915–17 1919–25 1961–62 1964 1966–85	5-SW 26-LF	yes after 4/1925	no	continuous
16013000	Mohihi Stream at altitude 3,420 feet near Waimea	SW	1920–26 1936–71	40-SW	yes after 7/1970	no	continuous
16014000	Kokee Ditch near Waimea	Ditch	1926–82	56-SW	yes	yes	ditch
16015000	Mohihi Stream near Waimea	SW	1909–17	--	yes after 7/1970	no	continuous
16016000	Waimea River at altitude 840 feet near Waimea	SW	1916–18 1925–68	40-SW	yes	no	continuous
16017000	Koaie Stream at altitude 3,770 feet near Waimea	SW	1919–32 1954–68	26-SW	no	no	continuous
16018000	Koaie Stream near Waimea	SW SW-CSG	1916–18 1963–71	9-CSG	no	no	continuous
16019000*	Waialae Stream at altitude 3,820 feet near Waimea	SW	1920–32 1952–P	52-SW	no	no	continuous
16020000	Waialae Stream near Waimea	SW	1910–16	3-SW	no	no	continuous
16021000	Waialae Stream at altitude 800 feet near Waimea	SW	1917–21	3-SW	no	no	continuous
16022000	Kekaha Ditch at Camp 1 near Waimea	Ditch	1908–68	53-SW	yes	yes	ditch
16024000	Kekaha Ditch at siphon near Waimea	Ditch	1910–12	--	yes	yes	ditch
16025000	Kekaha Ditch at flume 2 near Waimea	Ditch	1910–12	--	yes	yes	ditch
16027000	Kekaha Ditch below tunnel 12 near Waimea	Ditch	1908–34	22-SW	yes	yes	ditch
16028000	Waimea River below Kekaha Ditch intake near Waimea	SW SW-CSG	1921–55 1956–69	28-SW 42-CSG	yes	no	continuous
16029000	Waimea Ditch near Waimea	Ditch	1912–14 1916–21	5-SW	yes	yes	ditch
16029100	Waimea Ditch below wasteway near Waimea	Ditch	1960–72	11-SW	yes	yes	ditch
16029500	Mokihana Stream near Waimea	SW-LF	1962 1964–83	21-LF	no	no	continuous
16030000	Peekauai Ditch near Waimea	SW-LF	1911–19 1979–83	14-LF	yes	yes	ditch

Table 1. Surface-water gaging stations, island of Kauai, Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16031000*	Waimea River near Waimea	SW	1910–18	52-SW	yes	yes	continuous
			1919	54-CSG			
			1943–68				
			1969–72				
		SW-CSG	1972–75				
		SW	1975–P				
16032000	Olokele Ditch at tunnel 12 near Makaweli	Ditch	1910–17	6-SW	yes	yes	ditch
16033000	Olokele Ditch at weir near Makaweli	Ditch	1912–17	1-SW	yes	yes	ditch
16034000	Olokele River near Waimea	SW	1915–16	--	yes	no	ditch
16035000	Halekua Stream near Waimea	SW	1912–14	--	no	no	continuous
16036000*	Makaweli River near Waimea	SW	1943–P	50-SW	yes	no	continuous
16037000	Poowaiomahaihai Ditch near Waimea	Ditch	1911–13	1-SW	yes	yes	ditch
16037100	Makaweli River below Poowaiomahaihai Ditch near Waimea	SW	1911–17	4-SW	yes	no	continuous
16038000*	Waimea River at Waimea	SW-CSG-S	1944–P	50-CSG	yes	no	continuous
16039000	Hiloa Ditch near Eleele	Ditch	1911–15	3-SW	yes	yes	ditch
16042000	Hanapepe Ditch at Hanapepe Falls near Eleele	Ditch	1911–15	1-SW	yes	yes	ditch
16043000	Hanapepe Ditch below intake near Eleele	Ditch	1930–38	7-SW	yes	yes	ditch
16044000	Hanapepe Ditch at Koula near Eleele	Ditch	1910–21	31-SW	yes	yes	ditch
			1927–49				
16045000	Hanapepe Ditch below makai siphon near Eleele	Ditch	1929–32	1-SW	yes	yes	ditch
16046000	Hanapepe Ditch at weir near Hanapepe	Ditch	1912–13	2-SW	yes	yes	ditch
			1915–17				
16047000	Koula River at Koula near Eleele	SW	1910–16	6-SW	yes	no	continuous
16048000	Manuahi Stream at Koula near Eleele	SW	1917–20	3-SW	no	no	continuous
16049000*	Hanapepe River below Manuahi Stream near Eleele	SW	1917–21	69-SW	yes	no	continuous
			1926–P				
16050000	G Ditch at makai siphon near Eleele	Ditch	1929–32	1-SW	yes	yes	ditch
16051000	Hanapepe River at makai siphon near Eleele	SW	1929–32	1-SW	yes	no	continuous
16052000*	Hanapepe River at Hanapepe	SW-CSG-S	1950–P	44-CSG	yes	no	continuous
16052500*	Lawai Stream near Koloa	SW-CSG	1962–63	9-SW	yes	no	continuous
		SW	1963–72	32-CSG			
		SW-CSG	1973–P				
16053000	Kamooloa Stream near Koloa	SW	1939–41	--	no	no	continuous
16053400	Upper Haiku Ditch near Puhi	Ditch	1963–71	6-SW	yes	yes	ditch
16053600	Lower Haiku Ditch near Puhi	Ditch	1963–71	6-SW	yes	yes	ditch
16053800	Kamooloa Stream near Puhi	SW	1963–70	5-SW	no	no	continuous
16054000	Kuia Stream near Puhi	SW	1939–41	--	no	no	continuous
16054200	Koloa Ditch near Koloa	Ditch	1964–71	6-SW	yes	yes	ditch
16054400	Koloa tunnel near Koloa	Ditch	1966–71	4-SW	yes	yes	ditch
16054500	Kuia Stream near Puhi	SW	1963–66	1-SW	yes	yes	continuous

Table 1. Surface-water gaging stations, island of Kauai, Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4]		Stream classification[5]
					Low flow	Peak flow	
16055000*	Huleia Stream near Lihue	SW SW-CSG SW SW-CSG	1912–15 1961–67 1967–70 1970–P	6-SW 36-CSG	yes	yes	continuous
16056000	Hanamaulu Stream at Kapaia near Lihue	SW	1911–13	1-SW	no	no	continuous
16056800	Waiahi-Kuia aqueduct near Puhi	Ditch	1964–71	6-SW	yes	yes	ditch
16057000	Lihue Ditch near Lihue	Ditch	1910–19	4-SW	yes	yes	ditch
16058000	Hanamaulu Ditch near Lihue	Ditch	1910–20	7-SW	yes	yes	ditch
16058500	South Fork Wailua River near rock quarry near Lihue	SW-LF	1974–83	10-LF	yes	yes	continuous
16060000*	South Fork Wailua River near Lihue	SW	1911–P	76-SW	yes	no	continuous
16061000	North Wailua Ditch near Lihue	Ditch	1932–85	53-SW	yes	yes	ditch
16061200*	North Wailua Ditch below Waikoko Stream near Lihue	Ditch	1965–P	28-SW	yes	yes	ditch
16062000*	Stable Storm Ditch near Lihue	Ditch	1939–P	56-SW	yes	yes	ditch
16063000	North Fork Wailua River at altitude 650 feet near Lihue	SW	1914–85	69-SW	yes	no	continuous
16064000	Kanaha Ditch near Lihue	Ditch	1910–55	36-SW	yes	yes	ditch
16068000*	East Branch of North Fork Wailua River near Lihue	SW	1912–P	78-SW	no	no	continuous
16068700	North Fork Wailua River near Lihue	SW	1910–14	2-SW	yes	no	continuous
16069000*	Wailua Ditch near Kapaa	Ditch	1936–P	56-SW	yes	yes	ditch
16070000	Aahoaka Ditch near Kapaa	Ditch	1966–72	5-SW	yes	yes	ditch
16071000*	North Fork Wailua River near Kapaa	SW	1952–P	41-SW	yes	no	continuous
16071500*	Left Branch Opaekaa Stream near Kapaa	SW	1960–P	33-SW	no	no	continuous
16071800*	Wailua River near Kapaa	SW-CSG-S	1962–P	32-CSG	yes	no	continuous
16072000	Konohiki Stream at Makakualele mauka weir near Kapaa	SW	1911–13	2-SW	no	no	continuous
16073000	Konohiki Stream at Makakualele makai weir near Kapaa	SW	1912	--	no	no	continuous
16073500*	Konohiki Stream near Kapaa	SW-CSG	1964–67 1970–P	28-CSG	no	no	continuous
16074000	North Fork Kaehulua Stream at Kainahola weir near Kapaa	SW	1911–13	2-SW	no	no	continuous
16075000	South Fork Kaehulua Stream at Wainamuamu weir near Kapaa	SW	1911–13	2-SW	no	no	continuous
16076000	Kaehulua Stream at Kuhinoa weir near Kapaa	SW	1911–13	2-SW	no	no	continuous
16077000*	Makaleha Ditch near Kealia	Ditch	1936–P	56-SW	yes	yes	ditch
16078000	Kapaa Stream near Kealia	SW	1910–20	6-SW	yes	no	continuous
16079000*	Kapahi Ditch near Kealia	Ditch	1909–P	75-SW	yes	yes	ditch
16079200	Tunnel Ditch at Kapahi near Kapaa	Ditch	1909–11	1-SW	yes	yes	ditch
16079400	Pipe Ditch at Kapahi near Kapaa	Ditch	1909–11	1-SW	yes	yes	ditch
16079600	Kapaa Ditch at Kapahi near Kapaa	Ditch	1909–11	1-SW	yes	yes	ditch
16080000*	Kapaa Stream at Kapahi Ditch intake near Kapaa	SW SW-CSG	1936–85 1986–P	49-SW 58-CSG	yes	no	continuous
16081000	Akulikuli Spring at weir near Kapaa	Spring	1911–13	2-SW	no	no	spring
16081200*	Akulikuli Stream near Kapaa	SW-CSG	1964–P	30-CSG	no	no	continuous
16082000	Kaneha Ditch near Kealia	Ditch	1909–13	3-SW	yes	yes	ditch

Table 1. Surface-water gaging stations, island of Kauai, Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16084500*	Kapaa Stream at old highway crossing near Kealia	SW-CSG	1962–P	32-CSG	yes	no	continuous
16085000*	Homaikawaa Stream near Kealia	SW-CSG	1964–P	30-CSG	no	no	ephemeral
16086000	Anahola Ditch above wasteway near Kealia	Ditch	1915–21	--	yes	yes	ditch
16087000	Anahola Ditch wasteway near Kealia	Ditch	1936–85	49-SW	yes	yes	ditch
16088000*	Anahola Ditch above Kaneha Reservoir near Kealia	Ditch	1921–P	69-SW	yes	yes	ditch
16089000	Anahola Stream near Kealia	SW	1910 1913–85	70-SW	yes	no	continuous
16090000	Lower Anahola Ditch at Kiokala near Kealia	Ditch	1909–14	--	yes	yes	ditch
16091000*	Lower Anahola Ditch near Kealia	Ditch	1936–P	55-SW	yes	yes	ditch
16092000	Lower Anahola Ditch at makai weir near Kealia	Ditch	1909–10	--	yes	yes	ditch
16093000	Anahola Stream at Kiokala Dam near Kealia	SW	1910–12	--	yes	no	continuous
16093200	Anahola Stream at Anahola	SW-CSG SW	1962–65 1965–82	17-SW 21-CSG	yes	no	continuous
16094200	Ka Loko Ditch near Kilauea	Ditch	1932–68	36-SW	yes	yes	ditch
16095000	Puu Ka Ele Ditch near Kilauea	Ditch	1932–67	34-SW	yes	yes	ditch
16095200	Ross Ditch near Kilauea	Ditch	1955–67	9-SW	yes	yes	ditch
16095900	Kalihiwai Ditch above wasteway near Kilauea	Ditch	1960–68	8-SW	yes	yes	ditch
16096000	Kalihiwai Ditch near Kilauea	Ditch	1934–67	32-SW	yes	yes	ditch
16097000	Pohakuhonu Stream near Kilauea	SW	1957–72	14-SW	yes	no	continuous
16097300	Halaulani Stream near Kilauea	SW	1922–25	3-SW	no	no	continuous
16097500*	Halaulani Stream at altitude 400 feet near Kilauea	SW	1957–P	35-SW	no	no	continuous
16097900*	Puukumu Stream near Kilauea	SW-CSG	1964–68 1971–P	28-CSG	no	no	continuous
16098000	Kalihiwai River near Hanalei	SW	1914–23	7-SW	no	no	continuous
16099000	Kalihiwai River near Kilauea	SW	1912–13	1-SW	no	no	continuous
16099500	Hanalei Ditch near Kilauea	Ditch	1956–62	5-SW	yes	yes	ditch
16100000	Hanalei tunnel outlet near Lihue	Ditch	1932–85	53-SW	yes	yes	ditch
16101000	Hanalei River at altitude 625 feet near Hanalei	SW	1914–55	39-SW	yes	no	continuous
16102000	China Ditch near Hanalei	SW SW-LF	1911–19 1977–85	7-SW 9-LF	yes	yes	ditch
16103000*	Hanalei River near Hanalei	SW SW-CSG SW	1912–19 1962–63 1962–P	30-SW 31-CSG	yes	no	continuous
16104000	Kuna Ditch near Hanalei	Ditch	1912–14 1917–20	3-SW	yes	yes	ditch
16104200*	Hanalei River at highway 56 bridge near Hanalei	SW-CSG-S	1963–P	31-CSG	yes	no	continuous
16105000	Waioli Stream near Hanalei	SW	1914–32	15-SW	no	no	continuous
16106000	Lumahai River near Hanalei	SW	1914–33	16-SW	no	no	continuous
16108000*	Wainiha River near Hanalei	SW	1952–P	38-SW	no	no	continuous
16109000	Wainiha River above intake near Hanalei	SW	1914–16	--	no	no	continuous
16110000	Wainiha Canal at intake near Wainiha	Ditch	1910–16	5-SW	yes	yes	ditch

Table 1. Surface-water gaging stations, island of Kauai, Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16111000	Wainiha Canal at tunnel 18 near Wainiha	Ditch	1911	--	yes	yes	ditch
16113000	Wainiha River near Wainiha	SW	1912–16	3-SW	no	no	continuous
16115000	Hanakapiai Stream near Hanalei	SW	1931–52	20-SW	no	no	continuous
16116000	Hanakoa Stream near Hanalei	SW	1931–52	20-SW	no	no	continuous
16117000	Kalalau Stream near Hanalei	SW	1931–55	23-SW	no	no	continuous
16130000*	Nahomalu Valley near Mana	SW-CSG	1962–63	8-SW	no	no	ephemeral
		SW	1964–71	32-CSG			
		SW-CSG	1972–P				

1 *In operation 1994 water year

2 SW Continuous-record surface-water station
SW-CSG Crest-stage gage
SW-CSG-S Crest-stage gage, stage only
SW-LF Low-flow partial-record station
Ditch Station operated on ditch system
Spring Station that measures discharge from spring

3 Years of record as of the end of 1993 water year:
Number-SW is number of water years of complete continuous record
Number-CSG is number of annual peaks
Number-LF is number of years operated as a low-flow partial-record station

4 Regulated flow is when daily flow and annual peak flows are affected by more than 10 percent

5 Stream classification:

Continuous-flow or perennial streams include those considered continuous or interrupted in the Hawaii stream assessment (Hawaii Department of Land and Natural Resources, 1990). Continuous-flow streams flow to the sea year-round. Interrupted-flow streams flow year-round in the upper parts and intermittently at lower elevations.

Ephemeral flow or intermittent streams are those that do not meet the above criteria and flow only in direct response to precipitation

Ditches and springs are not classified by flow

Table 2. Surface-water gaging stations, island of Oahu, Hawaii, through 1994

[P, in operation 1994 water year; makai, oceanside; mauka, mountainside; -- less than 1 complete year of record]

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16200000*	North Fork Kaukonahua Stream above right branch near Wahiawa	SW	1913–53	70-SW	no	no	continuous
			1960–P				
16201000	Right Branch of North Fork Kaukonahua Stream near Wahiawa	SW	1913–53	34-SW	no	no	continuous
		SW-LF	1960–62	20-LF			
			1966				
			1968–83				
16203000	Mauka Ditch near Wahiawa	Ditch	1947–68	21-SW	yes	yes	ditch
16204000	North Fork Kaukonahua Stream near Wahiawa	SW	1946–68	22-SW	yes	yes	continuous
16206000	South Fork Kaukonahua Stream near Wahiawa	SW	1913–14	16-SW	no	no	continuous
			1915–16				
			1944–50				
16206500	Koolau Ditch at reservoir near Wahiawa	Ditch	1914–15	--	yes	yes	ditch
16207000	South Fork Kaukonahua Stream below U.S. Army reservoir near Wahiawa	SW	1914–17	2-SW	yes	no	continuous
16208000*	South Fork Kaukonahua Stream at east pump reservoir near Wahiawa	SW	1957–63	36-SW	yes	no	continuous
		SW-CSG	1963–64	38-CSG			
		SW	1964–P				
16208500	Right Branch of South Fork Kaukonahua Stream near Wahiawa	SW	1957–72	15-SW	yes	no	ephemeral
16209000	South Fork Kaukonahua Stream above Wahiawa reservoir near Wahiawa	SW	1946–58	11-SW	yes	no	continuous
16210500*	Kaukonahua Stream at Waialua	SW-CSG	1963	27-CSG	yes	no	continuous
			1967–P				
16210900	Poamoho Tunnel near Wahiawa	Ditch	1958–79	21-SW	yes	yes	ditch
16211000	Poamoho Stream near Wahiawa	SW	1947–73	26-SW	yes	no	ephemeral
16211200*	Poamoho Stream at Wailua	SW-CSG	1967–P	27-CSG	yes	no	continuous
16211300*	Makaleha Stream near Wailua	SW-CSG	1958–63	36-CSG	no	no	continuous
		SW	1964–65				
		SW-CSG	1966–P				
16211400*	Manini Gulch at Kaena	SW-CSG	1973–P	20-CSG	no	no	ephemeral
16211500*	Makua Stream at Makua	SW-CSG	1957–P	37-CSG	no	no	continuous
16211600*	Makaha Stream near Makaha	SW	1959–P	34-SW	no	no	continuous
16211700*	Makaha Stream at Makaha	SW-CSG	1966–P	28-CSG	yes	no	continuous
16211800*	Kaupuni Stream at altitude 374 feet near Waianae	SW	1960–72	12-SW	yes	no	continuous
		SW-CSG	1973–P	33-CSG			
16211850	Puea Mauka Ditch near Waianae	Ditch	1960–67	6-SW	yes	yes	ditch
16211900	Kaupuni Stream near Waianae	SW	1957–60	--	yes	no	continuous
16212000	Puhawai Stream at Lualualei near Waianae	SW	1930–44	12-SW	yes	no	ephemeral
16212200*	Mailiilii Stream near Waianae	SW-CSG	1958–P	35-CSG	no	no	continuous
16212250	Ulehawa Stream at Nanakuli	SW-CSG	1967–69	2-CSG	no	no	continuous
16212300*	Nanakuli Stream at Nanakuli	SW-CSG	1968–P	25-CSG	no	no	continuous
16212400	Awanui Gulch near Barbers Point Naval Air Station	SW-CSG	1957–58	1-CSG	no	no	ephemeral
16212401	Awanui Stream at Gilbert near Barbers Point	SW-CSG	1958–64	6-CSG	no	no	ephemeral
16212450*	Kaloi Gulch tributary near Honouliuli	SW-CSG	1968–P	25-CSG	yes	no	ephemeral
16212500*	Honouliuli Stream near Waipahu	SW-CSG	1955–P	38-CSG	yes	no	continuous
16212600	Waikele Stream at Schofield Barracks	SW-CSG	1957–58	1-CSG	yes	no	continuous
16212601*	Waikele Stream at Wheeler Field	SW-CSG	1957–58	36-CSG	yes	no	continuous
			1959–P				

Table 2. Surface-water gaging stations, island of Oahu, Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16212700*	Waikakalaua Stream near Wahiawa	SW-CSG	1957–P	36-CSG	yes	no	continuous
16212750*	Huliwai Gulch near Kunia Camp	SW-CSG	1973–P	21-CSG	no	no	ephemeral
16212800*	Kipapa Stream near Wahiawa	SW	1957–P	36-SW	no	no	ephemeral
16212900	Kipapa Stream near Waipahu	SW	1966–68	1-SW	yes	no	ephemeral
16213000*	Waikele Stream at Waipahu	SW	1951–59	40-SW	yes	no	continuous
			1960–P				
16214000	Pearl Harbor Springs at Waiawa	Spring	1931–34	30-SW	yes	yes	spring
			1937–64	20-LF			
			1967–68				
			1970–88				
16215000	Morikone pond outlet at Pearl City	Spring	1951–60	8-SW	yes	no	spring
16216000*	Waiawa Stream near Pearl City	SW	1952–P	41-SW	yes	no	continuous
16216500	Waimano flood channel at Pearl City	SW-CSG	1954–69	15-CSG	yes	no	ephemeral
16217000	Pearl Harbor Springs at Puukapu near Pearl City	Spring	1931–35	15-SW	yes	yes	spring
			1936–48				
16218000	Pearl Harbor Springs at Loko Kukona	Spring	1931–35	13-SW	yes	yes	spring
			1936–45				
16218500	Pearl Harbor Springs at Kaluaoopu near Pearl City	Spring	1931–37	5-SW	yes	yes	spring
16219000	Hawaiian Electric Company tunnel at Waiau near Pearl City	Ditch	1939–42	16-SW	yes	yes	ditch
			1942–45				
			1952–66				
16220000	Hawaiian Electric Company wasteway at Waiau near Pearl City	Ditch	1953–59	--	yes	yes	ditch
16222000	Pearl Harbor Springs at Waiau	Spring	1913–39	9-SW	yes	yes	spring
			1942–47				
16223000*	Waimalu Stream near Aiea	SW	1952–62	16-SW	yes	no	continuous
			1963–70	37-CSG			
		SW-CSG	1973–P				
16224000	Pearl Harbor Springs at Kalauao	Spring	1931–62	32-SW	yes	yes	spring
			1964–65	21-LF			
			1966–68				
			1970–88				
16224500*	Kalauao Stream at Moanalua Road at Aiea	SW	1957–82	25-SW	yes	no	continuous
		SW-CSG	1984–P	35-CSG			
16225000	Kalauao Stream at Aiea	SW	1953–57	3-SW	yes	no	continuous
16225800*	North Halawa Stream near Kaneohe	SW	1991–P	3-SW	no	no	continuous
16226000*	North Halawa Stream near Aiea	SW	1929–33	43-SW	no	no	continuous
			1953–P				
16226200*	North Halawa Stream near Honolulu	SW	1983–P	10-SW	no	no	continuous
16227000	Halawa Stream at Aiea	SW-CSG	1954–62	20-CSG	no	no	continuous
			1966–72				
			1977–79				
16227100*	Halawa Stream below H1	SW-LF	1989–P	5-LF	no	no	continuous
16227500	Moanalua Stream near Kaneohe	SW	1968–78	9-SW	no	no	continuous
16227700	Moanalua Stream tributary near Kaneohe	SW	1968–78	9-SW	no	no	continuous
16227900	Moanalua Stream tributary near Aiea	SW-LF	1972–78	7-LF	no	no	ephemeral

Table 2. Surface-water gaging stations, island of Oahu, Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4]		Stream classification[5]
					Low flow	Peak flow	
16228000*	Moanalua Stream near Honolulu	SW SW-CSG	1926–78 1979–P	52-SW 67-CSG	no	no	continuous
16228200*	Moanalua Stream near Aiea	SW-CSG	1969–P	25-CSG	no	no	continuous
16228500	Moanalua Stream at altitude 100 feet near Honolulu	SW-CSG	1957–70	11-CSG	no	no	continuous
16228600*	Moanalua Stream near Tripler Hospital	SW-CSG	1970–P	23-CSG	no	no	continuous
16228900*	Kalihi Stream near Kaneohe	SW SW-CSG	1966–71 1972–P	5-SW 27-CSG	no	no	continuous
16229000*	Kalihi Stream near Honolulu	SW	1913–14 1914–P	78-SW	no	no	continuous
16229300*	Kalihi Stream at Kalihi	SW	1962–P	31-SW	no	no	continuous
16230000	Lulumahu Ditch at upper Nuuanu Reservoir near Honolulu	Ditch	1911–13	2-SW	yes	yes	ditch
16231000	Luakaha weir in upper Nuuanu Valley near Honolulu	Ditch	1910–13	3-SW	yes	yes	ditch
16231500	Moole Ditch mauka station near Honolulu	Ditch	1917–20	2-SW	yes	yes	ditch
16231700	Moole Ditch makai station near Honolulu	Ditch	1918–23	3-SW	yes	yes	ditch
16232000*	Nuuanu Stream below reservoir 2 wasteway near Honolulu	SW	1913–21 1921–P	77-SW	yes	yes	continuous
16235000	Nuuanu Stream at Kuakini Street near Honolulu	SW	1911–12	--	yes	yes	continuous
16235100	Nuuanu Stream above Waolani Street at Honolulu	SW-LF	1960–62	3-LF	yes	yes	continuous
16235400*	Waolani Stream at Honolulu	SW-CSG	1957–P	36-CSG	yes	no	continuous
16235600	Waolani Stream at mouth at Honolulu	SW-LF	1960–62	3-LF	yes	no	continuous
16236000	Kahuawai Spring near Honolulu	Spring	1912–14	2-SW	yes	yes	spring
16237000	Pauoa Stream at upper Pauoa Valley near Honolulu	SW	1911–13	2-SW	yes	no	continuous
16237500*	Pauoa Stream at Honolulu	SW-CSG	1957–P	36-CSG	no	no	continuous
16238500	Waihi Stream at Honolulu	SW	1913–21 1925–83	65-SW	yes	no	continuous
16239500	East Manoa Ditch near Honolulu	Ditch	1915–16 1918–20 1926–39	16-SW	yes	yes	ditch
16240500*	Waiakeakua Stream at Honolulu	SW	1913–21 1925–P	75-SW	yes	no	continuous
16241000	Manoa Stream at upper Manoa Valley near Honolulu	SW	1910–13	1-SW	yes	no	continuous
16242000	Manoa Stream at College of Hawaii near Honolulu	SW	1909–10 1912–18	5-SW	yes	no	continuous
16243000	Manoa Stream at Waialae Road near Honolulu	SW	1910–12	--	yes	no	continuous
16244000	Pukele Stream near Honolulu	SW	1926–82	56-SW	no	no	continuous
16245000	Waiomao Stream at upper Palolo Valley near Honolulu	SW	1911–13	--	no	no	ephemeral
16246000	Waiomao Stream near Honolulu	SW	1911 1912 1926–71	45-SW	yes	no	ephemeral
16247000	Palolo Stream near Honolulu	SW	1952–79	27-SW	yes	no	continuous
16247100*	Manoa-Palolo drainage canal at Moiliili	SW-CSG	1967–P	26-CSG	yes	no	continuous
16247200	Waialaenui Gulch at Honolulu	SW-CSG	1957–68	11-CSG	no	no	continuous
16247500*	Wailupe Gulch at Aina Haina	SW-CSG	1957–P	36-CSG	no	no	continuous
16247900*	Kuliouou Valley at Kuliouou	SW-CSG	1957–59 1970–P	26-CSG	no	no	continuous

Table 2. Surface-water gaging stations, island of Oahu, Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16248800*	Inoaole Stream at Waimanalo	SW-CSG	1957–P	36-CSG	no	no	ephemeral
16248900	Waimanalo Ditch below main reservoir near Waimanalo (Maunawili Ditch)	Ditch	1912–13	--	yes	yes	ditch
16249000*	Waimanalo Stream at Waimanalo	SW	1967–70	3-SW	yes	no	continuous
		SW-CSG	1971–P	26-CSG			
16249100*	Kaelepulu Stream tributary at Kailua	SW-CSG	1963–P	21-CSG	no	no	ephemeral
16249200	Maunawili Stream near Waimanalo	SW	1912–16	2-SW	yes	no	continuous
16249400	Main Spring near Kailua	Spring	1914–16	2-SW	yes	yes	spring
16249500*	Maunawili Ditch at Aniani Spring near Kailua	Ditch	1992–P	2-SW	yes	yes	ditch
16249600	Makawao Spring near Kailua	Spring	1914–16	2-SW	yes	yes	spring
16249800	Makawao Ditch near Kailua	Ditch	1912–15	1-SW	yes	yes	ditch
16249900*	Maunawili Ditch above Aniani Nui Tunnel near Kailua	Ditch	1992–P	2-SW	yes	yes	ditch
16250000	Maunawili Ditch near Waimanalo	Ditch	1954–68	14-SW	yes	yes	ditch
16254000*	Makawao Stream near Kailua	SW	1912–16 1958–P	37-SW	yes	no	continuous
16256000	Kamakalepo Stream near Kailua	SW	1912 1913–16	2-SW	yes	no	continuous
16257000	Pohakea Stream near Kailua	SW	1912–14	--	no	no	continuous
16258000	Maunawili Stream above Wong Leongs Ditch near Kailua	SW	1922–23	--	yes	no	continuous
16260000	Maunawili Stream near Kailua	SW	1912 1913–16	--	yes	no	continuous
16260500*	Maunawili Stream at highway 61 near Kailua	SW-LF	1922 1956–62 1965–67	11-LF 6-SW 36-CSG	yes	no	continuous
		SW-CSG	1958–67				
		SW	1967–71				
		SW-CSG	1972–91				
		SW	1992–P				
16261000	North Branch Kahanaiki Stream near Kailua	SW	1913–14	--	yes	no	continuous
16262000	South Branch Kahanaiki Stream near Kailua	SW	1913–14	1-SW	no	no	continuous
16263000	Kahanaiki Stream near Kailua	SW	1912 1914–16	1-SW	yes	no	continuous
16264100	Kahanaiki Stream at highway 61 near Kailua	SW-LF	1960–63 1965–66 1971–81 1983–85	20-LF	yes	no	continuous
16264400	Kawainui Swamp drainage canal at Kailua Road at Kailua	Ditch	1961–65	4-CSG	yes	yes	ditch
16264500	Kawainui Swamp canal at Wanaao Road at Kailua	Ditch	1961–64	3-CSG	yes	yes	ditch
16264800*	Kawainui Canal at Kailua	SW-CSG-S	1956–60 1963–64 1967–P	33-CSG	yes	yes	ditch
16265000*	Kawa Stream at Kaneohe	SW	1914–16	1-SW	yes	no	continuous
		SW-CSG	1965 1968–74 1977–P	25-CSG			
16265500	Left tributary to Right Branch of Kamooalii Stream near Kaneohe	SW-LF	1983	1-LF	no	no	ephemeral
16265600*	Right Branch Kamooalii Stream near Kaneohe	SW	1983–P	10-SW	no	no	continuous

Table 2. Surface-water gaging stations, island of Oahu, Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16265700*	Kamooalii Stream at altitude 220 feet near Kaneohe	SW-LF	1983–85 1987 1988–P	10-LF	no	no	continuous
16266000	Kamooalii Stream near Kaneohe	SW	1914–16	1-SW	no	no	continuous
16266500*	Hooleinaiwa Stream at altitude 220 feet near Kaneohe	SW-LF	1983–85 1988–P	9-LF	no	no	continuous
16267000	Hooleinaiwa Stream near Kaneohe	SW	1914–16	--	no	no	continuous
16267500*	Hooleinaiwa Stream above confluence with Kamooalii Stream near Kaneohe	SW-LF	1983–85 1987 1988–P	10-LF	no	no	continuous
16268000	Piho Stream near Kaneohe	SW	1914–16	--	no	no	continuous
16269000	Kuou Ditch near Kaneohe	Ditch	1914–16	--	yes	yes	ditch
16269500*	Kuou Stream at altitude 220 feet near Kaneohe	SW-LF	1983–85 1988–P	9-LF	no	no	continuous
16270000	Kuou Stream near Kaneohe	SW	1914–16	--	no	no	continuous
16270500	Kamooalii Stream below Kuou Stream near Kaneohe	SW SW-LF SW	1967–70 1971 1972–76	9-SW 1-LF	no	no	continuous
16270900*	Luluku Stream at altitude 220 feet near Kaneohe	SW-LF SW SW-CSG SW	1960–63 1965–71 1971–84 1984–P	3-LF 26-CSG 13-SW	yes	no	continuous
16271000	North Luluku Ditch near Kaneohe	Ditch	1914–16	1-SW	yes	yes	ditch
16272000	Luluku Stream near Kaneohe	SW	1914–16	--	yes	no	continuous
16272200*	Kamooalii Stream below Luluku Stream near Kanoehe	SW	1976–P	16-SW	yes	yes	continuous
16273000	Young Mau Ditch near Kaneohe	Ditch	1914–16	1-SW	yes	yes	ditch
16273900	Kamooalii Stream at Kaneohe	SW	1959–63 1965–80	17-SW	yes	yes	continuous
16273950*	South Fork Kapunahala Stream at Kaneohe	SW	1987–P	6-SW	no	no	continuous
16274000	Ahlo Ditch near Kaneohe	Ditch	1914–16	1-SW	yes	yes	ditch
16274100*	Kaneohe Stream below Kamehameha highway	SW-LF	1989–P	5-LF	yes	yes	continuous
16274499*	Keaahala Stream at Kamehameha highway at Kaneohe	SW-CSG SW-LF	1958–P 1961–63 1965–66 1971–74	36-CSG 9-LF	no	no	continuous
16274500	Keaahala Stream at Kaneohe	SW-LF	1958–59	2-LF	no	no	continuous
16275000*	Haiku Stream near Heeia	SW	1914–19 1939–77 1982–P	56-SW	yes since 1944	no	continuous
16276000	Reservoir Ditch near Heeia	Ditch	1914–16	1-SW	yes	yes	ditch
16277000	Waipio Ditch near Heeia	Ditch	1914–16	1-SW	yes	yes	ditch
16278000	Iolekaa Stream mauka near Heeia	SW	1940–70	31-SW	yes since 7/1966	no	continuous
16279000	Iolekaa Stream near Heeia	SW	1914–16	1-SW	no	no	continuous
16279500*	Heeia Stream at Kaneohe	SW-CSG	1965–66 1968–P	28-CSG	no	no	continuous

Table 2. Surface-water gaging stations, island of Oahu, Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16280000	Wing Wo Tai Ditch near Heeia	Ditch	1914–16	1-SW	yes	yes	ditch
16281000	Hop Tuck Ditch near Heeia	Ditch	1914–16	1-SW	yes	yes	ditch
16282000	Lee Ditch near Heeia	Ditch	1914–16	1-SW	yes	yes	ditch
16283000	Kahaluu Stream near Heeia	SW	1935–71	36-SW	yes since 1947	no	continuous
16283100	Kahaluu Stream tributary	SW-LF	1948 1953–62	11-LF	yes	no	continuous
16283200*	Kahaluu Stream near Ahuimanu	SW	1983–P	11-SW	yes	no	continuous
16283400	Kahaluu Stream near Kahaluu	SW-CSG SW-LF	1962–81 1962–63 1966 1972–81	20-CSG 13-LF	yes	no	continuous
16283480*	Ahuimanu Stream near Kahaluu	SW-CSG SW-LF	1962–P 1962–63 1965–66 1968 1972–75	30-CSG 9-LF	no	no	continuous
16283500	Kahaluu Stream at Kahaluu	SW-CSG SW	1959–62 1964–65 1967–70	6-CSG 2-SW	yes	no	continuous
16283600*	South Fork Waihee Stream near Heeia	SW	1962–P	21-SW	yes	no	continuous
16283700*	North Fork Waihee Stream near Heeia	SW	1962–P	21-SW	yes	no	continuous
16283800	Waihee Stream at altitude 260 feet near Heeia	SW	1961–66	4-SW	yes	no	continuous
16284000	Waihee Stream near Heeia	SW	1935–82	46-SW	yes	no	continuous
16284200*	Waihee Stream near Kahaluu	SW	1974–P	19-SW	yes	no	continuous
16284500	Waihee Stream at Kahaluu	SW-LF SW SW-CSG	1958 1960–63 1965–66 1966–71 1972–75	7-LF 5-SW 9-CSG	yes	no	continuous
16285000	Waiahole tunnel at Waianu near Waiahole	Ditch	1950–69	18-SW	yes	yes	ditch
16286000	Waiahole tunnel wasteway at intake 31 near Waiahole	Ditch	1951–69	17-SW	yes	yes	ditch
16287000	Waiahole tunnel at north portal near Waiahole	Ditch	1951–69	17-SW	yes	yes	ditch
16287200	Waiahole tunnel at adit 8 near Waipahu	Ditch	1956–69	12-SW	yes	yes	ditch
16288000	Halona Stream near Waikane	SW	1911	--	no	no	continuous
16289000	Waihi Stream near Waikane	SW	1911	--	no	no	continuous
16290000	Waiahole Stream below powerhouse near Waiahole	SW	1915	--	yes	yes	continuous
16291000	Waiahole Stream at altitude 250 feet near Waiahole	SW SW-LF	1955–68 1970–72	13-SW 3-LF	yes	yes	continuous
16292000	Waiahole Stream near Waiahole	SW	1911–16	4-SW	yes	yes	continuous
16293000	Waianu Stream near Waikane	SW	1911	--	yes	no	continuous
16293100	Waianu Stream at Waiahole	SW-LF	1959–62 1965–66	6-LF	yes	no	continuous
16294000	Waiahole Stream at Waiahole near Waikane	SW	1911–12	--	yes	yes	continuous
16294900*	Waikane Stream at altitude 75 feet at Waikane	SW	1959–P	33-SW	yes	no	continuous

Table 2. Surface-water gaging stations, island of Oahu, Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16295000	Waikane Stream near Waikane	SW	1912	--	yes	no	continuous
16295200	Waikane Stream at Waikane	SW-CSG	1957–60	3-CSG	yes	no	continuous
16295900	Makaua Stream at Kaaawa	SW-CSG	1957–62	5-CSG	no	no	continuous
16295995	Kahana Stream at mauka trail crossing near Kahana	SW-LF	1960–62 1966 1971–72 1974–81 1983–85	17-LF	yes	no	continuous
16296000	Kahana Stream near Kahana	SW	1914–17	2-SW	no	no	continuous
16296500*	Kahana Stream at altitude 30 feet near Kahana	SW	1958–P	34-SW	yes	no	continuous
16297000	Kawa Stream near Kahana	SW SW-LF	1914–17 1958 1961–62 1966 1971–72 1974–81 1983–85	2-SW 17-LF	no	no	continuous
16299000	Punaluu Stream at altitude 539 feet near Punaluu	SW	1915–18	2-SW	no	no	continuous
16300000	Waihoi Stream near Punaluu	SW	1915–17	1-SW	no	no	continuous
16301000	Punaluu Stream at altitude 250 feet near Punaluu	SW	1914–18	3-SW	no	no	continuous
16302000*	Punaluu Ditch near Punaluu	Ditch	1953–P	40-SW	yes	yes	ditch
16303000*	Punaluu Stream near Punaluu	SW	1953–P	40-SW	yes	no	continuous
16304000	Kaluanui Stream near Hauula	SW	1915–17	1-SW	no	no	continuous
16304200*	Kaluanui Stream near Punaluu	SW	1967–P	26-SW	no	no	continuous
16304500*	Kaluanui Stream at Hauula	SW-CSG	1957–P	36-CSG	no	no	continuous
16305000	Kaipapau Stream near Hauula	SW	1906–07	--	no	no	continuous
16306000	Koloa Gulch near Laie	SW	1914–18	3-SW	no	no	continuous
16307000	Wailele Gulch near Laie	SW	1914–15 1916–18	1-SW	no	no	continuous
16308000	East Branch Kahawainui Stream near Laie	SW	1914–18	2-SW	no	no	continuous
16308990	Malaekahana Stream near Laie	SW	1963–71	8-SW	no	no	ephemeral
16309000	Malaekahana Stream near Kahuku	SW	1914–18	3-SW	no	no	ephemeral
16310000	Middle Branch Malaekahana Stream near Kahuku	SW	1914–18	3-SW	no	no	ephemeral
16310500	Malaekahana Stream at altitude 70 feet near Kahuku	SW-CSG	1957–58	1-CSG	no	no	ephemeral
16310501*	Malaekahana Stream at altitude 30 feet near Kahuku	SW-CSG	1957–P	36-CSG	no	no	ephemeral
16311000*	Oio Stream near Kahuku	SW-CSG	1957–P	36-CSG	no	no	continuous
16317800*	Kaunala Gulch near Sunset Beach	SW-CSG	1973–P	21-CSG	no	no	ephemeral
16318000*	Paumalu Gulch at Sunset Beach	SW-CSG	1967–P	26-CSG	no	no	continuous
16325000*	Kamananui Stream at Pupukea military road near Maunawai	SW-LF SW	1960–61 1963 1963–P	3-LF 30-SW	no	no	ephemeral
16329000	Kaiwikoele Stream tributary near Maunawai	SW	1967–71	4-SW	no	no	ephemeral
16330000*	Kamananui Stream at Maunawai	SW	1958–P	35-SW	yes	no	ephemeral
16331000*	Waimea Gulch near Kawailoa Camp	SW-CSG	1967–P	26-CSG	no	no	ephemeral

Table 2. Surface-water gaging stations, island of Oahu, Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16335000	Kawainui Stream above Kamananui Ditch near Wahiawa	SW-LF	1960–61	2-LF	no	no	ephemeral
16340000*	Anahulu River near Haleiwa	SW-CSG	1957–P	36-CSG	yes	no	continuous
16340500	Anahulu River tributary near Haleiwa	SW	1967–71	--	yes	no	ephemeral
16343000	Helemano Stream at Haleiwa	SW	1967–82	14-SW	yes	no	continuous
16345000*	Opaeula Stream near Wahiawa	SW	1959–P	34-SW	no	no	continuous
16350000*	Opaeula Stream near Haleiwa	SW-CSG	1955–P	38-CSG	yes	no	continuous

1 *In operation 1994 water year

2 SW — Continuous-record surface-water station
SW-CSG — Crest-stage gage
SW-CSG-S — Crest-stage gage, stage only
SW-LF — Low-flow partial-record station
Ditch — Station operated on ditch system
Spring — Station that measures discharge from spring

3 Years of record as of the end of 1993 water year:
Number-SW is number of water years of complete continuous record
Number-CSG is number of annual peaks
Number-LF is number of years operated as a low-flow partial-record station

4 Regulated flow is when daily flow and annual peak flows are affected by more than 10 percent

5 Stream classification:

Continuous-flow or perennial streams include those considered continuous or interrupted in the Hawaii stream assessment (Hawaii Department of Land and Natural Resources, 1990). Continuous-flow streams flow to the sea year-round. Interrupted-flow streams flow year-round in the upper parts and intermittently at lower elevations.

Ephemeral flow or intermittent streams are those that do not meet the above criteria and flow only in direct response to precipitation

Ditches and springs are not classified by flow

Table 3. Surface-water gaging stations on the island of Molokai, Hawaii, through 1994
[P, in operation 1994 water year]

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16400000*	Halawa Stream near Halawa	SW	1917–32 1937–P	69-SW	no	no	continuous
16401000	Papalaua Stream near Pukoo	SW	1919–29	8-SW	no	no	continuous
16402000	Pulena Stream near Wailau	SW	1919–28 1937–57	27-SW	no	no	continuous
16403000	Waiakeakua Stream near Wailau	SW	1919–29 1937–57	28-SW	no	no	continuous
16403400*	Kapuhi Stream at altitude 1,000 feet near Pelekunu	SW-LF	1968–P	26-LF	no	no	continuous
16403500*	Kawailena Stream near Pelekunu	SW-LF	1968–P	26-LF	no	no	continuous
16403600*	Kapuhi Stream near Pelekunu	SW SW-LF	1968–70 1974–P	2-SW 20-LF	no	no	continuous
16403700*	Kawainui Stream at altitude 1,000 feet near Pelekunu	SW-LF	1968–P	26-LF	no	no	continuous
16403800*	Kawaipoko Stream near Pelekunu	SW-LF	1968–P	26-LF	no	no	continuous
16403900*	Kawainui Stream near Pelekunu	SW SW-LF	1968–79 1980–P	11-SW 13-LF	no	no	continuous
16404000	Pelekunu Stream near Pelekunu	SW SW-CSG SW	1919–29 1937–47 1948–57 1968–71 1971–82	36-SW 40-CSG	no	no	continuous
16404200*	Pilipililau Stream near Pelekunu	SW	1968–P	25-SW	no	no	continuous
16405000	Lanipuni Stream near Pelekunu	SW	1919–29 1937–57	27-SW	no	no	continuous
16405100*	Molokai Tunnel at east portal	Ditch	1966–P	27-SW	yes	yes	ditch
16405300*	Molokai Tunnel at west portal	Ditch	1965–P	28-SW	yes	yes	ditch
16405500*	Waikolu Stream at altitude 900 feet near Kalaupapa	SW	1956–61 1962–P	32-SW	yes after 11/1960	no	continuous
16406000	Waikolu Stream at altitude 650 feet near Kalaupapa	SW	1920–23	2-SW	no	no	continuous
16408000*	Waikolu Stream below pipeline crossing near Kalaupapa	SW	1919–30 1931–32 1937–P	68-SW	yes after 11/1960	no	continuous
16409000	Waihanau Stream near Kalaupapa	SW	1930–32	1-SW	no	no	continuous
16410000	Keolewa Stream near Kalae	SW	1940–44	3-SW	no	no	ephemeral
16411000	Waialala Spring near Kalae	Spring	1940–60	18-SW	yes	yes	spring
16411300	Kakaako Gulch at Highway 46 near Mauna Loa	SW-CSG	1964–85	20-CSG	no	no	ephemeral
16411320*	Kakaako Gulch above Kamakahi Gulch near Mauna Loa	SW–CSG	1964–P	30-CSG	no	no	ephemeral
16411400*	Kakaako Gulch near Mauna Loa	SW SW-CSG	1963–72 1973–P	9-SW 30-CSG	no	no	ephemeral

Table 3. Surface-water gaging stations on the island of Molokai, Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16411600*	Kaunala Gulch near Mauna Loa	SW-CSG	1964–P	30-CSG	no	no	ephemeral
16411640*	Halena Gulch near Mauna Loa	SW-CSG	1965–P	29-CSG	no	no	ephemeral
16411800*	Kaluapeelua Gulch at Hoolehua	SW-CSG	1964–P	30-CSG	no	no	ephemeral
16411900	Kaluapeelua Gulch tributary near Molokai Airport	SW-CSG	1964–82	19-CSG	no	no	ephemeral
16412000	Mokomoko Gulch near Kalae	SW	1940–45	4-SW	yes	no	ephemeral
16413000	Kapuna Stream near Kalae	SW	1940–49	9-SW	no	no	ephemeral
16413500*	Manawainui Gulch near Kualapuu	SW-CSG	1965–P	29-CSG	no	no	ephemeral
16414000*	Kaunakakai Gulch near Kaunakakai	SW	1949–P	43-SW	yes after 5/1965	no	ephemeral
16414100	Kamiloloa Gulch at Kaunakakai	SW-CSG	1965–77	13-CSG	no	no	ephemeral
16415000	East Fork Kawela Gulch near Kamalo	SW	1946–71	25-SW	yes	no	ephemeral
16415400*	Wawaia Gulch at Kamalo	SW-CSG	1964–P	30-CSG	no	no	continuous
16416000	Punaula Gulch near Pukoo	SW	1947–72	25-SW	no	no	continuous
16419000*	Pohakupili Gulch near Halawa	SW-CSG	1964–P	30-CSG	no	no	continuous
16419500*	Papio Gulch at Halawa	SW	1963–P	30-SW	yes	no	continuous

1 *In operation 1994 water year

2 SW Continuous-record surface-water station
SW-CSG Crest-stage gage
SW-CSG-S Crest-stage gage, stage only
SW-LF Low-flow partial-record station
Ditch Station operated on ditch system
Spring Station that measures discharge from spring

3 Years of record as of the end of 1993 water year:
Number-SW is number of water years of complete continuous record
Number-CSG is number of annual peaks
Number-LF is number of years operated as a low-flow partial-record station

4 Regulated flow is when daily flow and annual peak flows are affected by more than 10 percent

5 Stream classification:

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Ephemeral flow or intermittent streams are those that do not meet the above criteria and flow only in direct response to precipitation

Ditches and springs are not classified by flow

Table 4. Surface-water gaging stations, island of Maui, Hawaii, through 1994

[P, in operation 1994 water year; -- less than 1 complete year of record]

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16500100*	Kepuni Gulch near Kahikinui House	SW SW-CSG	1963–72 1973–P	9-SW 30-CSG	no	no	ephemeral
16500300*	Hawelewele Gulch near Kaupo	SW-CSG	1966–P	28-CSG	no	no	ephemeral
16500800*	Kukuiula Gulch near Kipahulu	SW SW-CSG	1963–66 1967–68 1969–P	3-SW 28-CSG	no	no	ephemeral
16501000	Palikea Stream below diversion dam near Kipahulu	SW	1927–29 1931–35 1935–38 1939 1939–83	48-SW	no	no	continuous
16501200*	Oheo Gulch at Dam near Kipahulu	SW	1988–P	5-SW	no	no	continuous
16502000	Hahalawe Gulch near Kipahulu	SW SW-CSG SW-LF	1927–37 1938–69 1970–77 1970–77	37-SW 45-CSG 8-LF	no	no	continuous
16502400*	Pukuilua Gulch near Hana	SW-CSG	1963–P	31-CSG	no	no	ephemeral
16502800*	Moomoonui Gulch at Hana	SW-CSG	1963–P	31-CSG	no	no	continuous
16502900*	Kawaipapa Gulch at Hana	SW-CSG	1965–P	29-CSG	no	no	continuous
16503000	Kaeluku flume near Kaeleku	Ditch	1940–45	1-SW	yes	yes	ditch
16504000	Hana flume near Hana	Ditch	1940–45	1-SW	yes	yes	ditch
16506000	Makapipi Ditch near Nahiku	Ditch	1948–66	18-SW	yes	yes	ditch
16506500	West Makapipi Spring near Nahiku	Spring	1932–45	13-SW	no	no	spring
16507000	Makapipi Stream near Nahiku	SW	1932–45	13-SW	yes	no	continuous
16508000*	Hanawi Stream near Nahiku	SW	1914–16 1921–P	71-SW	no	no	continuous
16509000*	Hanawi Stream below government road near Nahiku	SW	1932–47 1992–P	16-SW	yes	no	continuous
16510000	Kapaula Gulch near Nahiku	SW	1921–63	40-SW	no	no	continuous
16511000	Kapaula Gulch below government road near Nahiku	SW	1932–47	15-SW	yes	no	continuous
16512000	Koolau Ditch at Nahiku weir near Nahiku	Ditch	1919–85	66-SW	yes	yes	ditch
16513000	Waiaaka Stream near Nahiku	SW	1932–47	15-SW	no	no	continuous
16514000	Paakea Gulch near Nahiku	SW	1932–47	15-SW	yes	no	continuous
16515000	Waiohue Gulch near Nahiku	SW	1921–63	40-SW	no	no	continuous
16516000	Kopiliula Stream near Keanae	SW	1914–17 1921–58	35-SW	no	no	continuous
16517000	East Wailuaiki Stream near Keanae	SW	1913–17 1922–58	37-SW	no	no	continuous
16518000*	West Wailuaiki Stream near Keanae	SW	1914–15 1916–17 1921–P	73-SW	no	no	continuous

Table 4. Surface-water gaging stations, island of Maui, Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16519000	West Wailuanui Stream near Keanae	SW	1913–17 1922–58	35-SW	no	no	continuous
16520000	East Wailuanui Stream near Keanae	SW	1914–17 1921–58	35-SW	no	no	continuous
16521000	Wailuanui Stream near Keanae	SW	1932–36 1938–47	11-SW	yes	no	continuous
16522000	Taro patch feeder ditch at Keanae	Ditch	1934–68	35-SW	yes	yes	ditch
16523000	Koolau Ditch near Keanae	Ditch	1910–12 1917–18 1918–85	69-SW	yes	yes	ditch
16524000	Honomanu Stream at Haiku-uka boundary near Kailiili	SW	1919–27 1932–34 1962–68	15-SW	yes after 9/1968	no	continuous
16525000	Seventh Branch Honomanu Stream at Haiku-uka near Kailiili	SW	1932–33	--	no	no	continuous
16526000	Fourth Branch Honomanu Stream at Haiku-uka near Kailiili	SW	1932–33	--	no	no	continuous
16527000	Honomanu Stream near Keanae	SW	1913–64	49-SW	no	no	continuous
16528000	Spreckels Ditch at station 1 near Huelo	Ditch	1910–13	2-SW	yes	yes	ditch
16529000	Spreckels Ditch at station 2 near Kuelo	Ditch	1911–13	2-SW	yes	yes	ditch
16530000	Spreckels Ditch at station 3 near Kuelo	Ditch	1910–13	2-SW	yes	yes	ditch
16531000	Kula diversion from Haipuaena Stream near Olinda	Ditch	1945–85	40-SW	yes	yes	ditch
16531100	Haipuaena Stream at Kula pipeline intake near Olinda	SW	1946–68	22-SW	yes	no	continuous
16532000	Haipuaena Stream at Haiku-uka boundary near Kailiili	SW SW-LF	1919–26 1932–34 1962–68	9-SW 7-LF	yes	no	continuous
16533000	Third Branch Haipuaena Stream at Haiku-uka near Kailiili	SW	1932–33	--	no	no	continuous
16534000	First Branch Haipuaena Stream at Haiku-uka near Kailiili	SW	1932–33	--	no	no	continuous
16535000	Haipuaena diversion ditch at Kolea Gulch near Keanae	Ditch	1938–60	22-SW	yes	yes	ditch
16536000	Haipuaena Stream above Spreckels Ditch near Huelo	SW	1913–67	54-SW	yes	no	continuous
16537000	Haipuaena Stream near Huelo	SW	1910–13	2-SW	yes	no	continuous
16538000	Spreckels Ditch at Haipuaena weir near Huelo	Ditch	1922–85	63-SW	yes	yes	ditch
16539000	Spreckels Ditch at station 4 near Huelo	Ditch	1910–13	2-SW	yes	yes	ditch
16541000	Koolau Ditch at Haipuaena near Huelo	Ditch	1932–87	55-SW	yes	yes	ditch
16541500	Manuel Luis Ditch at Puohokamoa Gulch near Huelo	Ditch	1917–24 1925–85	66-SW	yes	yes	ditch
16542000	East Branch Puohokamoa Stream at Haiku-uka boundary near Kailiili	SW SW-LF	1919–27 1932–33 1963–68	6-SW 6-LF	no	no	continuous
16543000	Middle Branch Puohokamoa Stream at Haiku-uka boundary near Kailiili	SW	1919–27 1932–34 1962–69	15-SW	yes	no	continuous

Table 4. Surface-water gaging stations, island of Maui, Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16544000	West Branch Puohokamoa Stream at Haiku-uka boundary near Kailiili	SW	1919–28 1932–34	11-SW	yes	no	continuous
16545000	Puohokamoa Stream above Spreckels Ditch near Huelo	SW	1913–71	58-SW	yes	no	continuous
16546000	Puohokamoa Stream near Huelo	SW	1910–13	1-SW	yes	no	continuous
16547000	Puohokamoa intake of Koolau Ditch near Huelo	Ditch	1922–30	6-SW	yes	yes	ditch
16551000	Koolau Ditch at Wahinepee near Huelo	Ditch	1922–29	7-SW	yes	yes	ditch
16552000	Spreckels Ditch at Wahinepee near Huelo	Ditch	1929–30 1931–38	8-SW	yes	yes	ditch
16552200	Spreckels Ditch at station 5 near Huelo	Ditch	1911–13	1-SW	yes	yes	ditch
16552500	Manuel Luis Ditch west of Puohokamoa Stream near Huelo	Ditch	1930–35	4-SW	yes	yes	ditch
16552600	Waikamoi Stream at Puuluau near Olinda	SW	1949–66	16-SW	no	no	ephemeral
16552800	Waikamoi Stream above reservoir at Kula pipeline intake near Olinda	SW	1953–68	15-SW	yes	no	continuous
16553000	Waikamoi Stream below reservoir at Kula pipeline intake near Olinda	SW	1945–49	--	yes	no	continuous
16554000	Waikamoi Stream at Haiku-uka boundary near Kailiili	SW	1918 1919–28 1932–34	10-SW	yes	no	continuous
16554500	East Branch Waikamoi Stream at Haiku-uka boundary near Kailiili	SW	1918–28 1932–33	10-SW	yes	no	continuous
16555000	Waikamoi Stream above Wailoa Ditch near Huelo	SW	1922–57	35-SW	yes	no	continuous
16556000	Waikamoi Stream near Huelo	SW	1910–22	10-SW	yes	no	continuous
16557000	Alo Stream near Huelo	SW	1910–57	46-SW	no	no	continuous
16558000	Koolau Ditch at Alo diversion weir near Huelo	Ditch	1908–11	3-SW	yes	yes	ditch
16560000	Spreckels Ditch at station 6 near Huelo	Ditch	1911–13	--	yes	yes	ditch
16561000	Center Ditch below Kolea reservoir near Huelo	Ditch	1918 1919 1920–24 1925–30	8-SW	yes	yes	ditch
16562000	Center Ditch near Huelo	Ditch	1910–12	2-SW	yes	yes	ditch
16565000	Kaaiea Gulch near Huelo	SW	1921–62	40-SW	no	no	continuous
16565500	Spreckels Ditch below Kaaiea Gulch near Huelo	Ditch	1917–30	11-SW	yes	yes	ditch
16566000	Oopuola Stream near Huelo	SW	1930–57	26-SW	no	no	continuous
16567000	Oopuola Stream above Spreckels Ditch crossing near Huelo	SW	1910–15	3-SW	yes	no	continuous
16567500	Spreckels Ditch at station 7 near Huelo	Ditch	1911–12	--	yes	yes	ditch
16568000	Spreckels Ditch at station 8 near Huelo	Ditch	1911–13	1-SW	yes	yes	ditch
16569000	Second Branch Nailiilihaele Stream at Haiku-uka	SW	1932–33	--	no	no	ephemeral
16569100	Nailiilihaele Stream near Kailiili	SW-LF	1963–68	6-LF	no	no	ephemeral
16569700	West Branch Nailiilihaele Stream near Kailiili	SW-LF	1966–68	3-LF	no	no	ephemeral

Table 4. Surface-water gaging stations, island of Maui, Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16570000	Nailiihaele Stream near Huelo	SW	1910–11 1913–18 1919–24 1925–75	58-SW	no since 1922	no	continuous
16571000	Nailiilihaele Stream below new Hamakua Ditch near Huelo	SW	1912	--	yes	no	continuous
16572000	New Hamakua Ditch at Nailiilihaele weir near Huelo	Ditch	1910–12	2-SW	yes	yes	ditch
16573000	New Hamakua Ditch at station 1 near Kailiili	Ditch	1912–13	--	yes	yes	ditch
16574000	Kailua Stream at Haiku-uka boundary near Kailiili	SW	1918–28 1932–34	11-SW	no	no	continuous
16574500	Kailua Stream near Kailiili	SW	1963–71	8-SW	yes	no	continuous
16575000	Tenth Branch Kailua Stream at Haiku-uka near Kailiili	SW	1932–33	--	no	no	ephemeral
16576000	Ninth Branch Kailua Stream at Haiku-uka near Kailiili	SW	1932–33	--	no	no	ephemeral
16576200	East Branch Kailua Stream near Kailiili	SW-LF	1963–68	6-LF	no	no	continuous
16577000	Kailua Stream near Huelo	SW	1910–11 1913–18 1919–58	39-SW	no	no	continuous
16578000	New Hamakua Ditch at station 2 near Huelo	Ditch	1912–13	--	yes	yes	ditch
16579000	New Hamakua Ditch at station 3 near Huelo	Ditch	1912–13	--	yes	yes	ditch
16579500	New Hamakua Ditch at station 4 near Huelo	Ditch	1912–13	--	yes	yes	ditch
16580000	Oanui Stream near Huelo	SW	1910–11 1913–16	2-SW	no	no	continuous
16582000	New Hamakua Ditch at station 5 near Huelo	Ditch	1912–13	--	yes	yes	ditch
16583000	Old Hamakua Ditch at Kailua near Huelo	Ditch	1919–22	2-SW	yes	yes	ditch
16584000	Kailua Stream near Huelo	SW	1912–13	--	yes	no	continuous
16585000	Hoolawanui Stream near Huelo	SW	1910–71	60-SW	no	no	continuous
16586000	Hoolawaliilii Stream near Huelo	SW	1911–57	45-SW	no	no	continuous
16587000*	Honopou Stream near Huelo	SW	1910–P	82-SW	no	no	continuous
16588000	Wailoa Ditch at Honopou near Huelo	Ditch	1922–87	64-SW	yes	yes	ditch
16589000	New Hamakua Ditch at Honopou near Huelo	Ditch	1918–85	67-SW	yes	yes	ditch
16590000	Old Hamakua Ditch at Honopou near Huelo	Ditch	1918–22 1936–65	32-SW	yes	yes	ditch
16591000	Honopou Stream at Lowrie Ditch siphon near Huelo	SW	1932–47	15-SW	yes	yes	continuous
16592000	Lowrie Ditch at Honopou Gulch near Huelo	Ditch	1910–27 1930–85	71-SW	yes	yes	ditch
16593000	Honopou Stream above Haiku Ditch near Huelo	SW	1932–47	15-SW	yes	yes	continuous
16594000	Haiku Ditch at Honopou Gulch near Kailua	Ditch	1910–28 1930–85	70-SW	yes	yes	ditch
16595000	Honopou Stream below Haiku Ditch near Huelo	SW	1932–47	15-SW	yes	yes	continuous
16596000	New Hamakua Ditch at Halehaku weir near Huelo	Ditch	1910–14 1915–23	11-SW	yes	yes	ditch

Table 4. Surface-water gaging stations, island of Maui, Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16596200	Halehaku Gulch near Kailiili	SW	1965–71	6-SW	no	no	continuous
16597000	Halehaku Gulch weir at New Hamakua Ditch near Huelo	Ditch	1910–12	2-SW	yes	yes	ditch
16598000	Halehaku Gulch near Huelo	SW	1910–12	--	yes	yes	continuous
16599000	East Branch Opana Gulch at Haiku-uka boundary near Kailiili	SW	1932–33	--	no	no	continuous
16599500*	Opana Tunnel near Kailiili	Ditch	1965–P	28-SW	yes	yes	ditch
16600000	Opana Ditch near Huelo	Ditch	1910–12	2-SW	yes	yes	ditch
16601000	Opana Stream near Huelo	SW	1910–12	--	no	no	continuous
16602000	Kauhikoa Ditch at Opana weir near Huelo	Ditch	1910–13 1913–15 1916–28	15-SW	yes	yes	ditch
16602400	Awalau Gulch near Kailiili	SW	1965–71	6-SW	yes	no	continuous
16603000	Kaluanui Ditch at Puuomalei near Hamakuapoko	Ditch	1910–12	2-SW	yes	yes	ditch
16603300*	Unnamed Gulch at Maliko Bay	SW-CSG	1963–P	31-CSG	no	no	ephemeral
16603700*	Kalialinui Gulch tributary near Pukalani	SW-CSG	1966–P	28-CSG	no	no	ephemeral
16603800*	Kaluapulani Gulch tributary near Pukalani	SW-CSG	1963–P	31-CSG	no	no	ephemeral
16603850*	Kalialinui Gulch near Kahului	SW-CSG	1966–P	28-CSG	no	no	ephemeral
16604000	Iao Stream near Wailuku	SW	1910–15	2-SW	no	no	continuous
16604500*	Iao Stream at Kepaniwai Park near Wailuku	SW	1983–P	10-SW	no	no	continuous
16605000	Maniania Ditch near Wailuku	Ditch	1910–13	2-SW	yes	yes	ditch
16607000*	Iao Stream at Wailuku	SW SW-CSG	1950–51 1952–P	1-SW 42-CSG	yes	no	continuous
16608000	North Waiehu Stream near Wailuku	SW	1912–15	3-SW	no	no	continuous
16609000	North Waiehu Ditch near Wailuku	Ditch	1910–11 1916–17	--	yes	yes	ditch
16609500	North Waiehu Stream below North Waiehu Ditch near Wailuku	SW	1910–11	--	yes	no	continuous
16610000	South Waiehu Stream near Wailuku	SW	1910–17	1-SW	yes	no	continuous
16611000	South Waiehu Ditch near Wailuku	Ditch	1913	--	yes	yes	ditch
16612000	Waihee River near Waihee	SW	1913–17	1-SW	yes	no	continuous
16613000	Waihee Canal near Waihee	Ditch	1910–12	--	yes	yes	ditch
16613500	Waihee Canal at Waiale weir near Wailulu	Ditch	1911–12	1-SW	yes	yes	ditch
16614000*	Waihee River at dam near Waihee	SW	1910–13 1983–P	9-SW	no	no	continuous
16615000	Spreckels Ditch near Waihee	Ditch	1910–13	2-SW	yes	yes	ditch
16616000	Spreckels Ditch at Waiale weir near Wailuku	Ditch	1910–11	1-SW	yes	yes	ditch
16616500*	Unnamed Gulch at Maluhia Camp	SW-CSG	1964–P	30-CSG	no	no	ephemeral
16617000	Left Branch Makamakaole Stream near Waihee	SW	1939–52	13-SW	yes	no	continuous
16617700	Kahakuloa Stream at altitude 1,380 feet near Honokohau	SW	1913–14	--	no	no	continuous

Table 4. Surface-water gaging stations, island of Maui, Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16618000*	Kahakuloa Stream near Honokohau	SW	1939–43 1947–70 1974–P	42-SW	no	no	continuous
16619000	Kahakuloa Stream at Kahakuloa near Waihee	SW	1912–13	--	yes	no	continuous
16619600	Owaluhi Gulch near Kahakuloa	SW-CSG	1964–70	6-CSG	no	no	ephemeral
16619700*	Poelua Gulch near Kahakuloa	SW-CSG	1964–P	30-CSG	no	no	continuous
16620000*	Honokohau Stream near Honokohau	SW	1911 1913–20 1922–88 1990–P	75-SW	no	no	continuous
16621000	Honokohau Ditch intake near Honokohau	Ditch	1907–13	5-SW	yes	yes	ditch
16622000	Honokohau Ditch above Honolua Stream near Honokohau	Ditch	1910–11	1-SW	yes	yes	ditch
16623000	Honolua Stream near Honokohau	SW	1913–17	3-SW	no	no	continuous
16623400	Honokeana Gulch near Honokahua	SW-CSG	1963–85	22-CSG	no	no	ephemeral
16624000	Honokohau Ditch at Honokowai weir near Lahaina	Ditch	1910–12	2-SW	yes	yes	ditch
16625000	Honolua Ditch near Honokohau	Ditch	1911–12	--	yes	yes	ditch
16626000	Honolua Stream at Honolua Ranch near Honokohau	SW	1911	--	yes	no	continuous
16627000	Kapaloa Stream at weir 1 near Lahaina	SW	1901	--	no	no	continuous
16628000	Kapaloa Stream near Lahaina	SW	1911–12	--	yes	no	continuous
16629000	Honokowai Ditch near Lahaina	Ditch	1912–17 1918–58 1958–67	53-SW	yes	yes	ditch
16630000	Honokowai Stream near Lahaina	SW	1913–17	3-SW	yes	no	continuous
16630200*	Honokowai Stream at Honokowai	SW-CSG	1961–63 1965–P	31-CSG	yes	no	continuous
16633000	Kahoma development tunnel near Lahaina	Ditch	1911–17	5-SW	yes	yes	ditch
16634000	Kahoma Stream near Lahaina	SW	1911–12 1913–17	3-SW	yes	no	continuous
16635000	Lahainaluna Stream at weir 1 near Lahaina (Kanaha Stream)	SW	1901	--	yes	no	contninuous
16635500	Lahainaluna Stream at weir 2 near Lahaina (Kanaha Stream)	SW	1901	--	yes	no	continuous
16636000	Kanaha Stream above pipeline intake near Lahaina	SW	1916–25 1926–32	14-SW	no	no	continuous
16637000	Lahainaluna Ditch near Lahaina	Ditch	1913–14	--	yes	yes	ditch
16638000	Kanaha Stream near Lahaina	SW	1911–16	4-SW	yes	no	continuous
16638500*	Kahoma Stream at Lahaina	SW SW-CSG	1962–89 1990–P	26-SW 29-CSG	yes	no	continuous
16639000	North Fork Kauaula Stream near Lahaina	SW	1901	--	no	no	continuous
16640000	South Fork Kauaula Stream near Lahaina	SW	1901	--	no	no	continuous
16641000	Kauaula Stream near Lahaina	SW	1912 1914–17	1-SW	yes	no	continuous

Table 4. Surface-water gaging stations, island of Maui, Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16643000	Kauaula Ditch near Lahaina	Ditch	1911–17	4-SW	yes	yes	ditch
16643300*	Kauaula Stream near mouth near Lahaina	SW-CSG	1960 1962 1963–P	33-CSG	yes	no	continuous
16644000	Launiupoko Stream near Lahaina	SW	1911–18	4-SW	yes	yes	continuous
16645000	Olowalu Ditch near Olowalu	Ditch	1911–16 1916–20 1920–58 1958–67	45-SW	yes	yes	ditch
16646000	Olowalu Stream near Olowalu	SW	1913–16	2-SW	yes	yes	ephemeral
16646200*	Olowalu Stream at Olowalu	SW SW-CSG	1963–72 1973–P	9-SW 30-CSG	yes	yes	ephemeral
16647000	Ukumehame Gulch near Olowalu	SW	1911–12 1913–16 1916–19	5-SW	no	no	continuous
16647100	Ukumehame Gulch at mouth near Olowalu	SW-CSG	1964–71	6-CSG	no	no	continuous
16647500*	Malalowaiaole Gulch near Maalaea	SW-CSG	1963–P	31-CSG	no	no	ephemeral
16648000	South side Waikapu Ditch near Waikapu	Ditch	1910–17	6-SW	yes	yes	ditch
16649000	Palolo Ditch near Waikapu	Ditch	1910–17	6-SW	yes	yes	ditch
16650000	Waikapu Stream near Waikapu	SW	1910–17	5-SW	yes	no	continuous
16650500*	Waikapu Stream near Kihei	SW-CSG	1963–P	31-CSG	yes	no	continuous
16658500*	Waiakoa Gulch tributary near Waiakoa	SW-CSG	1963–P	30-CSG	no	no	ephemeral
16659000*	Waiakoa Gulch at Kihei	SW-CSG	1963–P	31-CSG	no	no	ephemeral
16660000*	Kulanihakoi Gulch near Kihei	SW SW-CSG	1962–70 1971–P	7-SW 30-CSG	no	no	ephemeral
16663500*	Kamaole Gulch at Kamaole	SW-CSG	1972–P	22-CSG	no	no	ephemeral
16664000*	Liilioholo Gulch at Kamaole	SW-CSG	1972–P	22-CSG	no	no	ephemeral

1 *In operation 1994 water year
2 SW Continuous-record surface-water station
SW-CSG Crest-stage gage
SW-CSG-S Crest-stage gage, stage only
SW-LF Low-flow partial-record station
Ditch Station operated on ditch system
Spring Station that measures discharge from spring
3 Years of record as of the end of 1993 water year:
Number-SW is number of water years of complete continuous record
Number-CSG is number of annual peaks
Number-LF is number of years operated as a low-flow partial-record station
4 Regulated flow is when daily flow and annual peak flows are affected by more than 10 percent
5 Stream classification:
Continuous-flow or perennial streams include those considered continuous or interrupted in the Hawaii stream assessment (Hawaii Department of Land and Natural Resources, 1990). Continuous-flow streams flow to the sea year-round. Interrupted-flow streams flow year-round in the upper parts and intermittently at lower elevations.
Ephemeral flow or intermittent streams are those that do not meet the above criteria and flow only in direct response to precipitation
Ditches and springs are not classified by flow

Table 5. Surface-water gaging stations, island of Hawaii, through 1994

[P, in operation 1994 water year; makai, oceanside; mauka, mountainside; -- less than 1 complete year of record]

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16700000*	Waiakea Stream near Mountain View	SW	1930–P	63-SW	no	no	ephemeral
16700900*	Olaa Flume Spring near Kaumana	Spring	1974–P	19-SW	yes	yes	spring
16700950*	Lyman Springs No. 2 near Piihonua	Spring	1981–P	12-SW	no	no	spring
16701000	Olaa Flume at Kaumana near Hilo	Ditch	1917–20	1-SW	yes	yes	ditch
16701200	Waiakea Stream near Hilo	SW	1957–67	9-SW	yes	no	ephemeral
16701300*	Waiakea Stream at Hilo	SW-CSG	1968–P	26-CSG	yes	no	ephemeral
16701400*	Palai Stream at Hilo	SW-CSG	1965–P	29-CSG	no	no	ephemeral
16701700	Wailuku River near Pua Akala	SW	1964–65	1-SW	no	no	ephemeral
16701750	Wailuku River near Humuula	SW	1965–82	17-SW	no	no	ephemeral
16701800	Wailuku River near Kaumana	SW	1966–82	16-SW	no	no	ephemeral
16703000	Wailuku River at Pukamaui near Hilo	SW	1923–28 1929–40	11-SW	yes	no	ephemeral
16704000*	Wailuku River at Piihonua	SW	1928–40 1940–47 1948–P	62-SW	yes	no	continuous
16705000	Hilo Boarding School Ditch at intake near Hilo	Ditch	1931–40	8-SW	yes	yes	ditch
16706000	Hilo Boarding School Ditch near Hilo	Ditch	1918–19	1-SW	yes	yes	ditch
16707000	Kapehu Ditch diversion near Hilo	Ditch	1954–62	8-SW	yes	yes	ditch
16708000	Kapehu Ditch near Hilo	Ditch	1938–41 1942–48 1948–51 1951–62	20-SW	yes	yes	ditch
16709000	Kapehu Stream at Piihonua near Hilo	SW	1928–37	7-SW	yes	no	continuous
16710000	Wailuku River near Hilo	SW	1911–13 1918–19	2-SW	yes	yes	continuous
16713000*	Wailuku River at Hilo	SW	1977–79 1980–87 1988–P	14-SW	yes	no	continuous
16716000	Honolii Stream near Hilo	SW	1924–32	6-SW	no	no	continuous
16717000*	Honolii Stream near Papaikou	SW	1911–13 1967–P	27-SW	no	no	continuous
16717400*	Kalaoa Mauka Stream near Hilo	SW-CSG	1963–P	31-CSG	no	no	continuous
16717500	Kawainui Stream near Pepeekeo	SW	1912	--	yes	no	continuous
16717600*	Alia Stream near Hilo	SW SW-CSG	1962–72 1973–P	9-SW 32-CSG	no	no	continuous
16717650*	Kapehu Stream near Pepeekeo	SW-CSG	1963–P	31-CSG	no	no	continuous
16717800*	Pohakupuka Stream near Papaaloa	SW SW-CSG	1963–80 1983–P	17-SW 28-CSG	no	no	continuous
16717820	Manowaiopae Stream near Laupahoehoe	SW	1965–71	6-SW	yes	no	continuous
16717850*	Keehia Gulch near Ookala	SW-CSG	1963–P	31-CSG	no	no	ephemeral
16717920*	Ahualoa Gulch at Honokaa	SW-CSG	1963–P	31-CSG	no	no	ephemeral
16717950*	Honokaia Gulch tributary near Honokaa	SW-CSG	1963–P	31-CSG	no	no	ephemeral

Table 5. Surface-water gaging stations, island of Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16718000	Upper Hamakua Ditch at Puualala near Kukuihaele	Ditch	1913–20	6-SW	yes	yes	ditch
16720000*	Kawainui Stream near Kamuela	SW	1964–P	29-SW	no	no	continuous
16720300*	Kawaiki Stream near Kamuela	SW	1968–P	25-SW	no	no	continuous
16720500*	Upper Hamakua Ditch below Kawaiki Stream near Kamuela	Ditch	1964–P	29-SW	yes	yes	ditch
16721000	Kawainui Stream at altitude 2,120 feet near Waipio	SW	1901–02	--	yes	no	continuous
16721500	Branch 3 Kawainui Stream at altitude 1,700 feet near Waipio	SW	1901–02	--	yes	no	continuous
16722000	Kawainui Stream at altitude 1,435 feet near Waipio	SW	1901–02	--	yes	no	continuous
16722300	Branch 3 Kawainui Stream at altitude 1,405 feet near Waipio	SW	1901–02	--	no	no	continuous
16722600	Branch 1 Kawainui Stream at altitude 1,380 feet near Waipio	SW	1901–02	--	yes	no	continuous
16723000	Kawainui Stream near Waipio	SW	1901–02	--	yes	no	continuous
16724000	Kawainui Stream at altitude 775 feet near Waipio	SW	1901–02	--	yes	no	continuous
16724800*	Upper Hamakua Ditch above Alakahi Stream near Kamuela	Ditch	1968–P	25-SW	yes	yes	ditch
16725000*	Alakahi Stream near Kamuela	SW	1964–P	29-SW	yes	no	continuous
16726000*	Upper Hamakua Ditch above Waimea Reservoir diversion near Kamuela	Ditch	1974–P	19-SW	yes	yes	ditch
16727000*	Upper Hamakua Ditch above Puukapu Reservoir near Kamuela	Ditch	1977–P	16-SW	yes	yes	ditch
16728000	Alakahi Stream at altitude 1,200 feet near Waipio	SW	1901–02	--	yes	no	continuous
16729000	Alakahi Stream at altitude 730 feet near Waipio	SW	1901–02	--	yes	no	continuous
16730000	Koiawe Stream at altitude 1,120 feet near Waipio	SW	1901–02	--	yes	no	continuous
16731000	Koiawe Stream at altitude 610 feet near Waipio	SW	1901–02	--	yes	no	continuous
16732000	Waipio Stream below Koiawe Stream near Waipio	SW	1901–02	--	yes	no	continuous
16732100	Waima Stream at altitude 790 feet near Waipio	SW	1901–02	--	yes	no	continuous
16732150	Waima Stream at altitude 385 feet near Waipio	SW	1901–02	--	yes	no	continuous
16732200	Wailoa Stream near Waipio	SW	1901–02 1911–12 1964–69	5-SW	yes	no	continuous
16732300	Upper Hamakua Ditch at Puualala and Reservoir No. 3	Ditch	1913–20	7-SW	yes	yes	ditch
16732600	Lower Hamakua Ditch at Waima flume near Kukuihaele	Ditch	1910–13	2-SW	yes	yes	ditch
16732900	Lower Hamakua Ditch at main weir near Kukuihaele	Ditch	1910–20	9-SW	yes	yes	ditch
16733000	Lower Hamakua Ditch wasteway near Kukuihaele	Ditch	1964–73	8-SW	yes	yes	ditch
16733100	Lower Hamakua Ditch below main weir near Kukuihaele	Ditch	1964–73	8-SW	yes	yes	ditch
16733200	Honokaa diversion at Honokaa	Ditch	1964–73	8-SW	yes	yes	ditch
16733300	Lower Hamakua Ditch below Honokaa diversion at Honokaa	Ditch	1964–73	8-SW	yes	yes	ditch
16737000	Waiilikahi Stream near Waimanu	SW	1939–60	20-SW	no	no	continuous
16737500*	Waimanu Stream near Kamuela	SW	1991–P	3-SW	no	no	continuous
16738000	Kaimu Stream near Waimanu	SW	1939–47 1950–52	10-SW	no	no	continuous
16739000	Punalulu Stream near Waimanu	SW	1939–52	12-SW	no	no	continuous
16740000	Waiaalala Stream near Waimanu	SW	1939–52	12-SW	no	no	continuous
16741000	Paopao Stream near Waimanu	SW	1939–52	12-SW	no	no	continuous

Table 5. Surface-water gaging stations, island of Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16742000	Kukui Stream near Waimanu	SW	1939–52 1959–66	18-SW	no	no	continuous
16743000	Awini Ditch at East Honokane iki Gulch near Niulii	Ditch	1927–38 1938–49 1950–72	42-SW	yes	yes	ditch
16744000	East Honokane iki intake to Awini Ditch near Niulii	Ditch	1927–36 1937–38 1939–40 1940–49 1951–72	37-SW	yes	yes	ditch
16745000	Awini Ditch above Honokane Gulch near Kohala	Ditch	1918	--	yes	yes	ditch
16745500	Awini Ditch at Awini weir near Kohala	Ditch	1907–17 1963–72	18-SW	yes	yes	ditch
16747000	East Branch Honokane nui Stream at altitude 1,300 feet near Honokane	SW	1901	--	yes	no	continuous
16747500	East Branch Honokane nui Stream near Niulii	SW	1963–69	6-SW	yes	no	continuous
16748000	East Branch Honokane nui Stream at altitude 770 feet near Honokane	SW	1901	--	yes	no	continuous
16749000	West Branch Honokane nui Stream at altitude 1,370 feet near Honokane	SW	1901	--	yes	no	continuous
16749500	West Branch Honokane nui Stream at altitude 775 feet near Honokane	SW	1901	--	yes	no	continuous
16750000	Kohala Ditch at Honokane weir near Kohala	Ditch	1907–12	5-SW	yes	yes	ditch
16750900	Kohala Ditch at Honokane near Niulii	Ditch	1963–72	9-SW	yes	yes	ditch
16751000	Kohala Ditch at Pololu near Niulii	Ditch	1927–38 1938–72	44-SW	yes	yes	ditch
16752000	Kohala Ditch at Niulii weir near Kohala	Ditch	1907–17	9-SW	yes	yes	ditch
16752600*	Hapahapai Gulch at Kapaau	SW-CSG	1963–P	21-CSG	no	no	continuous
16755000	Kehena Ditch near Kohala	Ditch	1917–19 1928–66	39-SW	yes	yes	ditch
16755800*	Luahine Gulch near Waimea	SW-CSG	1963–P	21-CSG	no	no	ephemeral
16756000*	Kohakohau Stream near Kamuela	SW	1956–P	37-SW	yes	no	ephemeral
16756500*	Keanuiomano Stream near Kamuela	SW SW-CSG	1964–72 1973-P	8-SW 30-CSG	yes	no	ephemeral
16757000	Waikoloa Stream near Kamuela	SW	1947–71	24-SW	no	no	continuous
16758000*	Waikoloa Stream at Marine Dam near Kamuela	SW	1949–P	46-SW	yes	no	continuous
16759000*	Hauani Gulch near Kamuela	SW	1956–P	37-SW	yes	no	ephemeral
16759040*	Paiakuli Reservoir tributary near Waimea	SW-CSG	1963–P	31-CSG	no	no	ephemeral
16759060*	Kamakoa Gulch near Waimea	SW-CSG	1963–P	31-CSG	no	no	ephemeral
16759080*	Popoo Gulch near Waikii	SW-CSG	1963–P	31-CSG	no	no	ephemeral
16759180*	Keopu Stream near Kailua	SW-CSG	1962 1965–P	30-CSG	no	no	ephemeral
16759200	Right Branch Waiaha Stream near Holualoa	SW	1960–82	23-SW	no	no	ephemeral
16759300*	Waiaha Stream at Luawai near Holualoa	SW SW-CSG	1960–71 1971–P	11-SW 33-CSG	yes	no	ephemeral
16759500	Waiaha Stream near Holualoa	SW	1957–68	10-SW	yes	no	ephemeral

Table 5. Surface-water gaging stations, island of Hawaii, through 1994--Continued

Station[1]	Station name	Type of station[2]	Period of record	Years of record[3]	Regulated[4] Low flow	Regulated[4] Peak flow	Stream classification[5]
16759800	Kiilae Stream near Honaunau	SW	1958–82	24-SW	no	no	ephemeral
16760000	Waiohinu Springs, mauka station near Naalehu	Spring	1917–18	--	no	no	spring
16761000	Waiohinu Springs, makai station near Naalehu	Spring	1917–18	--	yes	yes	spring
16761200	Kahilipali Nui Gulch at Waiohinu	SW-CSG	1962–65	3-CSG	no	no	ephemeral
16762000*	Alapai Gulch at Naalehu	SW-CSG	1963–P	31-CSG	no	no	ephemeral
16764000*	Hilea Gulch tributary near Honuapo	SW	1966–P	27-SW	no	no	ephemeral
16765000	Hilea Gulch tributary 2 near Honuapo	SW	1966–82	16-SW	no	no	ephemeral
16767000*	Ninole Gulch near Punaluu	SW SW-CSG	1966-82 1983–P	16-SW 28-CSG	no	no	ephemeral
16770000*	Hionamoa Gulch at Pahala	SW-CSG	1963–P	31-CSG	no	no	ephemeral
16770200	Hionamoa Gulch tributary at Pahala	SW-CSG	1962–68	6-CSG	no	no	ephemeral
11677050*	Paauau Gulch at Pahala	SW SW-CSG	1962–79 1980–P	16-SW 32-CSG	no	no	ephemeral

1 *In operation 1994 water year

2 SW Continuous-record surface-water station
SW-CSG Crest-stage gage
SW-CSG-S Crest-stage gage, stage only
SW-LF Low-flow partial-record station
Ditch Station operated on ditch system
Spring Station that measures discharge from spring

3 Years of record as of the end of 1993 water year:
Number-SW is number of water years of complete continuous record
Number-CSG is number of annual peaks
Number-LF is number of years operated as a low-flow partial-record station

4 Regulated flow is when daily flow and annual peak flows are affected by more than 10 percent

5 Stream classification:

Continuous-flow or perennial streams include those considered continuous or interrupted in the Hawaii stream assessment (Hawaii Department of Land and Natural Resources, 1990). Continuous-flow streams flow to the sea year-round. Interrupted-flow streams flow year-round in the upper parts and intermittently at lower elevations.

Ephemeral flow or intermittent streams are those that do not meet the above criteria and flow only in direct response to precipitation

Ditches and springs are not classified by flow

Table 21. Stations where surface-water quality data have been collected on the island of Kauai, Hawaii, through 1994

Station	Station name	Type of water-quality data available[2]	Period of record	Years of record[3]
16010000	Kawaikoi Stream near Waimea	N	1976–89	14
		P	1976–77	2
16014000	Kokee Ditch near Waimea	N	1976–83	8
		P	1976–77	2
16019000[1]	Waialae Stream at altitude 3,820 feet near Waimea	N	1972–p	22
		P	1972–p	22
16031000[1]	Waimea River near Waimea	O	1971–p	23
		P	1971–p	23
		Q	1974–p	20
		R	1974–81	8
16036000	Makaweli River near Waimea	N	1976–89	14
		P	1976–77	2
16049000	Hanapepe River below Manuahi Stream near Eleele	N	1971–89	19
		P	1971–77	7
16052500	Lawai Stream near Koloa	N	1972–76	5
		P	1972–76	5
16054500	Kuia Stream near Puhi	N	1971–76	6
		P	1971–76	6
16055000	Huleia Stream near Lihue	N	1971–76	6
		P	1971–76	6
16060000	South Fork Wailua River near Lihue	N	1971–89	19
		P	1971–77	7
16061000	North Wailua Ditch near Lihue	N	1976–85	10
		P	1976–77	2
16061200	North Wailua Ditch below Waikoko Stream near Lihue	N	1976–89	14
		P	1976–77	2
16062000	Stable Storm Ditch near Lihue	N	1976–89	14
		P	1976	1
16063000	North Fork Wailua River at altitude 650 feet near Lihue	N	1976–85	10
		P	1976	1
16068000	East Branch of North Fork Wailua River near Lihue	N	1972–89	18
		P	1972–77	6
16069000	Wailua Ditch near Kapaa	N	1976–89	14
		P	1976–77	2
16071000	North Fork Wailua River near Kapaa	N	1971–89	19
		P	1971–77	7
16071500	Left Branch Opaekaa Stream near Kapaa	N	1976–89	14
		P	1976–77	2
16077000	Makaleha Ditch near Kealia	N	1976–89	14
		P	1976–77	2
16079000	Kapahi Ditch near Kealia	N	1976–89	14
		P	1976	1
16080000	Kapaa Stream at Kapahi Ditch intake near Kapaa	N	1976–85	10
		P	1976–77	2
16087000	Anahola Ditch wasteway near Kealia	N	1976–85	10
		P	1976	1
16088000	Anahola Ditch above Kaneha Reservoir near Kealia	N	1976–89	14
		P	1976–77	2
16089000	Anahola Stream near Kealia	N	1976–85	10
		P	1976–77	2
16091000	Lower Anahola Ditch near Kealia	N	1976–82	10
			1985–87	1
		P	1976	
16093200	Anahola Stream at Anahola	N	1971–83	13
		P	1971–77	7
16097500	Halaulani Stream at altitude 400 feet near Kilauea	N	1976–89	14
		P	1976–77	2

Table 21. Stations where surface-water quality data have been collected on the island of Kauai, Hawaii, through 1994 --Continued

Station	Station name	Type of water-quality data available[2]	Period of record	Years of record[3]
16100000	Hanalei tunnel outlet near Lihue	N	1976–85	10
		P	1976–77	2
16103000	Hanalei River near Hanalei	N	1971–89	19
		P	1971–77	8
			1979	1
		Q	1979	
16108000	Wainiha River near Hanalei	N	1971–89	19
		P	1971–77	7

1 In operation 1994 water year
2 N, Physical
O, Physical (including instantaneous sediment)
P, Common ions, metals, and general organic parameters
Q, Biological
R, Phytoplankton taxonomy tables
S, Pesticide
T, Continuous records of specific conductance
U, Continuous records of suspended sediment discharge
V, Continuous records of water temperature
3 Number of water years for which water-quality data are available

Table 22. Stations where surface-water quality data have been collected, island of Oahu, Hawaii, through 1994

Station	Station name	Type of water-quality data available[2]	Period of record	Years of record[3]
16200000	North Fork Kaukonahua Stream above Right Branch near Wahiawa	N	1970–86	17
		O	1968	1
		P	1970–77	8
16201000	Right Branch of North Fork Kaukonahua Stream near Wahiawa	N	1971	1
		P	1971	1
16204000	North Fork Kaukonahua Stream near Wahiawa	N	1970	1
		P	1970	1
16208000	South Fork Kaukonahua Stream at east pump reservoir near Wahiawa	N	1971–86	16
		O	1968, 1970	2
		P	1970–77	8
16208500	Right Branch of South Fork Kaukonahua Stream near Wahiawa	N	1970, 1976	2
		O	1968	1
		P	1970, 1976	2
16210500	Kaukonahua Stream at Waialua	N	1970	1
		P	1970	1
16211000	Poamoho Stream near Wahiawa	O	1968, 1970	2
16211600	Makaha Stream near Makaha	N	1972–86	15
		O	1968–71	4
		P	1970–77	8
16211800	Kaupuni Stream at altitude 374 feet near Waianae	N	1971–73	3
		O	1970	1
		P	1970–73	4
16212500	Honouliuli Stream near Waipahu	N	1976	1
16212800	Kipapa Stream near Wahiawa	N	1983–86	4
		O	1968, 1970–82	14
		P	1970–77	8
		U	1973–82	10
16212900	Kipapa Stream near Waipahu	O	1967–68	2
16213000[1]	Waikele Stream at Waipahu	O	1967–p	27
		P	1970–p	24
		Q	1974–p	20
		R	1974–81	8
		S	1975–82	8
		T	1973–81	9
		U	1972–93	22
		V	1973–81	9
16216000	Waiawa Stream near Pearl City	N	1973–86	14
		O	1968–72	5
		P	1970–77	8
16216500	Waimano flood channel at Pearl City	N	1976	1
16218000	Pearl Harbor Springs at Loko Kukona	O	1976	1
16223000	Waimalu Stream near Aiea	O	1968, 1970–71	3
16224500	Kalauao Stream at Moanalua Road at Aiea	N	1970, 1972–82	12
		O	1968, 1971	2
		P	1970–77	8
16225800[1]	North Halawa Stream near Kaneohe	O	1991–p	3
		S	1991	1
		U	1991–p	3
16226000	North Halawa Stream near Aiea	N	1970–86	17
		P	1970–71, 1973 1976–77	5
16226200[1]	North Halawa Stream near Honolulu	O	1983–p	11
		P	1983–84, 1987–p	9
		Q	1983–84, 1987–p	9
		S	1984, 1987–p	8
		U	1983–p	11

Table 22. Stations where surface-water quality data have been collected, island of Oahu, Hawaii, through 1994--Continued

Station	Station name	Type of water-quality data available[2]	Period of record	Years of record[3]
16227100[1]	Halawa Stream below H1	O	1989–p	5
		P	1989–p	5
		Q	1989–p	5
		S	1989–p	5
16227500	Moanalua Stream near Kaneohe	O	1970–71, 1974, 1976–77	5
		P	1970–71, 1974, 1976, 1977	5
		Q	1977	1
		U	1972–78	7
16227700	Moanalua Stream tributary near Kaneohe	N	1976–77	2
		O	1970–74	5
		P	1970–71, 1974 1976–77	5
		Q	1977	1
16227900	Moanalua Stream tributary near Aiea	O	1973–77	5
		P	1974	1
16228000	Moanalua Stream near Honolulu	O	1970–72, 1977	4
		P	1970–71, 1977	3
		Q	1977	1
16228200	Moanalua Stream near Aiea	O	1969, 1971, 1974–84	13
		P	1974–77, 1979	5
		Q	1977	1
16228600	Moanalua Stream near Tripler Hospital	N	1976–77	2
		O	1971, 1975	2
		P	1976–77	2
		Q	1977	1
16228900	Kalihi Stream near Kaneohe	N	1970	1
		O	1968	1
16229000	Kalihi Stream near Honolulu	N	1980–93	14
		O	1969–79	11
		P	1969, 1972–93	23
16229300	Kalihi Stream at Kalihi	O	1967–93	27
		P	1970–93	24
		Q	1967, 1975–93	20
		R	1975–81	7
		S	1975–82	8
16232000	Nuuanu Stream below reservoir 2 wasteway near Honolulu	N	1970–86	17
		P	1970–77	8
16238500	Waihi Stream at Honolulu	N	1972–83	12
		O	1970–71	2
		P	1970–77	8
16240500	Waiakeakua Stream at Honolulu	N	1972–86	15
		O	1970–71	2
		P	1970–77	8
16244000	Pukele Stream near Honolulu	N	1970, 1973–82	11
		P	1970, 1973–77	6
16246000	Waiomao Stream near Honolulu	N	1970	1
16247000	Palolo Stream near Honolulu	N	1970–79	10
		P	1970–77	8
16247100	Manoa-Palolo drainage canal at Moiliili	N	1971–76	6
		P	1971–76	6
16249000	Waimanalo Stream at Waimanalo	N	1971–75	5
		O	1968, 1970	2
		P	1970–75	6
16254000	Makawao Stream near Kailua	N	1970, 1974–86 1968, 1972	14
		O	1970, 1972, 1974,	2
		P	1976–77	5
16260500	Maunawili Stream at highway 61 near Kailua	O	1967–75	9
		P	1969–75	7

Table 22. Stations where surface-water quality data have been collected, island of Oahu, Hawaii, through 1994--Continued

Station	Station name	Type of water-quality data available[2]	Period of record	Years of record[3]
16265500	Left Tributary to Right Branch of Kamooalii Stream near Kaneohe	N	1983	1
		P	1983	1
		Q	1983	1
16265600[1]	Right Branch Kamooalii Stream near Kaneohe	O	1983–p	11
		P	1983–p	11
		Q	1983–p	11
		S	1983–85, 1988–p	9
		U	1983–p	11
16265700[1]	Kamooalii Stream at altitude 220 feet near Kaneohe	O	1983–85, 1988–p	9
		P	1983–85, 1988–p	9
		Q	1983–85, 1988–p	9
		S	1983–84, 1991–p	5
16266000	Kamooalii Stream near Kaneohe	N	1988–89	2
		R	1988–89	2
16266500[1]	Hooleinaiwa Stream at altitude 220 feet near Kaneohe	O	1983–84, 1988–p	8
		P	1983–84, 1988–p	8
		Q	1983–84, 1988–p	8
		S	1984, 1991–p	4
16267500[1]	Hooleinaiwa Stream above confluence with Kamooalii Stream near Kaneohe	O	1983–85, 1988–p	9
		P	1983–85, 1988–p	9
		Q	1983–85, 1988–p	9
		S	1983–85, 1991–p	6
16269500[1]	Kuou Stream at altitude 220 feet near Kaneohe	O	1983–85, 1988–p	9
		P	1983–85, 1988–p	9
		Q	1983–85, 1988–p	9
		S	1983–84, 1991–p	5
16270500	Kamooalii Stream below Kuou Stream near Kaneohe	O	1967–76	10
		P	1969–71, 1973,1976	5
		U	1972–76	5
16270900[1]	Luluku Stream at altitude 220 feet. near Kaneohe	O	1970, 1972, 1976, 1978, 1983–p	15
		P	1970, 1972, 1976, 1983–p	14
		Q	1983–p	11
		S	1983–86, 1988–p	10
		U	1985–p	9
16272200[1]	Kamooalii Stream below Luluku Stream near Kaneohe	O	1977–p	17
		P	1977, 1983–p	12
		Q	1983–p	11
		S	1983–85, 1987–p,	10
		U	1977–p	17
16273900	Kamooalii Stream at Kaneohe	O	1967–80	14
		P	1969–77	9
16273950[1]	South Fork Kapunahala Stream at Kaneohe	O	1985, 1987–p	8
		P	1987–p	7
		Q	1987–p	7
		S	1987–p	7
		U	1991–p	3
16274100[1]	Kaneohe Stream below Kam highway	O	1989–p	5
		P	1989–p	5
		Q	1989–p	5
		S	1989–p	5
16275000[1]	Haiku Stream near Heeia	N	1970–77, 1986	9
		O	1983–85, 1987–p	10
		P	1970–77, 1983-84, 1988–p	16
		Q	1983–84, 1988–p	8
		S	1983–84, 1988–p	8
		U	1984, 1987–p	8
16283000	Kahaluu Stream near Heeia	N	1970	1
16283200	Kahaluu Stream near Ahuimanu	N	1984–86	3

Table 22. Stations where surface-water quality data have been collected, island of Oahu, Hawaii, through 1994--Continued

Station	Station name	Type of water-quality data available[2]	Period of record	Years of record[3]
16283500	Kahaluu Stream at Kahaluu	O	1967–73	7
		P	1969–73	5
16283600	South Fork Waihee Stream near Heeia	N	1971, 1976–86	12
		P	1971, 1976–77	3
16283700	North Fork Waihee Stream near Heeia	N	1971, 1976–86	12
		P	1971, 1976–77	3
16284000	Waihee Stream near Heeia	N	1970–71,1976-82	9
		P	1970–71, 1976–77	4
16284200	Waihee Stream near Kahaluu	N	1976–86	11
		P	1976–77	2
16284500	Waihee Stream at Kahaluu	O	1967–73,1976-81	13
		P	1969–73, 1976–81	11
16294900	Waikane Stream at altitude 75 feet.at Waikane	N	1970–86	17
		P	1970–77	8
16296500	Kahana Stream at altitude 30 feet. near Kahana	N	1970–81,1983-86	16
		P	1970–77	8
16302000	Punaluu Ditch near Punaluu	N	1973, 1976-79,1986	6
		P	1973, 1976	2
16303000	Punaluu Stream near Punaluu	N	1970–86	17
		P	1970–77	8
16304200	Kaluanui Stream near Punaluu	N	1970–81, 1983–86	16
		P	1970–77	8
16308990	Malaekahana Stream near Laie	N	1970–71	2
		P	1970–71	2
16325000	Kamananui Stream at Pupukea military road near Maunawai	N	1976–86	11
		O	1970, 1973	2
		P	1970, 1973, 1976–77	4
16329000	Kaiwikoele Stream tributary near Maunawai	O	1968–69	2
16330000	Kamananui Stream at Maunawai	N	1971–86	16
		O	1968, 1970	2
		P	1970–77	8
16343000	Helemano Stream at Haleiwa	N	1971–82	12
		O	1968, 1970	2
		P	1970–77	8
16345000	Opaeula Stream near Wahiawa	N	1975–86	12
		O	1968, 1970–74	6
		P	1970–77	8
16350000	Opaeula Stream near Haleiwa	N	1971–73	3
		P	1971–73	3

1 In operation 1994 water year

2 N = Physical parameters
O = Physical (including instantaneous sediment) parameters.
P = Common ions, metals, and general organic parameters.
Q = Biological parameters
R = Phytoplankton taxonomy tables
S = Pesticide parameters
T = Continuous records of specific conductance
U = Continuous records of suspended sediment discharge
V = Continuous records of water temperature

3 Number of water years for which water-quality data are available

Table 23. Stations where surface-water quality data have been collected on the island of Molokai, Hawaii

Station	Station name	Type of water-quality data available[2]	Period of record	Years of record[3]
16400000[1]	Halawa Stream near Halawa	O	1969–p	25
		P	1969–p	25
		Q	1975–p	19
		R	1975–81	7
16403900	Kawainui Stream near Pelekunu	N	1976–80, 1982–83	7
		P	1976–77	2
16404000	Pelekunu Stream near Pelekunu	N	1969–82	14
		P	1969–77	9
16404200	Pilipililau Stream near Pelekunu	N	1976–89	14
		P	1976–77	2
16405100	Molokai Tunnel at east Portal	N	1980–89	10
16405300	Molokai Tunnel at west Portal	N	1969–71, 1976–89	17
		P	1969–71, 1976–77	5
16405500	Waikolu Stream at altitude 900 feet near Kalaupapa	N	1969–70, 1972–89	20
		P	1969–70, 1972–76	7
16408000	Waikolu Stream below pipeline crossing near Kalaupapa	N	1969, 1971, 1976-89	16
		P	1969, 1971, 1976-77	4
16414000	Kaunakakai Gulch near Kaunakakai	N	1972, 1977	2
		P	1972	1
16415000	East Fork Kawela Gulch at Kaunakakai	N	1969–72	4
		P	1969–72	4
16416000	Punaula Gulch near Pukoo	N	1969–71	3
		P	1969–71	3
16419500	Papio Gulch at Halawa	N	1971–72, 1976–89	16
		P	1971–72, 1976	3

[1] In operation 1994 water year
[2] N = Physical parameters.
O = Physical (including instantaneous sediment) parameters.
P = Common ions, metals, and general organic parameters.
Q = Biological parameters.
R = Phytoplankton taxonomy tables.
S = Pesticide parameters.
T = Continuous records of specific conductance.
U = Continuous records of suspended-sediment discharge.
V = Continuous records of water temperature.
[3] Number of water years for which water-quality data are available.

Table 24. Stations where surface-water quality data have been collected on the island of Maui, Hawaii

Station	Station name	Type of water-quality data available[2]	Period of record	Years of record[3]
16501000	Kepuni Gulch near Kahikinui House	N	1972–83	12
		P	1972–77	6
16508000	Hanawi Stream near Nahiku	N	1972–89	18
		P	1972–77	6
16512000	Koolau Ditch at Nahiku weir near Nahiku	N	1976–85	10
		P	1976–77	2
16518000	West Wailuaiki Stream near Keanae	N	1972–89	18
		P	1972–77	6
16523000	Koolau Ditch near Keanae	N	1976–85	10
		P	1976–77	2
16531000	Kula diversion from Haipuaena Stream near Olinda	N	1976–85	10
		P	1976–77	2
16538000	Spreckels Ditch at Haipuaena weir near Huelo	N	1976–85	10
		P	1976–77	2
16541000	Koolau Ditch at Haipuaena near Huelo	N	1976–87	12
		P	1976–77	2
16541500	Manuel Luis Ditch at Puohokamoa Gulch near Huelo	N	1976–85	10
		P	1976–77	2
16570000	Nailiihaele Stream near Huelo	N	1972–75	4
		P	1972–75	4
16587000	Honopou Stream near Huelo	N	1976–89	14
		P	1976–77	2
16588000	Wailoa Ditch at Honopou near Huelo	N	1972–87	16
		P	1972–77	6
16589000	New Hamakua Ditch at Honopou near Huelo	N	1976–85	10
		P	1976–77	2
16592000	Lowrie Ditch at Honopou Gulch near Huelo	N	1976–85	10
		P	1976–77	2
16594000	Haiku Ditch at Honopou Gulch near Kailua	N	1976–85	10
		P	1976–77	2
16599500	Opana Tunnel near Kailiili	N	1972–89	18
		P	1972–76	5
16604500	Iao Stream at Kepaniwai Park near Wailuku	N	1984–89	6
16607000	Iao Stream at Wailuku	N	1972–82	11
		P	1972–77	6
16614000	Waihee River at dam near Waihee	N	1984–89	6
166818000[1]	Kahakuloa Stream near Honokohau	O	1975–p	19
		P	1975–p	19
		Q	1975–p	19
		R	1975–81	7
16620000	Honokohau Stream near Honokohau	N	1972–89	18
		P	1972–77	6
16638500	Kahoma Stream at Lahaina	N	1977–89	13
		P	1977	1
16645000	Olowalu Ditch near Olowalu	N	1972	1
		P	1972	1
16646200	Olowalu Stream at Olowalu	N	1972–75	4
		P	1972–75	4

1 In operation 1994 water year

2 N = Physical parameters
O = Physical (including instantaneous sediment) parameters
P = Common ions, metals, and general organic parameters
Q = Biological parameters
R = Phytoplankton taxonomy tables
S = Pesticide parameters
T = Continuous records of specific conductance
U = Continuous records of suspended-sediment discharge
V = Continuous records of water temperature

3 Number of water years for which water-quality data are available

Table 25. Stations where surface-water quality data have been collected, island of Hawaii, Hawaii

Station	Station name	Type of water-quality data available[2]	Period of record	Years of record[3]
16700000	Waiakea Stream near Mountain View	N	1972–89	18
		P	1972–77	6
16700900	Olaa Flume Spring near Kaumana	N	1976–89	14
		P	1976–77	2
16700950	Lyman Springs No. 2 near Piihonua	N	1981–89	9
16701750	Wailuku River near Humuula	N	1976–82	7
		P	1976,1978	2
		Q	1978	1
16701800	Wailuku River near Kaumana	N	1976–82	7
		P	1976,1978	2
		Q	1978	1
16704000	Wailuku River near Piihonua	N	1980–89	10
		O	1972–79	8
		P	1972–79	8
		Q	1975–79	5
		R	1975–79	5
		T	1975–79	5
		V	1975–79	5
16713000	Wailuku River at Hilo	O	1977–93	17
		P	1977–93	17
		Q	1977–93	17
		R	1980–81	2
		T	1983–85	3
		U	1977–84	8
		V	1983–85	3
16717000	Honolii Stream near Papaikou	O	1969–93	25
		P	1969–93	25
		Q	1977–93	17
		S	1970–73 1975–82	12
16717600	Alia Stream near Hilo	N	1981	1
		P	1981	1
16717800	Pohakupuka Stream near Papaaloa	N	1972–79	8
		P	1972–77	6
16717820	Manowaiopae Stream near Laupahoehoe	N	1981	1
		P	1981	1
16720000	Kawainui Stream near Kamuela	N	1976–89	14
		P	1976–77	2
16720300	Kawaiki Stream near Kamuela	N	1976–89	14
		P	1976–77	2
16720500	Upper Hamakua Ditch below Kawaiki Stream near Kamuela	N	1976–89	14
		P	1976	
16724800	Upper Hamakua Ditch above Alakahi Stream near Kamuela	N	1974–89	16
		P	1974–77	4
16725000	Alakahi Stream near Kamuela	N	1974–89	16
		P	1974–77	4
16726000	Upper Hamakua Ditch above Waimea Reservoir diversion near Kamuela	N	1976–89	14
		P	1976–77	2
16727000	Upper Hamakua Ditch above Puukapu Reservoir near Kamuela	N	1978–80 1982–88	10
16733100	Lower Hamakua Ditch below main weir near Kukuihaele	N	1981	1
		P	1981	1
16737500	Waimanu Stream near Kamuela	O	1991–p	3
		P	1991–p	3
		Q	1991–p	3
		S	1991–p	3
16755000	Kehena Ditch near Kohala	N	1969	1
		P	1969	1
16756000	Kohakohau Stream near Kamuela	N	1972–89	18
		P	1972–77	6
16758000	Wailoloa Stream at Marine Dam near Kamuela	N	1972–89	18
		P	1972–77	6

Table 25. Stations where surface-water quality data have been collected, island of Hawaii, Hawaii--Continued

Station	Station name	Type of water-quality data available[2]	Period of record	Years of record[3]
16759000	Hauani Gulch near Kamuela	N	1976–89	14
		P	1976–77	2
16759200	Right Branch Waiaha Stream near Holualoa	N	1972–82	11
		P	1972–77	6
16759800	Kiilae Stream near Honaunau	N	1974–82	9
		P	1974–77	4
16764000	Hilea Gulch tributary near Honuapo	N	1972–89	18
		P	1972–77	6
16765000	Hilea Gulch tributary 2 near Honuapo	N	1976–80	5
		P	1976	1
16767000	Ninole Gulch near Punaluu	N	1976,1982	2
		P	1976	1
16770500	Paauau Gulch at Pahala	N	1976,1979	2
		P	1976	1

[1] *In operation 1994 water year

[2] N = Physical parameters
O = Physical (including instantaneous sediment) parameters
P = Common ions, metals, and general organic parameters
Q = Biological parameters
R = Phytoplankton taxonomy tables
S = Pesticide parameters
T = Continuous records of specific conductance
U = Continuous records of suspended-sediment discharge
V = Continuous records of water temperature

[3] Number of water years for which water-quality data are available

Table 26. Active rain gages on the island of Kauai, Hawaii, March, 1993

[H, hourly: D, daily: W, weekly: M, monthly: --, unknown: NWS, National Weather Service: DLNR, Hawaii Department of Land and Natural Resources: USGS, U.S. Geological Survey. Source of data: unpublished files of NWS and DLNR.]

Station name	State key number	Observer	Altitude of gage (feet)	First year of record	Recording frequency	Real time data	Coordinating agency
Alexander reservoir	983	McBryde Sugar Co.	1,610	1926	D, H	no	NWS
Anahola	1114	Lihue Plantation Co.	180	1934	D, H	no	NWS
Anahola number 2	1111.4	NWS	240	1992	D, H	yes	NWS
Brydeswood station	985	McBryde Sugar Co.	720	1910	D	no	NWS
Camp 3	1034	Kekaha Sugar Co.	10	1946	--	no	DLNR
East Lawai	934	McBryde Sugar Co.	440	1902	D	no	NWS
EKW 3	1094	Lihue Plantation Co.	370	1932	D	no	DLNR
EKW 4	1097	Lihue Plantation Co.	335	1932	D	no	DLNR
EKW 5	1061	Lihue Plantation Co.	475	1932	D	no	DLNR
Eleele	927	McBryde Sugar Co.	150	1901	D	no	NWS
Field 123 KSC	1030	Kekaha Sugar Co.	45	1946	--	no	DLNR
Field 663 KSC	1040.3	Kekaha Sugar Co.	1,025	1966	--	no	DLNR
H-23 camp 9	1064	Lihue Plantation Co.	275	1924	--	no	DLNR
H-27	1064.2	Lihue Plantation Co.	405	1968	D	no	DLNR
H-46	1061.3	Lihue Plantation Co.	504	1961	--	no	DLNR
Halaula	1110	Lihue Plantation Co.	253	1902	D	no	NWS
Halenanaho	1006	Lihue Plantation Co.	490	1932	D	no	NWS
Hanalei	1117.8	NWS	5	1991	D, H	yes	NWS
Hanalei tunnel	1053	Lihue Plantation Co.	1,220	1928	M	no	DLNR
Hanamaulu	1022	Lihue Plantation Co.	175	1893	D	no	DLNR
Hanapepe	966.4	NWS	370	1992	D, H	yes	NWS
HI-1 old office	1021	Lihue Plantation Co.	200	1885	D	no	DLNR
HI-4 (field 4A)	1016	Lihue Plantation Co.	260	1940	D	no	DLNR
Hukipo	945	Kekaha Sugar Co.	800	1940	D	no	NWS
Iliiliula intake	1050	Lihue Plantation Co.	1,070	1935	D	no	DLNR
Intake Wainiha PC	1086	McBryde Sugar Co.	690	1907	W	no	NWS
Kalaheo	986.2	NWS	800	1977	D, H	yes	NWS
Hanalohuluhulu	1075	State Division of Parks	3,600	1931	D, H	no	NWS
Kaneha Reservoir	1092	Lihue Plantation Co.	810	1946	D	no	NWS
Kapaa Stables	1104	Lihue Plantation Co.	175	1940	D, H	no	NWS
Kapahi	1094.2	NWS	530	1992	D, H	yes	NWS
Kaunalewa	942	Kekaha Sugar Co.	10	1946	--	no	DLNR
Kealia	1112	Lihue Plantation Co.	10	1899	D	no	DLNR
Kekaha	944	Kekaha Sugar Co.	9	1983	D, H	yes	NWS
Kilauea	1134	Nick Rapozo	320	1885	D	no	NWS
Kilohana	1084	USGS	4,040	1910	D	no	DLNR
Kitano Reservoir	1037.1	Kekaha Sugar Co.	2,150	1955	--	no	DLNR
Kokee	1076	NWS	4,200	1991	D, H	yes	NWS
Kolo	1033	Kekaha Sugar Co.	36	1936	D, H	no	NWS

Table 26. Active rain gages on the island of Kauai, Hawaii, March, 1993--Continued

Station name	State key number	Observer	Altitude of gage (feet)	First year of record	Recording frequency	Real time data	Coordinating agency
Koloa	936	McBryde Sugar Co.	240	1887	D	no	NWS
Koloa mauka	994	McBryde Sugar Co.	640	1904	W	no	NWS
Koloko Reservoir	1137	B.J. Barnard	490	1934	D	no	NWS
Kukuiula	935	McBryde Sugar Co.	100	1903	D	no	NWS
L-20	1020.5	Lihue Plantation Co.	175	1947	D	no	DLNR
L-24	1020.4	Lihue Plantation Co.	125	1947	D	no	DLNR
L-4	1015.3	Lihue Plantation Co.	240	1965	--	no	DLNR
Lake	1118.5	Princeville management	250	1971	D, H	no	DLNR
Left Branch Opeakaa	1068	USGS	458	1960	D, H	no	DLNR
Lihue	1020	Lihue Plantation Co.	207	1904	D	no	NWS
Lihue variety station	1062.1	Lihue Plantation Co.	380	1945	D, H	no	NWS
Lihue WSO AP	1020.1	NWS	103	1950	D, H	no	NWS
Limaloa	1027	Kekaha Sugar Co.	10	1946	--	no	DLNR
M-19	1104.2	Lihue Plantation Co.	80	1968	--	no	DLNR
M-2B	1102	Lihue Plantation Co.	350	1921	D	no	DLNR
Mahaulepu	941.1	McBryde Sugar Co.	80	1951	D	no	NWS
Makaweli	965	Olokele Sugar Co.	140	1892	D	no	NWS
Mana	1026	Kekaha Sugar Co.	20	1904	D	no	NWS
McBryde VS	986.1	Experiment station HSPA	630	1956	D	no	DLNR
Mimino	1095	Lihue Plantation Co.	280	1934	D	no	DLNR
Mohihi Koaie DV	1085	USGS	4,000	1910	D	no	DLNR
Mohihi upr cross	1083	USGS	3,420	1910	D, H	no	NWS
Moloaa	1145	Theodore Javellana Jr.	330	1926	W	no	NWS
Mt. Waialeale	1047	USGS	5,148	1910	D, H	no	NWS
North Wailua	1051	USGS	1,110	1928	W	no	NWS
North Wailua River	1055	Lihue Plantation Co.	650	1915	M	no	DLNR
Niu Ridge	1035	Kekaha Sugar Co.	1,250	1939	D	no	NWS
Nohili	1028	Kekaha Sugar Co.	215	1965	--	no	DLNR
Paukahana	1080	USGS	3,723	1910	D	no	DLNR
Ph Wainiha	1115	McBryde Sugar Co.	101	1907	D, H	yes	NWS
Princeville AP	1117.9	NWS	215	1990	D, H	yes	NWS
Princeville Ranch	1117	Princeville Ranch Inc.	217	1910	D, H	no	NWS
Puehu Ridge	1040	Kekaha Sugar Co.	1,600	1939	D	no	NWS
Puhi	1013	Lihue Plantation Co.	329	1945	D	no	NWS
Puulua Reservoir	1072.3	Kekaha Sugar Co.	3,250	--	--	no	DLNR
RES 5 LSC	1011	Lihue Plantation Co.	385	1935	D	no	DLNR
Saki Mana	1031	Kekaha Sugar Co.	10	1945	--	no	DLNR
SP. Monument	1100.1	Lihue Plantation Co.	410	1968	D	no	DLNR
Stable Storm Ditch	1055.1	Lihue Plantation Co.	750	1954	D	no	DLNR
Wahiawa	930	McBryde Sugar Co.	215	1904	D	no	NWS
Wai-uka	1062	Lihue Plantation Co.	250	1924	D	no	DLNR

Table 26. Active rain gages on the island of Kauai, Hawaii, March, 1993--Continued

Station name	State key number	Observer	Altitude of gage (feet)	First year of record	Recording frequency	Real time data	Coordinating agency
Waiahi lower	1054	Lihue Plantation Co.	550	1910	D	no	DLNR
Waiahi upper	1052	Lihue Plantation Co.	780	1931	D	no	NWS
Waiakoali	1082	USGS	3,420	1910	D	no	DLNR
Waialae	1042	USGS	3,860	1955	D	no	DLNR
Waialeale trail	1045	USGS	4,520	1984	D, H	no	DLNR
Waiawa	943	Kekaha Sugar Co.	10	1894	D	no	NWS
Wailua Kai	1065	Lihue Plantation Co.	50	1924	D	no	NWS
Wailua UH Exp Stn	1061.5	NWS	550	1976	D, H	yes	NWS
Waimea	947	Kekaha Sugar Co.	20	1911	D	no	NWS
Waioli Mission	1117.6	Steve Johnson	20	1846	D	no	DLNR
West Lawai	931	McBryde Sugar Co.	210	1902	D	no	NWS
Woods 1117	1118.4	Princeville Management	220	1971	D	no	DLNR

Table 27. Active rain gages on the island of Oahu, Hawaii, March 1993

[H, hourly: D, daily: W, weekly: M, monthly: --, unknown: NWS, National Weather Service: DLNR, Hawaii Department of Land and Natural Resources: USGS, U.S. Geological Survey. Source of data: unpublished files of NWS and DLNR.

Station name	State key number	Observer	Altitude of gage (feet)	First year of record	Recording frequency	Real time data	Coordinating agency
Adit 8	834.7	Oahu Sugar Co.	730	1948	--	no	DLNR
Ahuimanu Loop	839.12	Don Michel	320	1968	D, H	yes	NWS
Aiea Heights	764.6	Gordon Fowler	780	--	D	no	NWS
Alewa mauka	704.12	Board of Water Supply	1,000	1970	D	no	DLNR
Aloha Tower	704.8	NWS	152	1969	D, H	yes	NWS
B.Y.U. Laie	903.1	B.Y.U. Hawaii campus	20	--	D	no	NWS
Beretania pump	705	Board of Water Supply	9	1945	D	no	NWS
Brodie	860	Dole package food	800	1924	D	no	DLNR
Brodie west	818	Dole package food	480	1938	D	no	DLNR
Camp 84	807	CPC	680	1924	D, H	no	NWS
Camp Erdman	841.16	Salvadore Gemeno	5	--	D	no	NWS
Campbell Ind Park	702.5	Chevron USA Inc.	10	1966	D	no	NWS
Coconut Island	840.1	Hawaii Inst. Marine Biology	15	1949	D	no	NWS
Dowsett	775.4	Mrs. Virginia Kochs	390	--	D	no	NWS
Ewa Plantation	741	Oahu Sugar Co.	50	1891	D	no	NWS
Field 110 OSC	739	Oahu Sugar Co.	360	1945	--	no	DLNR
Field 205 DMC	857	Del Monte Corp.	920	1933	--	no	DLNR
Field 205 OSC	742.1	Oahu Sugar Co.	375	1945	--	no	DLNR
Field 221 OSC	818.1	Oahu Sugar Co.	525	1954	W	no	DLNR
Field 235 OSC	817.3	Oahu Sugar Co.	600	1919	--	no	DLNR
Field 260 OSC	813.3	Oahu Sugar Co.	610	1960	W	no	DLNR
Field 275 OSC	809.3	Oahu Sugar Co.	850	1969	D	no	DLNR
Field 310 OSC	752.1	Oahu Sugar Co.	25	1933	--	no	DLNR
Field 32 DMC	808	Del Monte Corp.	970	1944	--	no	DLNR
Field 62 OSC	747	Oahu Sugar Co.	35	1926	--	no	DLNR
Hahaione Valley	725	Robert Layson	60	1928	--	no	DLNR
Haiku	839.3	Board of Water Supply	630	1942	W	no	DLNR
Hakipuu mauka	886.8	NWS	130	1974	D, H	yes	NWS
Halawa shaft	771.2	Board of Water Supply	170	1955	D, H	no	NWS
Hawaii Kai Course	724.19	Hawaii Kai Golf Course	21	1977	D, H	yes	NWS
Hawaii Loa College	838.7	Joe Saguto	290	1969	--	no	DLNR
Heeia Waena	838.3	Ronald Walker	100	1968	D	no	DLNR
Hokuloa	725.2	HV Von Holt	2,201	1948	D, H	no	NWS
Honolulu Observ.	702.2	NWS	5	1960	D	no	NWS
Honolulu WSFO AP	703	NWS	7	1947	D, H	no	NWS
K-5 Pump	827	Dole Package Food	1,005	1925	D	no	DLNR
K-5 Station	823	Dole Package Food	820	1925	D	no	DLNR
Kaena Point	841.3	U.S. Air Force	1,240	1959	D	no	NWS
Kahana	883	Waiahole Irr. Co.	800	1916	D	no	NWS
Kahana Stream	886.4	USGS	30	1961	D	no	DLNR
Kahuku	912	Kahuku Plantation	25	1891	D, H	no	NWS
Kailua Fire Stn.	791.3	Kailua Fire Department	10	1958	D, H	no	NWS

Table 27. Active rain gages on the island of Oahu, Hawaii, March 1993--Continued

Station name	State key number	Observer	Altitude of gage (feet)	First year of record	Recording frequency	Real time data	Coordinating agency
Kaimuki	711.1	Board of Water Supply	30	1949	D	no	DLNR
Kalihi Res. Site	777	Board of Water Supply	910	1927	D	no	NWS
Kalihi Shaft	773.1	Board of Water Supply	155	1949	W	no	DLNR
Kalihi Stream	773.3	USGS	60	1962	D, H	no	DLNR
Kalihi Valley	773.7	Ms. Aileen Perstein	400	--	--	no	DLNR
Kamananui Stream	897.1	USGS	590	1963	D	no	DLNR
Kamehame	724.7	NWS	817	1993	D, H	yes	NWS
Kaneohe	838.1	Ms. Margaret Ulibern	60	1924	D	no	NWS
Kaneohe mauka	781	Hawaii State Hospital	190	1928	D	no	NWS
Kapaka Farm	904.1	Ms. Margaret Pettigrew	10	--	D	no	NWS
Kapalama	773	Kamehameha School	614	1922	D	no	NWS
Kawaihapai	841	Waialua Sugar Co.	40	1930	D	no	NWS
Keeaumoku HSPA	707	Board of Water Supply	50	1918	D	no	DLNR
Kemoo	862	Dole Package Food	850	1924	D	no	DLNR
Kemoo Camp 8	855	Waialua Sugar Co.	725	1924	D	no	NWS
Kii-Kahuku	911	AM Orient Aquafarm	15	1946	D	no	NWS
Kipapa Stream	832.2	USGS	690	1957	D, H	no	DLNR
Kokokahi	781.6	Mrs. Carolyn Burr	130	--	--	no	DLNR
Koolau Dam	833	U.S. Army Schofield Brks.	1,160	1914	W	no	NWS
Kunia	806	Del Monte Corp.	860	1923	--	no	DLNR
Kunia Station	740.4	Oahu Sugar Co.	2,850	--	D, H	yes	DLNR
Leilehua	805	Del Monte Corp.	980	1924	--	no	DLNR
Lower Luakaha	782	Board of Water Supply	880	1890	D	no	DLNR
Lualualei	804	NWS	113	1925	D, H	yes	NWS
Luluku	781.7	NWS	240	1967	D, H	yes	NWS
Makaha Country Club	800	Capital Investment	440	1936	D, H	no	NWS
Makaha Stream	842.1	USGS	957	1959	D, H	no	DLNR
Manoa	712.1	Charles Cooke	220	1947	D	no	NWS
Manoa	714.1	C.H. Speigelberg	320	1947	D	no	DLNR
Manoa Lyon Arbor.	785.2	Lyon Arboretum	500	--	D, H	yes	NWS
Manoa Tunnel	716	Board of Water Supply	650	1927	D	no	NWS
Maunawili	787.1	HSPA	395	1991	D, H	yes	NWS
Maunawili Circle	790.6	Ms. Dorothy Bickneil	110	1955	D	no	DLNR
Mililani	820.6	NWS	760	1988	D, H	yes	NWS
Moanalua	770	John A. Roxburgh	20	1901	D	no	NWS
Moanalua nr. Kaneohe	772.3	USGS	1,100	1968	D, H	no	DLNR
Moanalua Stream	772	USGS	338	1926	D, H	no	DLNR
Moanalua Stream	772.6	USGS	660	1968	D, H	no	DLNR
Moanalua Stream	772.5	NWS	230	1979	D, H	yes	NWS
Moanalua Trib.	772.4	USGS	1,150	1968	D, H	no	DLNR
Mokulama	794	Waimanalo Irrigation	20	1894	--	no	DLNR
Mount Kaala	844	NWS	4,015	1931	D, H	no	NWS
North Halawa nr. Hon.	--	USGS	160	1983	D, H	no	DLNR
North Halawa Str.	772.1	USGS	320	1953	D, H	no	DLNR
Niu Valley	723.8	NWS	140	1973	D, H	yes	NWS

Table 27. Active rain gages on the island of Oahu, Hawaii, March 1993--Continued

Station name	State key number	Observer	Altitude of gage (feet)	First year of record	Recording frequency	Real time data	Coordinating agency
Nuuanu Pali	786	Board of Water Supply	1,150	1927	W	no	DLNR
Nuuanu Reservoir 4	783	Board of Water Supply	1,048	1905	D	no	NWS
Nuuanu Reservoir 5	775	Board of Water Supply	410	1890	W	no	NWS
Nuuanu Upper	782.3	NWS	780	1973	D, H	yes	NWS
Old Pali Road	783.3	R.W. Power	710	1955	D	no	DLNR
Olomana Fire Stn.	790.7	NWS	20	1991	D, H	yes	NWS
Opaeula	870	Waialua Sugar Co.	1,060	1902	D, H	no	NWS
Pacific Heights	706	Board of Water Supply	680	1926	W	no	DLNR
Paiko Drive	723.4	D.L. Grubb	10	1959	D	no	NWS
Pali Golf Course	788.1	Dept. of Parks and Rec.	480	1959	D	no	NWS
Palisades Res.	835.2	NWS	860	1980	D, H	yes	NWS
Palolo Fire Stn.	721.2	NWS	380	1991	D, H	yes	NWS
Palolo Valley	718	Board of Water Supply	995	1926	D	no	NWS
Pauoa Flats	784	Board of Water Supply	1,640	1926	D	no	NWS
Pearl City CC	760.2	Pearl City Country Club	220	1942	D, H	no	NWS
Poamoho	865	Del Monte Corp.	940	1922	--	no	DLNR
Poamoho Exp. Farm	855.2	NWS	680	1973	D, H	yes	NWS
Poamoho RG No. 1	883.12	USGS	2,480	1967	D, H	no	DLNR
Poamoho RG No. 2	882.4	USGS	1,960	1967	D, H	no	DLNR
Poamoho RG No. 3	882.3	USGS	1,850	1967	D	no	DLNR
Pump 7	742	Oahu Sugar Co.	45	1923	--	no	DLNR
Punaluu Pump	905.2	D. Fujii	20	1971	D, H	yes	NWS
Punaluu RG	884.3	USGS	750	1967	D	no	DLNR
Punchbowl Crater	709	National Memorial Cemetary	360	1950	D	no	NWS
Pupukea Heights	896.4	Jack Wheeler	900	1968	D, H	no	NWS
Pupukea Road RG	897.9	USGS	1,160	1967	D, H	v	DLNR
Puu Manawahua	725.6	Richard Feiner	1,690	1977	D	no	NWS
Reservoir 10 OSC	727	Oahu Sugar Co.	30	1911	--	no	DLNR
Reservoir 6 OSC	732	Oahu Sugar Co.	90	1904	--	no	DLNR
Reservoir 9 OSC	737	Oahu Sugar Co.	210	1924	--	no	DLNR
Rock Pile	751.2	Oahu Sugar Co.	25	1962	--	no	DLNR
S. Fork Waihee	839.9	USGS	616	1962	D	no	DLNR
Sacred Falls	883.13	DLNR Climatology	2,650	1991	D, H	yes	DLNR
Tantalus 2	780.5	Robert E. White	1,330	1948	D	no	NWS
Tantalus mauka	780.3	Charles Wichman	1,600	1953	D	no	DLNR
University of Hawaii	713	University of Hawaii	79	1918	D	no	NWS
Upper Wahiawa	874.3	Wayne Jones	1,045	1954	D	no	NWS
Wahiawa Dam	863	Waialua Ag.	855	1905	D, H	no	NWS
Waiahole	837	Waiahole Irrigation Co.	745	1916	D, H	no	NWS
Waialae Kahala	715	Waialae Country Club	10	1921	D	no	NWS
Waialae Kahala	722.5	Wilfred H. Paul	15	1965	D	no	DLNR
Waialua	847	Waialua Sugar Co.	15	1901	D, H	no	NWS
Waianae	798.2	Ben Mays	50	1970	D	no	NWS
Waianae Kawiwi	801.1	Mountain View Dairy	40	1970	D, H	yes	NWS
Waiawa	836	Waiahole Irrigation	800	1916	M	no	NWS

Table 27. Active rain gages on the island of Oahu, Hawaii, March 1993--Continued

Station name	State key number	Observer	Altitude of gage (feet)	First year of record	Recording frequency	Real time data	Coordinating agency
Waiawa C.F.	834.13	NWS	770	1992	D, H	yes	NWS
Waihee	837.5	William R. Kramer	110	--	D	no	NWS
Waihee Pump	839.8	NWS	196	1992	D, H	yes	NWS
Waihee Ridge CRS	839.11	USGS	520	1962	D	no	DLNR
Waikane Stream	886.6	USGS	75	1959	D	no	DLNR
Waikiki	717.2	Honolulu Zoo	10	1957	D	no	NWS
Wailupe Valley School	723.6	Wailupe Valley School	180	1966	D, H	no	NWS
Waimanalo	700	Oahu Sugar Co.	75	1902	--	no	DLNR
Waimanalo Exp.	795.1	U. H. Waimanalo Exp. Farm	60	1950	D	no	NWS
Waimanalo Stream	794.3	USGS	20	1967	D, H	no	DLNR
Waimanalo-Nonoki	795.2	Waimanalo Exp. Farm	100	1969	D, H	yes	NWS
Waimea	892	Waialua Ag.	420	1916	D, H	no	NWS
Waimea Arboretum	892.2	Keith R. Woolliams	40	--	D	no	NWS
Waipahu	750	Waiahole Water Co.	59	1897	D	no	NWS
Waipio Heights	824.2	NWS	410	1988	D, H	yes	NWS
Whitemore	873.1	Dole Package Food	990	1948	D	no	DLNR
Wilhelmina Rise	721	Board of Water Supply	1,100	1927	D	no	NWS
Wilson Tunnel	777.3	NWS	1,050	1969	D, H	yes	NWS

Table 28. Active rain gages on the island of Molokai, Hawaii, March 1993

[H, hourly: D, daily: W, weekly: M, monthly: --, unknown: NWS, National Weather Service: DLNR, Hawaii Department of Land and Natural Resources: USGS, U.S. Geological Survey. Source of data: unpublished files of NWS and DLNR.]

Station name	State Key number	Observer	Altitude of gage (feet)	First year of record	Recording frequency	Real time data	Coordinating agency
Halawa Valley	542.9	Hal Newsome	10	1980	D	no	NWS
Kakaako Gulch	551.5	USGS	380	1964	D, H	no	DLNR
Kalaupapa	563	Kalaupapa Settlement	30	1933	D	no	NWS
Kamalo	542.1	NWS	20	1992	D, H	yes	NWS
Kaunakakai	536	Molokai Ranch	12	1931	M	no	NWS
Kaunakakai mauka	536.5	Molokai General Hospital	70	1965	D, H	yes	NWS
Keoneleele Pens	551	Molokai Ranch	560	1933	M	no	NWS
Kepuhi Sheraton	550.02	Kaluakoi Golf Course	20	1981	D, H	no	NWS
Kualapuu	534	CPC	870	1900	D, H	no	NWS
Kualapuu Res.	531.1	Department of Agriculture	800	1969	D	no	DLNR
Molokai AP	524	Hawaiian Airport	450	1939	D	no	NWS
Pelekunu Stream	543.1	USGS	700	1969	D	no	DLNR
Puu-O-Hoku Ranch	542.1	Puu-O-Hoku Ranch	710	1943	D, H	no	NWS
Waikolu	540	Molokai Ranch	3550	1930	M	no	NWS
Wailolu Stream	540.1	USGS	900	1957	D	no	DLNR

Table 29. Active rain gages on the island of Maui, Hawaii, March 1993

[H, hourly: D, daily: W, weekly: M, monthly: --, unknown: NWS, National Weather Service: DLNR, Hawaii Department of Land and Natural Resources: USGS, U.S. Geological Survey. Source of data: unpublished files of NWS and DLNR.]

Station name	State key number	Observer	Altitude of gage (feet)	First year of record	Recording frequency	Real time data	Coordinating agency
Auwahi	252	Ulupalakua Ranch	2,060	1925	D	no	NWS
Central Crater	259.4	Haleakala National Park	7,320	--	--	no	DLNR
Field 14 MPC	465	Maui Pineapple Co.	725	1935	D	no	DLNR
Field 28 MPC	471	Maui Pineapple Co.	750	1944	M	no	DLNR
Field 34 MPC	470	Maui Pineapple Co.	340	1937	D	no	DLNR
Field 37 WSC	386.5	Wailuku Agribusiness	440	1971	D	no	DLNR
Field 46	474	Maui Pineapple Co.	1,045	1962	D, H	no	NWS
Field 64 MPC	496	Maui Pineapple Co.	530	1937	W	no	DLNR
Field 65 MPC	495	Maui Pineapple Co.	760	1940	W	no	DLNR
Field 218 MPC	487.2	Jeff Pittman	200	--	D	no	DLNR
Field 242 MPC	430	Jeff Pittman	1,160	1934	D	no	DLNR
Field 252 MPC	425	Jeff Pittman	1,200	1939	--	no	DLNR
Field 263 MPC	421	Jeff Pittman	660	1948	--	no	DLNR
Field 271 MPC	424	Jeff Pittman	1,290	1933	--	no	DLNR
Field 273 MPC	427	Jeff Pittman	1,700	1927	--	no	DLNR
Field 290 MPC	327	Jeff Pittman	2,620	1933	--	no	DLNR
Field 291 MPC	325	Jeff Pittman	1,960	1933	--	no	DLNR
Field 46	474	Maui Pineapple Co.	1,045	1962	D, H	no	NWS
Garcia	323	Haleakala Ranch	2,490	1946	--	no	DLNR
Gomi	330	Haleakala Ranch	3,500	1912	--	no	DLNR
Haelaau	477	Maui Land and Pineapple	2,980	1932	M	no	NWS
Haiku	488.7	NWS	350	1984	D, H	yes	NWS
Haleakala Exp. Farm	434	IBSNAT Projects	2,100	1921	D	no	NWS
Haleakala R. S.	338	Haleakala National Park	7,080	1939	D	no	NWS
Haleakala Ranch	432	Haleakala Ranch	1,850	1891	M	no	NWS
Haliimaile	423	Maui Land and Pineapple	1,070	1928	D	no	NWS
Hamakuapoko	485	Hawaiian Com. and Sugar	320	1898	D	no	NWS
Hana Airport	355	Princeville Airways	61	1951	D,H	no	NWS
Hayashi	391	Wailuku Agribusiness	340	1932	--	no	DLNR
Holua Cabin	259.5	Haleakala National Park	281	1964	M	no	NWS
Honokohau	480	Maui Land and Pineapple	870	1907	M	no	NWS
Honokohua	493	Maui Land and Pineapple	220	1912	D	no	NWS
Honolua Field 49	494	Maui Land and Pineapple	125	1893	D	no	NWS
Honomanu	451	East Maui Irrigation Co.	1,700	1904	--	no	DLNR
Honomanu Gulch	341	Haleakala Ranch	6,280	1933	M	no	NWS
Hoolawa	441	East Maui Irrigation Co.	640	1936	--	no	DLNR
Hopoi Reservoir	387	Wailuku Agribusiness	380	1933	--	no	DLNR
Iao Valley	387.1	Wailuku Agribusiness	290	1955	--	no	DLNR
Iki 8	348.3	East Maui Irrigation Co.	1,650	--	M	no	DLNR
Kahakuloa	482.4	NWS	1,100	1992	D, H	yes	NWS
Kahakuloa Mauka	482.3	Edward Chang	650	1992	D, H	no	NWS
Kahoma Intake	374	Pioneer Mill Co.	2,000	1910	M	no	NWS
Kahului WSO AP	398	NWS	40	1944	D, H	no	NWS

Table 29. Active rain gages on the Island of Maui, Hawaii, March 1993--Continued

Station name	State key number	Observer	Altitude of gage (feet)	First year of record	Recording frequency	Real time data	Coordinating agency
Kailiili	436	East Maui Irrigation Co.	2,520	1949	M	no	NWS
Kailua	446	East Maui Irrigation Co.	700	1904	D	no	NWS
Kalialinui	325.1	Haleakala Ranch	1,950	1913	--	no	DLNR
Kamaole Ah Mee	263	Haleakala Ranch	1,980	1936	--	no	DLNR
Kamaole Mauka	265	Haleakala Ranch	2,690	1936	--	no	DLNR
Kamaole Pen	262	Haleakala Ranch	1,720	1945	--	no	DLNR
Kanahena	248	Ulupalakua Ranch	850	1925	--	no	DLNR
Kapalua West Maui AP	458.3	Kapalua West Maui	240	1987	D	no	NWS
Kauaula Intake	375	Pioneer Mill Co.	1,585	1912	M	no	NWS
Kaulaula	254.2	Ulupalakua Ranch	3,800	1965	W	no	DLNR
Kaupakulua	435.3	James Neiss	1,400	1988	D, H	no	NWS
Kaupo Ranch House	259	Kaupo Ranch	1,020	1930	D, H	no	NWS
Keahua	410	Hawaiian Com. and Sugar	480	1946	D	no	NWS
Keanae	346	East Maui Irrigation Co.	980	1904	M	no	NWS
Keawakapu	260.2	Haleakala Ranch	20	1951	D	no	DLNR
Keeke	257.2	Kaupo Ranch	850	1959	--	no	DLNR
Keoneio	248.2	Ulupalakua Ranch	10	1971	--	no	DLNR
Kepuni Gulch	255	USGS	740	1964	D, H	no	DLNR
Kihei	311	Hawaiian Com. and Sugar	160	1903	D	no	NWS
Kihei No. 2	311.5	NWS	140	1992	D, H	yes	NWS
Kula Branch Stn.	324.5	U.H. Maui Ag. Research	3,050	1979	D, H	yes	NWS
Kula Hospital	267	Kula Hospital	3,004	1916	D	no	NWS
Kulani Hakoi	311.3	USGS	130	1963	D, H	no	DLNR
Lahaina	361	Pioneer Mill Co.	45	1913	D, H	no	NWS
Lahainaluna	361.1	NWS	570	1976	D, H	yes	NWS
Launiupoko Intake	376	Pioneer Mill Co.	1,280	1913	M	no	NWS
Launiupoko Village	372	Pioneer Mill Co.	220	1918	D	no	NWS
Luapelani	251.1	Ulupalakua Ranch	2,880	--	--	no	DLNR
Lupi Upper	442	East Maui Irrigation Co.	1,240	1897	M	no	NWS
Mahinahina	466	Pioneer Mill Co.	715	1914	D	no	NWS
Mahinahina Camp	465.1	NWS	720	1978	D, H	yes	NWS
Makena	249	Ulupalakua Ranch	10	--	--	no	DLNR
Makena Golf Course	249.1	Makena Golf Course	100	1982	D, H	no	NWS
Mountain	331	Haleakala Ranch	5,500	1946	M	no	DLNR
Naholoku	259.1	Kaupo Ranch	2,300	1959	--	no	DLNR
Nakalalua	481	Maui Pineapple Co.	4,450	1933	--	no	DLNR
Nakalele Field 60	497	Maui Pineapple Co.	340	1937	D	no	NWS
Nakula	257.1	Kaupo Ranch	1,570	1959	--	no	DLNR
Nuu	257	Kaupo Ranch	25	1950	--	no	DLNR
Ohe'o	258.6	Haleakala National Park	120	1970	D	no	NWS
Olinda	329.2	Mrs. James Lindsey	3,850	--	--	no	DLNR
Olinda No. 1	332	East Maui Irrigation Co.	4,127	1910	W	no	NWS
Olowalu	296.1	Pioneer Mill Co.	30	1950	D	no	NWS
Olowalu Stream	297	USGS	130	1964	D, H	no	DLNR
Paakea	350	East Maui Irrigation Co.	1,260	1904	D, H	no	NWS

Table 29. Active rain gages on the Island of Maui, Hawaii, March 1993--Continued

Station name	State key number	Observer	Altitude of gage (feet)	First year of record	Recording frequency	Real time data	Coordinating agency
Paia	406	Hawaiian Com. and Sugar	170	1894	D	no	NWS
Paliku	259.3	Haleakala National Park	6,360	1941	--	no	DLNR
Papaka	248.1	Ulupalakua Ranch	980	1955	--	no	DLNR
Panileihulu	259.2	Kaupo Ranch	3,570	1960	M	no	NWS
Piiholo	433	Jeff Pittman	1,780	1928	--	no	DLNR
Pohakea Bridge	307.2	Wailuku Abribusiness	167	1953	D	no	NWS
Polipoli Springs	267.2	State Division of Forestry	6,150	1955	M	no	NWS
Pukalani	426.6	NWS	1,620	1991	D, H	yes	NWS
Puohokamoa No. 2	343	East Maui Irrigation Co.	2,980	1922	M	no	NWS
Puu Kukui	380	Maui Land and Pineapple	5,788	1928	M	no	NWS
Puukakae	321	Haleakala Ranch	1,600	1946	--	no	DLNR
Puukao	256.1	Haleakala Ranch	3,800	1953	M	no	DLNR
Puukolii	457	Pioneer Mill Co.	440	1912	D	no	NWS
Puuloa	261	Ulupalakua Ranch	1,100	1925	--	no	DLNR
Puunene	396	Hawaiian Com. and Sugar	60	1899	D	no	NWS
Rain Catchment	257.3	Haleakala National Park	515	1958	--	no	DLNR
Reservoir 1 WSC	390.1	Wailuku Agribusiness	1,100	1949	--	no	DLNR
Spreckelsville	400.2	Hawaiian Com. and Sugar	85	1952	D	no	NWS
Store	257.4	Kaupo Ranch	281	1961	W	no	DLNR
Ukulele	333	Haleakala Ranch	5,230	1904	M	no	NWS
Ukumehame	301	Pioneer Mill Co.	75	1929	D	no	NWS
Ulupalakua Ranch	250	Ulupalakua Ranch	1,900	1905	D, H	yes	NWS
Wahikuli	364	Pioneer Mill Co.	580	1912	D	no	NWS
Wailua 5	348.2	East Maui Irrigation Co.	2,000	1949	M	no	DLNR
Waiehu Camp	484	Wailuku Agribusiness	320	1910	D	no	NWS
Waihee Valley	482	Wailuku Agribusiness	300	1913	D	no	NWS
Waihee Village	483	Wailuku Agribusiness	215	1898	D	no	DLNR
Waihou	264	Ulupalakua Ranch	3,600	1930	--	no	DLNR
Waikamoi	449	East Maui Irrigation Co.	1,200	1906	M	no	NWS
Waikamoi Dam	336	Maui County DWS	4,320	1910	D, H	no	NWS
Waikapu	390	Wailuki Sugar Co.	470	1895	D, H	no	NWS
Waikapu C.C.	390.4	NWS	480	1992	D, H	yes	NWS
Wailuku	386	Wailuku Agribusiness	440	1887	D, H	yes	NWS
Waiopai	256.2	Haleakala Ranch	620	1897	D	no	DLNR
Waiopai Ranch	256	Haleakala Ranch	220	1920	D	no	NWS

Table 30. Active rain gages on the island of Hawaii, Hawaii, March 1993

H, hourly: D, daily: W, weekly: M, monthly: --, unknown: NWS, National Weather Service: DLNR, Hawaii Department of Land and Natural Resources: USGS, U.S. Geological Survey. Source of data: unpublished files of NWS and DLNR.]

Station name	State key number	Observer	Altitude of gage (feet)	First year of record	Recording frequency	Real time data	Coordinating agency
Ahualoa	215.3	Hamakua Sugar Co.	1,835	1964	W	no	DLNR
Ainahou	58	Hawaii Volcano Nat. Park	2,975	1942	--	no	DLNR
Alakahi	190	Department of Agriculture	3,875	1913	D	no	DLNR
Amauulu	89.2	Maunakea Sugar Co.	1,490	1953	W	no	NWS
Andrade	144.6	Maunakea Agriculture	650	1948	--	no	DLNR
Anuenue	209	Hamakua Sugar Co.	1,470	1964	W	no	DLNR
Cape Kumukahi	--	NWS	50	1985	D, H	yes	NWS
F 480	36.2	Ka'u Agribusiness	3,075	1962	W	no	DLNR
Field 114	202.1	Hamakua Sugar Co.	1,565	1952	W	no	DLNR
Field 138 HSC	130.2	Hamakua Sugar Co.	900	1953	--	no	DLNR
Field 328 HSC	218.2	Hamakua Sugar Co.	345	1948	--	no	DLNR
Field 330 HSC	221.2	Hamakua Sugar Co.	1,455	1950	--	no	DLNR
Field 416 HSC	222.7	Hamakua Sugar Co.	440	1951	--	no	DLNR
Field 427 HSC	118.4	Hamakua Sugar Co.	2,280	1968	--	no	DLNR
Field 439 HSC	118.2	Hamakua Sugar Co.	1,770	1951	--	no	DLNR
Field E23 HSC	220.3	Hamakua Sugar Co.	900	1955	D	no	DLNR
Field E3 HSC	216.5	Hamakua Sugar Co.	920	--	--	no	DLNR
Haina	214	Hamakua Sugar Co.	461	1885	D	no	NWS
Hakalau	142	Hamakua Sugar Co.	160	1892	D	no	NWS
Halemaumau	52	Hawaiian National Park	3,640	1932	M	no	NWS
Halepohaku	111	Maunakea Obs.	9,220	1939	M	no	NWS
Haw'n OC VM EST	3.9	Davis Isbell	1,900	1956	D, H	no	NWS
Hawi	168	Hawi A&E Corp.	580	1888	D, H	no	NWS
HI Vol. Nat. Pk HQ	54	Hawaiian National Park	3,871	1913	D, H	no	NWS
Hilea Gulch Trib.	12.13	USGS	3,000	1967	D, H	no	DLNR
Hilo A&F	85.0	Div. of Forest & Wildlife	35	1926	D	no	DLNR
Hilo WSO AP	87	NWS	30	1939	D, H	no	NWS
Holualoa	70	William Nakagawa	3,220	1919	M	no	NWS
Honaunau	27	Shigeta Tanaka	940	1938	D	no	NWS
Honaunau No. 2	27.6	NWS	1,306	1992	D, H	yes	NWS
Honohina	137	Maunakea Sugar Co.	300	1894	D	no	NWS
Honokaa	215	Hamakua Sugar Co.	1,070	1910	D	no	DLNR
Honomu Mauka	138	Maunakea Agribusiness	1,100	1939	D, H	no	NWS
Honomu Seaside	144.5	Maunakea Agriculture	130	1948	--	no	DLNR
Honuaula	71	Palani Ranch	6,250	1928	M	no	NWS
Hualalai	72	Palani Ranch	7,720	1929	M	no	NWS
Huehue	92.1	Huehue Ranch	1,960	1903	D, H	no	NWS
HVO Uwekahua	52.1	Hawaii Volcano Nat. Park	4,050	1948	--	no	DLNR
Kaalaiki	12	Ka'u Agribusiness	1,340	1939	D	no	DLNR

Table 30. Active rain gages on the island of Hawaii, Hawaii, March 1993--Continued

Station name	State key number	Observer	Altitude of gage (feet)	First year of record	Recording frequency	Real time data	Coordinating agency
Kaalaiki Airstr.	13.8	Ka'u Agribusiness	1,750	--	--	no	DLNR
Kaawaloa	29	George Schattauer	1,340	1942	D	no	NWS
Kahua Ranch HQ	176.3	Kahua Ranch Headquaters	3,240	1977	D, H	yes	NWS
Kaiaakea	132.1	Hamakua Sugar Co.	445	1967	D	no	DLNR
Kainaliu	73.2	UH Hawaii Ag. Exp. Stn.	1,500	1931	D	no	NWS
Kainaliu Beach	73.12	Wall Ranch	15	1959	M	no	DLNR
Kamakoa	192.6	NWS	2,511	1991	D, H	yes	NWS
Kamaoa Puueo	5.1	Ms. Florence Schultz	850	1983	D	no	NWS
Kamoku	203.1	Dept. of Hawaiian Homes	2,800	1962	M	no	DLNR
Kamuela 1	201.2	HAES	2,700	1964	D, H	yes	NWS
Kamuela Upper	192.7	NWS	3,040	1992	D, H	yes	NWS
Kapapala Ranch	36	Gordon Cran	2,140	1886	D	no	NWS
Kapoho Beach	93.11	James A. White	10	1969	D	no	NWS
Kapoho Landing	93.5	Dept. of Water Supply	290	1960	W	no	NWS
Kaukahoku	74.1	Wall Ranch	4,030	1956	M	no	DLNR
Kaumana	88.1	Hilo Sugar Co.	1,125	1970	D, H	no	NWS
Kawainui Lower	193	Hamakua Sugar Co.	1,080	1910	D	no	NWS
Kawela	213	Hamakua Sugar Co.	390	1890	--	no	DLNR
Ke-ahole Pt.	68.13	Nat Energy Lab Hi.	20	1970	D	no	NWS
Keaau	92	AMFAC Tropical Products	220	1901	D	no	NWS
Keaiwa Camp	22.1	Hawaiian Agribusiness	1,700	1952	D, H	no	NWS
Kealakekua	26.2	Amy Greenwell Ethnobotanical	1,450	1901	--	no	DLNR
Kealakekua No. 4	29.11	NWS	1,070	1945	D, H	no	NWS
Kealakekua T.F.	29.12	NWS	1,760	1980	D, H	yes	NWS
Keanakolu	124	Div. of Forest & Wildlife	5,280	1929	--	no	DLNR
Keanakolu Camp	124.2	State Division of Forest	5,280	1965	D, H	no	NWS
Keanuiomano Str.	190.4	USGS	2,410	1963	D, H	no	DLNR
Keaukana Forest	67.9	Dept. of Water Supply	744	1960	W	no	DLNR
Kipuka Nene	38.7	Hawaii Volcano Nat. Park	--	1971	W	no	DLNR
Kohala Mission	175.1	Iole Development	537	1890	D	no	NWS
Kioawe Lower	196	Hamakua Sugar Co.	720	1910	D	no	NWS
Kona Village	93.8	Kona Village Resort HTC	20	1967	D	no	NWS
Kukaiau	222	Hamakua Sugar Co.	840	1895	D	no	NWS
Kukuihaele HIC	199	Hamakua Sugar Co.	980	1909	D	no	NWS
Kukuihaele Mill	206	Hamakua Sugar Co.	300	1891	D	no	NWS
Kulani Camp	79	St. Dept. of Social Service	5,170	1947	D	no	NWS
Kulani Mauka	76	Mauna Loa Slope Obs.	8,300	1950	W	no	NWS
Kulani School Site	78	Mauna Loa Slope Obs.	5,735	1947	D	no	NWS
Lae Apuki	67.12	Hawaii Volcano Nat. Park	80	1989	D	no	NWS
Lalakea	202	Hamakua Sugar Co.	1,955	1910	--	no	DLNR
Lalamilo Fd. Off.	191.1	DLNR	2,615	1965	D, H	no	NWS

Table 30. Active rain gages on the island of Hawaii, Hawaii, March 1993--Continued

Station name	State key number	Observer	Altitude of gage (feet)	First year of record	Recording frequency	Real time data	Coordinating agency
Lamamilo Farm	191.4	HAES	2,620	1963	D	no	DLNR
Lanihau	68.2	Kona Experiment State	1,530	1930	D	no	NWS
Laupahoehoe P.D.	133.3	NWS	360	1975	D, H	yes	NWS
Lehuula	73.7	Wall Ranch	1,410	1956	--	no	DLNR
Leilani Estate	67.11	Ross Gidley	725	--	D	no	NWS
Lower Alakahi	194	Hamakua Sugar Co.	840	1910	W	no	DLNR
Lower Nienie	212.1	Dept. of Hawaiian Homes	2,745	1962	M	no	DLNR
Lower Piihonua	89.7	Louis Shuster	815	1950	D, H	yes	DLNR
Lower Waima	197	Hamakua Sugar Co.	980	1913	W	no	DLNR
Mahailua	92.6	Huehue Ranch	960	1986	W	no	NWS
Makahalau	103	Parker Ranch	3,820	1971	D	no	NWS
Makino	11	Ka'u Agribusiness	120	1939	--	no	DLNR
Manuka	2	State Divsion of Parks	1,760	1929	D	no	NWS
Mauka Reservoir	3.11	Kahuku Ranch	4,990	1983	W	no	NWS
Mauna Loa 6700	45.3	Hawaii Volcano Nat. Park	5,900	1952	--	no	DLNR
Mauna Loa Slope	39	Mauna Loa Slope Obs.	11,150	1956	D	no	NWS
Middle Pen	147.1	Hahua Ranch	1,380	1931	D	no	NWS
Milolii	2.34	Patrick Flanigan	920	1985	D	no	NWS
Moanuiahea	92.7	Huehue Ranch	2,820	1986	W	no	NWS
Moaula	17	Ka'u Agribusiness	1,950	1911	--	no	DLNR
Mountain View	91.9	James Jacobs	1,580	1901	D, H	yes	NWS
Naalehu	14	Ka'u Agribusiness	800	1890	D	no	NWS
Napoopoo	28	UH Kona Experiment Station	425	1938	W	no	NWS
New Stable	213.1	Hamakua Sugar Co.	1,125	1964	D	no	DLNR
Ookala	223	Hamakua Sugar Co.	430	1891	D, H	no	NWS
Ookala Mauka	130	Hamakua Sugar Co.	1,780	1928	--	no	DLNR
Opihihale No. 2	24.1	Tary Truman	1,270	1955	D	no	NWS
Orchid Land Est	91.5	Dept. of Water Supply	445	1960	W	no	NWS
Paauhau	217	Hamakua Sugar Co.	415	1890	D, H	no	NWS
Paauhau Airstrip	216.3	Hamakua Sugar Co.	2,075	1955	D	no	NWS
Paauilo	221	Hamakua Sugar Co.	800	1903	D	no	NWS
Paauilo Mill	218	Hamakua Sugar Co.	180	1900	D	no	DLNR
Pahala	21.0	Ka'u Agribusiness	840	1892	--	no	DLNR
Pahala Mauka	21.3	Ka'u Agribusiness	1,170	1985	D	no	NWS
Pahoa	65	AMFAC Tropical Products	565	1902	D	no	NWS
Pahoa Beacon	91.9	NWS	490	1981	D, H	yes	NWS
Pahoa Sch. Site	64	George Salazar	683	1979	D, H	no	NWS
Papaaloa Office	133	Hamakua Sugar Co.	290	1905	--	no	DLNR
Papaikou	144.1	Hamakua Sugar Co.	190	1899	D	no	NWS
Papaikou Mauka	140.1	Hamakua Sugar Co.	1,285	1913	W	no	NWS
Piihonua Camp 5	88.4	Mauna Kea Sugar Co.	1,220	1951	W	no	NWS

Table 30. Active rain gages on the island of Hawaii, Hawaii, March 1993--Continued

Station name	State key number	Observer	Altitude of gage (feet)	First year of record	Recording frequency	Real time data	Coordinating agency
PMA	216.4	Hamakua Sugar Co.	1,250	1963	D	no	DLNR
Pohakuloa	107	State Division of Forest	6,511	1938	D, H	no	NWS
Puu Loa	127	Hawaii Volcano Nat. Park	2,550	1918	D	no	DLNR
Puu Waawaa	94.1	Puu Waawaa Ranch	2,750	1894	D, H	no	NWS
Puuhonua Honaunau	27.4	U.S. Dept of International	15	1965	D	no	NWS
Puukohola Heiau	98.1	Supt Puu Heiau-NHS	140	1976	D	no	NWS
Quarry Saddle Rd.	83	USGS	4,140	1967	M	no	DLNR
S. Glenwood	55.2	Ms. Susan Carey	2,130	1980	D, H	yes	NWS
S. Kona No. 2	2.32	Walter B. Fisher	2,360	1989	D	no	NWS
Sea Mountain	12.15	Sea Mountain at Punalu'u	70	1982	D	no	NWS
South Point	5.2	NWS	953	1991	D, H	yes	NWS
Up Hamakua Ditch	185.4	USGS	4,020	1964	D, H	no	DLNR
Upolu Point USCG	159.2	U.S. Coast Guard	40	1956	D	no	NWS
Upper Nienie	110.2	Dept. of Hawaiian Homes	3,845	1962	M	no	DLNR
V 345	13.1	Ka'u Agribusiness	1,675	1953	W	no	DLNR
Vol. Golf Course	59.1	Mr. Arthur Wriston	3,000	--	--	no	DLNR
Volcano Haunani	55	Mr.Dick McBride	3,740	1970	--	no	DLNR
Waiaha Str.	70.7	USGS	2,580	1960	M	no	DLNR
Waiakea SCD	88.2	Shinichi Kaneshiro	1,050	1953	D	no	NWS
Waiakea-Uka	85.2	NWS	1,000	1977	D, H	yes	NWS
Waikoloa	95.8	Transcontinental Devl.	900	1975	M	no	NWS
Waikoloa Beach Res.	95.9	Transcontinental Devl.	50	1989	D	no	NWS
Wailoloa Res. No. 6	190.5	Department of Agriculture	3,310	1964	D	no	DLNR
Waimea Res.	192.6	Department of Agriculture	2,970	1957	D	no	DLNR
Waipunaula	26.3	Mr. George Brenner	2,320	1969	D	no	DLNR
Waiubata	13	Ka'u Agribusiness	1,375	1939	--	no	DLNR
Wood Valley	35.6	Ka'u Agribusiness	2,200	1955	--	no	DLNR