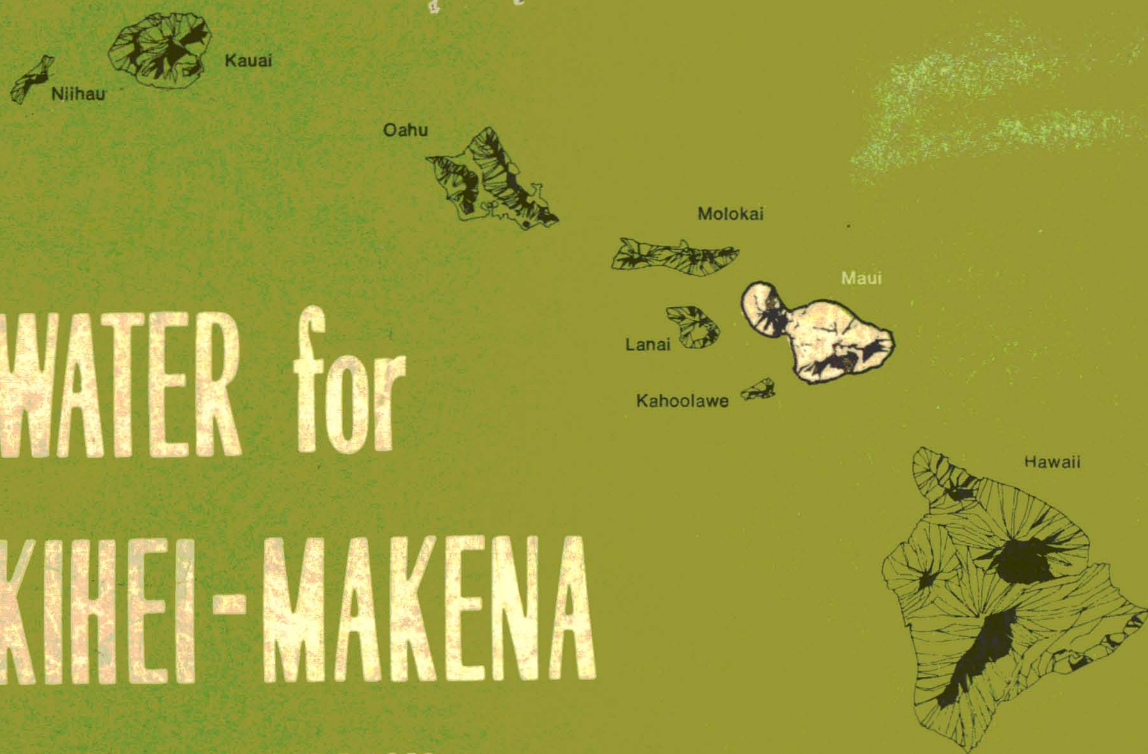


WATER for KIHEI-MAKENA

ISLAND OF MAUI

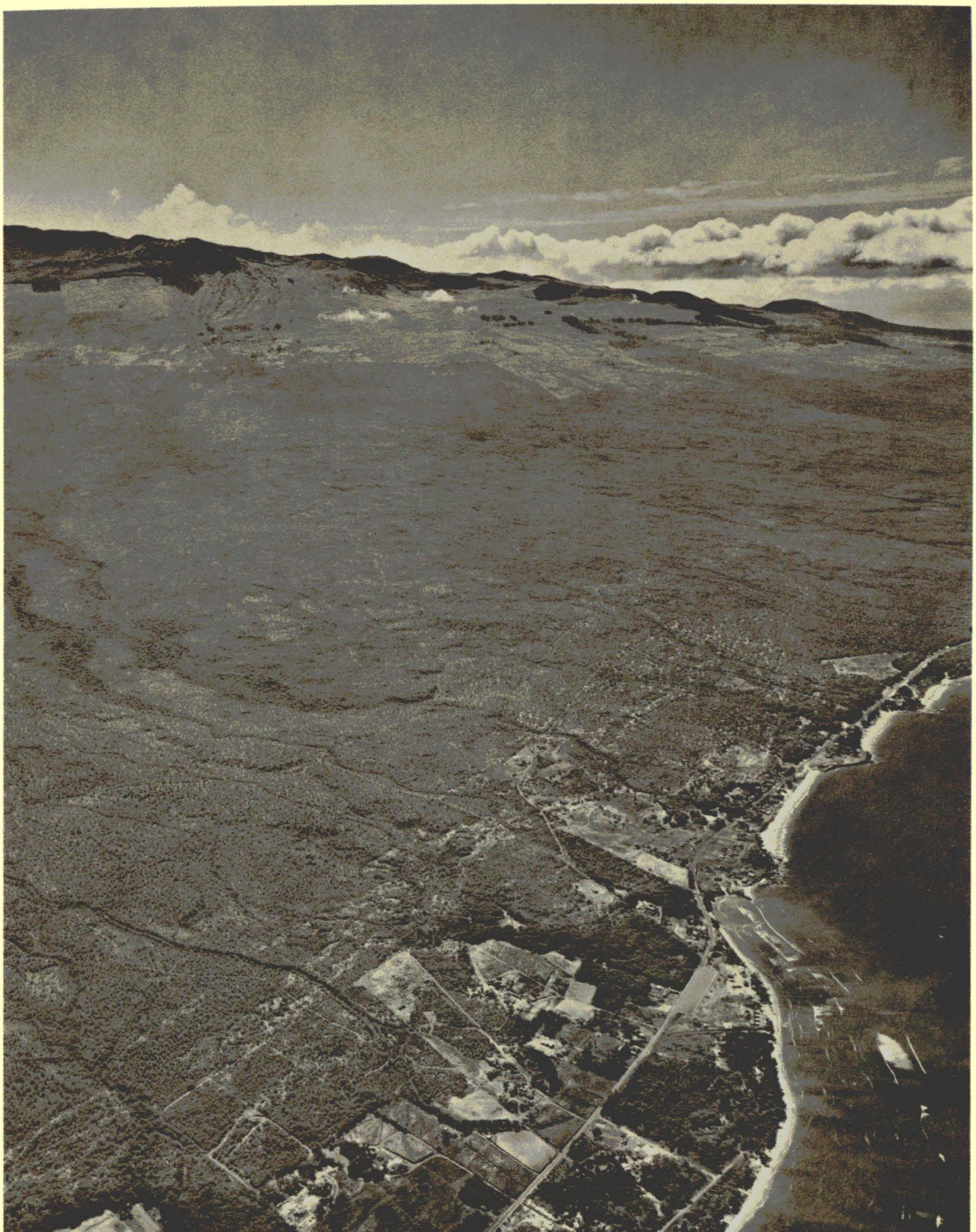
prepared for

DEPARTMENT OF WATER SUPPLY
COUNTY OF MAUI

by

DEPARTMENT OF LAND AND NATURAL RESOURCES
Division of Water and Land Development
State of Hawaii

Report R38



Leeward East Maui—Kamaole Homesteads in foreground

Water for Kihei-Makena

ISLAND OF MAUI

PREPARED FOR

DEPARTMENT OF WATER SUPPLY

County of Maui

BY

Hawaii.

DEPARTMENT OF LAND AND NATURAL RESOURCES
Division of Water and Land Development
State of Hawaii

Report R38

Honolulu, Hawaii

October 1970

COUNTY OF MAUI

ELMER F. CRAVALHO, Mayor

BOARD OF WATER SUPPLY

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CONVEYANCES
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STATE PARKS
WATER AND LAND DEVELOPMENT

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P. O. BOX 621
HONOLULU, HAWAII 96809

November 1970

Chairman and Members
Board of Water Supply
County of Maui
P.O. Box 547
Kahului, Hawaii 96732

Gentlemen:

At your request, we have examined the water situation at the Kihei-Makena area and wish to submit herewith the results of our studies to formulate a plan of water development for the area.

Our evaluation indicates that in view of the lack of developable quantities of potable water within the coastal service area, future supplies of water would have to be developed elsewhere and brought into the area.

We have recommended a plan of water development based on a major supply source just outside of the service area, in Upper Kihei, where an exploratory well is presently being drilled to test aquifer potential. In addition, we have recommended an alternative plan based on the development of supply sources in windward West Maui (priority development given a site in Waikapu) in the event the Upper Kihei-based plan proves infeasible, because of source limitations or otherwise, to implement. Both plans are amenable to future adjustments, allowing for the integrating of elements according to conditions then prevailing.

We hope that this report will prove valuable in preparing for growth in the Kihei-Makena area. It has been a pleasure undertaking this study for you.

Very truly yours,

BOARD OF LAND AND NATURAL RESOURCES

Sunao Kido

SUNAO KIDO
Chairman and Member

Acknowledgments

The successful completion of the studies herein reported was made possible by the splendid cooperation of many individuals and organizations. Special acknowledgment is made to the Maui County Department of Water Supply for whom this report was prepared. Mr. Carl Kaiama, its director, and members of his staff provided invaluable support. Staff members of the U. S. Geological Survey cooperated in discussing results of preliminary water resource investigations for the Wailuku District. Director Howard K. Nakamura of the Maui County Planning Department and Mr. Robert O. Ohata, its past director, provided counsel and economic data for the study area.

The preparation of this report was under the direction of Mr. James Y. Yoshimoto, Chief, Project Development Branch, Division of Water and Land Development, Department of Land and Natural Resources. Mr. Daniel Lum and Mr. George S. Matsumoto, Department of Land and Natural Resources, served as project geologist and project engineer, respectively.

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Summary

INTRODUCTION

The Kihei-Makena coastal area on the island of Maui is expected to grow substantially in the coming years and it is important that the servicing water facilities be improved to handle the increasing loads. This report discusses the prevailing situation, makes an analysis of water availability with respect to estimated future requirements, and presents a plan of water development for the area.

THE STUDY AREA

The study area of this report includes Central Maui and the adjacent slopes of windward West Maui and leeward East Maui. The Kihei-Makena subarea, the focus of this study, lies in leeward East Maui and stretches from Maalaea Bay to Cape Kinau at the island's southernmost tip, covering about 22 miles of shoreline.

The area's climate is relatively dry, with temperature averaging 77°F and rainfall ranging from an average 10 inches at Kihei to 20 inches at Cape Kinau. Winds are generally from the northeast, though local breezes generated by the interaction of Central Isthmus winds with Cape Kinau eddies oftentimes prevail.

A few large land owners occupy much of the lands in the study area; small land owners are situated primarily along the coastal area. Grazing lands mauka of the coastal urban-designated land belt are owned by three large ranches--Haleakala Ranch Co., Kaonoulu Ranch Co., and Ulupalakua Ranch Co., Ltd.

The shoreline land of Wailea, amounting to about half of the coastal lands zoned for urban use, is owned by Alexander and Baldwin, Inc.

Population in the study area is approximately 1500. The bulk of the residents are those who live in the area but work elsewhere, retired persons, and part-time residents.

Land now in urban use is minimal. While large tracts of surrounding land are used for cattle-raising and the growing of sugarcane, the area presently lacks the basic employment-generating industries to sustain a growing community.

Tourism is expected to significantly alter the character of the area. The economic and environmental transformation envisioned is expounded in the recently prepared County of Maui planning report, "Kihei Civic Development Plan". The population rise projected--from the 1500 persons at present to 41,300 persons in 1990--is indicative of the magnitude of growth anticipated.

WATER RESOURCES

Water resources in the study area are uniquely concentrated in the windward slope of West Maui from Waikapu to Waihee, due to a favorable combination of geology and high annual rainfall. Located in this area are abundant surface waters in perennial streams; high-level, dike-confined ground-water sources; and extensive fresh basal ground-water bodies. This singular distribution of water resources plays an important role in the water supply problems of the study area.

Elsewhere, in the Central Maui Isthmus and Kihei-Makena areas, brackish basal ground water represents the chief water resource. Northeast, in the Paia-Haiku area, abundant brackish basal water and limited fresh basal water comprise the available water resources.

In windward West Maui, roughly 60 percent (70 mgd) of estimated available surface water resources have been developed for irrigation of sugarcane, whereas only about 15 percent (9 mgd) of available fresh basal ground-water resources have been developed for irrigation and municipal uses. Throughout the rest of the study area, large brackish water sources have been developed for irrigation of sugarcane.

Estimates of water resources availability indicate that windward West Maui from Maalaea to Waihee receives an average rainfall of 230 mgd. Of this amount, about 20 percent (50 mgd) returns to the atmosphere by evapotranspiration, about 50 percent (120 mgd) becomes surface runoff in major streams, and about 30 percent (60 mgd) percolates deeply to become ground water. In the remaining areas of Central Maui and leeward slopes of East Maui, rainfall and its contribution to ground-water recharge is appreciably less, resulting in chiefly brackish water occurrence. Although reliable estimates of natural ground-water recharge are not available, it is known that about 230 mgd of irrigation water for sugarcane are imported to Central Maui from East and West Maui sources. Part of this irrigation water recharges the ground-water body and plays an important role in sustaining the extensive brackish basal water sources of Central Maui.

Indications are that major fresh water resources are singularly concentrated in windward West Maui.

EXISTING WATER FACILITIES

The Department of Water Supply of Maui County owns and operates the domestic water system in the study area. The water facilities in Kihei-Kamaole are an integral part of the Department's Wailuku District water system, which serves the towns of Wailuku and Kahului primarily.

Three wells in Mokuhau at the outskirts of Wailuku town and a tunnel in Iao Valley comprise the system's sources of supply. Two of the Mokuhau wells are equipped with pumps of 4 mgd capacity; the remaining well, with a pump of 6 mgd capacity. The Iao Tunnel water is shared by the County with Wailuku Sugar Co., which has ownership interests in the tunnel facility.

The County's water system services three general areas: (1) the Wailuku area, including Wailuku Heights, Waikapu, and the Waiehu Beach area; (2) the Kahului area, including Spreckelsville and Paia; and (3) the Maalaea-Kihei-Kamaole area. Major storage facilities servicing the above areas consist of a 1.0-million gallon tank at Mokuhau; two tanks of 2.6 million gallon combined capacity along Iao Valley Road; a 2.0-million gallon tank along Waimu Road south of Wailuku town; and a 1.0 million gallon tank near Kamaole Homesteads toward Wailea. The supply of water for the Kihei-Kamaole service area is transmitted through an 18-inch pipeline from Wailuku.

PRESENT WATER PRODUCTION AND FUTURE REQUIREMENTS

Records show a gradual rise in the quantity of water consumed in the study area. Pumpage at the Mokuhau wells during the past year (1969) has averaged 3.58 mgd and diversions from the Iao Tunnel have averaged 1.49 mgd, representing a total production approximating 1.66 times production 10 years ago in 1959.

Consumption in the Maalaea-Kihei-Kamaole area presently amounts to about 0.32 mgd.

Land planning studies predict an accelerated rate of growth for the Maalaea-Kihei-Makena area. This growth is predicated on the belief that tourism will vastly alter the area's present character. The urban Wailuku-Kahului area, on the other hand, is expected to continue its leisurely growth. Quinquennial population projections and corresponding water requirements for the Wailuku-Kahului and Kihei-Makena areas are shown below.

PROJECTED POPULATION AND MEAN WATER REQUIREMENTS

Year	WAILUKU-KAHULUI Population	WAILUKU-KAHULUI Water Reqt. (mgd)	KIHEI-MAKENA Population	KIHEI-MAKENA Water Reqt. (mgd)	COMBINED AREA Population	COMBINED AREA Water Reqt. (mgd)
1970	21,270	3.83	1,500	0.27	22,771	4.10
1975	22,600	4.06	4,860	0.88	27,460	4.94
1980	24,030	4.32	11,440	2.06	35,470	6.38
1985	25,530	4.60	21,630	3.89	47,160	8.49
1990	27,000	4.86	41,300	7.43	~~62,300~~ 68 300	12.29

In addition to the above estimates, supplemental projections of future water needs based on proposed land uses were made to determine quantities required under full land development. Utilized for this projection were the County of Maui's reports: "Urban Planning: Wailuku-Kahului", 1962, and "Kihei Civic Development Plan", 1970. Ultimate water needs derived for the Wailuku area amount to about 2.9 mgd; for the Kahului area, about 5.8 mgd; and for the coastal Kihei-Makena area, about 12.3 mgd.

PLAN FOR WATER DEVELOPMENT AND TRANSFER

Studies of the area's water resources indicate that potable water is not readily available along the coastal Kihei-Makena service area. As surface waters are lacking or committed to other uses, new source developments for municipal purposes were directed toward the use of ground water. The likely source of supply is the basal ground-water aquifer underlying windward West Maui and leeward East Maui.

Several possible sites for new ground-water developments to augment the present Iao Tunnel and Mokuhau well sources were considered:

Site 1 - Upper Kihei
Site 2 - Waikapu
Site 3 - Kepaniwai Park in Iao Valley
Site 4 - Happy Valley
Site 5 - Waiehu

The prospects of developing an adequate supply of potable water at the four sites in West Maui are good, while at the Upper Kihei site such prospects are somewhat speculative.

The attractiveness of the Kihei site's proximity to the service area has prompted the State to investigate further the site's potential as a water source. An exploratory well is currently being drilled, and the results obtained would materially determine the course of action to be followed in the water development program.

Pending the outcome of the present drilling, two primary plans are proposed as the basis for future improvements. One plan centers on the full development of a water source in Upper Kihei. The other plan proposes the further development of the basal ground-water source in windward West Maui; more specifically, at a site in Waikapu. It is conceivable that the plan followed in the future would incorporate elements of both plans, with the extent of integration hinging mainly on the quantity of good quality water available at the Upper Kihei site.

Basic to both of the above plans would be (1) the provision of an additional supply source for the Wailuku high-level service system, and (2) the enlargement in electrical capacity at the existing Mokuhau pumping station.

In essence, the plan recommended herein proposes the implementation of the Kihei-based development plan if the results of the current site exploration prove favorable, and the alternative implementation of the Waikapu-based development plan if the exploration proves otherwise.

The recommended plan would be implemented under two separate project programs, with the elements of each being initiated when the need arises. One program involves the improvements to the Wailuku high-level service system consisting of the drilling of test holes and development wells at Kepaniwai Park and the installation of the necessary pumps, controls, and connecting pipelines or the alternative installation of a booster pumping station to deliver Mokuhau well water to the Iao storage tanks. Present estimates indicate costs of capital recovery and operation and maintenance of a Kepaniwai Park source to be competitive with the cost of presently purchased tunnel water if aquifer yield is at least 2.0 mgd and dike-confined water stands no deeper than about 350 feet from ground level. Based on present rates, booster-pumped Mokuhau Well water would be more expensive than presently purchased Iao Tunnel water.

The other program involves the improvements proposed for the servicing of the Kihei-Makena area. Because of the present absence of definitive data on the adequacy of the Upper Kihei source, separate plans based on full development to meet projected requirements were prepared for the Kihei and Waikapu sources.

Listed below are the estimated construction costs, by programs and stages, for the recommended plan of development. The elements of each program, discussed in detail in the text, are additional to the existing water system and are to be implemented in conjunction with that existing system.

Program I: Improvements to Wailuku High-Level Service System

1. Kapaniwai Park Wells and appurtenant facilities.... $204,000
2. Alternative Booster-Pumping of Mokuhau Well Supply .... $ 33,000

Program II: Improvements to Kihei-Makena Service System

1. Kihei-Based Development Plan

Stage I		$1,782,500
Stage II		883,000
Stage III		2,144,000
	Total Cost	$4,809,500

2. Alternative Waikapu-Based Development Plan

Stage I		$1,782,500
Stage II		646,000
Stage III		1,954,000
Stage IV		2,388,000
	Total Cost	$6,770,500

Introduction

The Kihei-Makena coastal region, Island of Maui, a largely undeveloped area on the lee slopes of Mt. Haleakaka, is blessed with appealing natural amenities. Master planned to be developed into an attractive and balanced resort and residential community, it is an area that will see many new changes in the decades ahead.

The single most critical factor in the successful long term development of the Kihei-Makena area as a viable community lies in the availability of water. The present water facilities servicing the area, while sufficiently adequate for immediate-future needs, will require major improvements to meet long-range requirements. Recognizing that the growth potential of the Kihei-Makena lands will be limited by the extent to which its water resources are developed and delivered, the Maui County Department of Water Supply in cooperation with the State Department of Land and Natural Resources undertook a study to evaluate those resources. This report represents the end-product of the study.

The Study Area

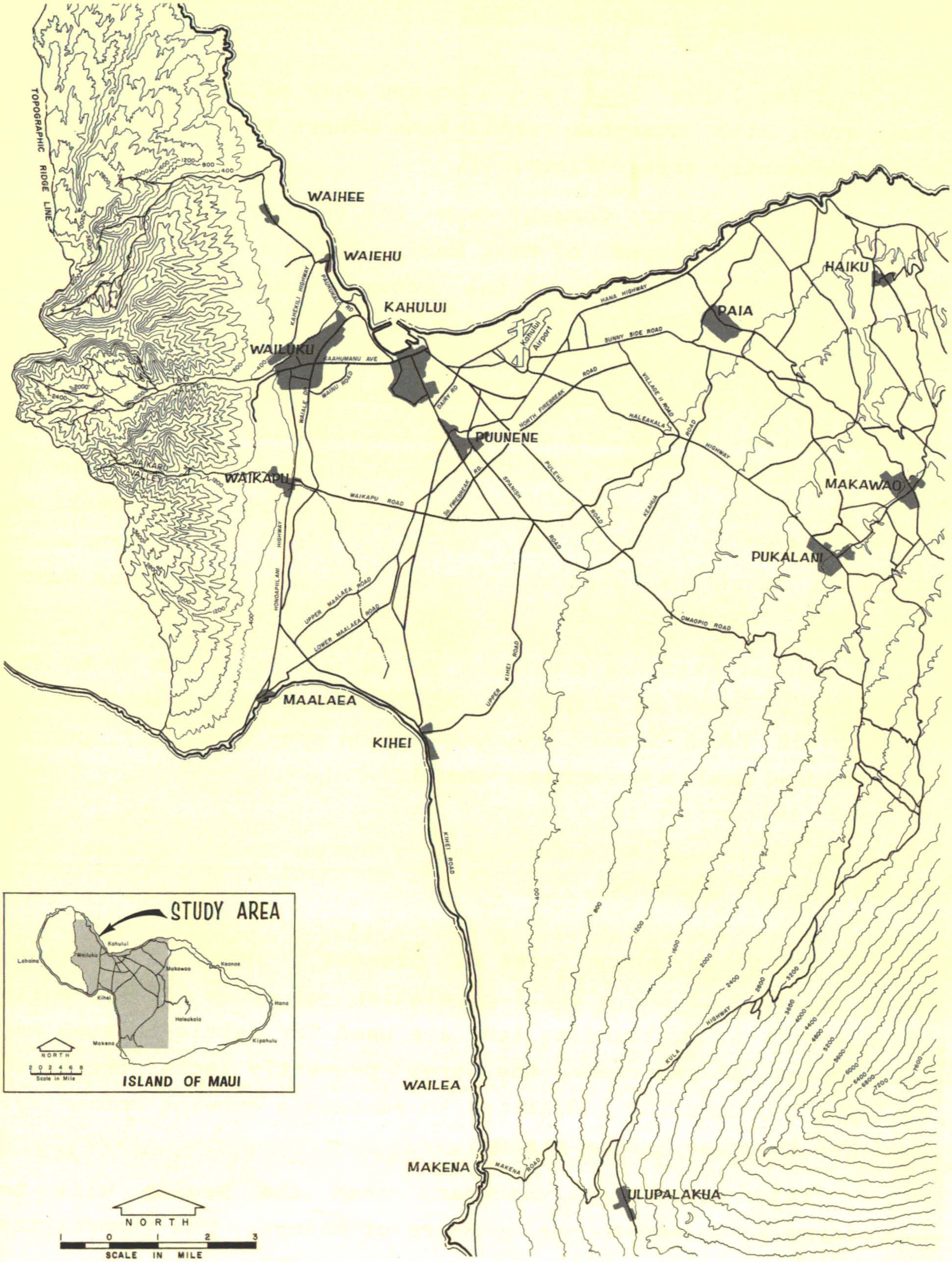
PHYSICAL GEOGRAPHY

The study area of this report includes Central Maui and the adjacent slopes of windward West Maui and leeward East Maui (Figure 1). The Kihei-Makena subarea, the focus of this study, stretches from Maalaea Bay at the south end of Central Maui to Cape Kinau at the southern tip of East Maui, covering about 22 miles of shoreline.

The Kihei-Makena terrain rises from the coast with gentle slopes of less than 10 percent. Loose stones and sparse vegetation characterize the land surface. Most of the land at present (1970) is unused or in marginal use for pasture. The soils are generally unsuited for agriculture.

Like other leeward coastal lands throughout the Hawaiian Islands, the study area enjoys a climate that is uniformly sunny and warm throughout the seasons. Temperature averages about 77°F near shore and increases slightly higher up the slopes.

Winds prevail from the northeast, with occasional breaks in the tradewind regime by southerly patterns. Of interest is a wind condition peculiar to the Kihei-Makena area. The tradewind funneling at increased velocity through the low Central Isthmus between West and East Maui fans out as it reaches Maalaea Bay and with only slightly diminished velocity continues southward until it meets the eddies of trades rounding the southern slopes of East Maui. The resulting interaction of winds produces capricious winds from Kamaole to Cape Kinau.



LOCATION MAP

Figure 1

LAND OWNERSHIP

A few large land owners occupy much of the lands in the study area, with numerous small land owners situated primarily in the community areas (Figure 2).

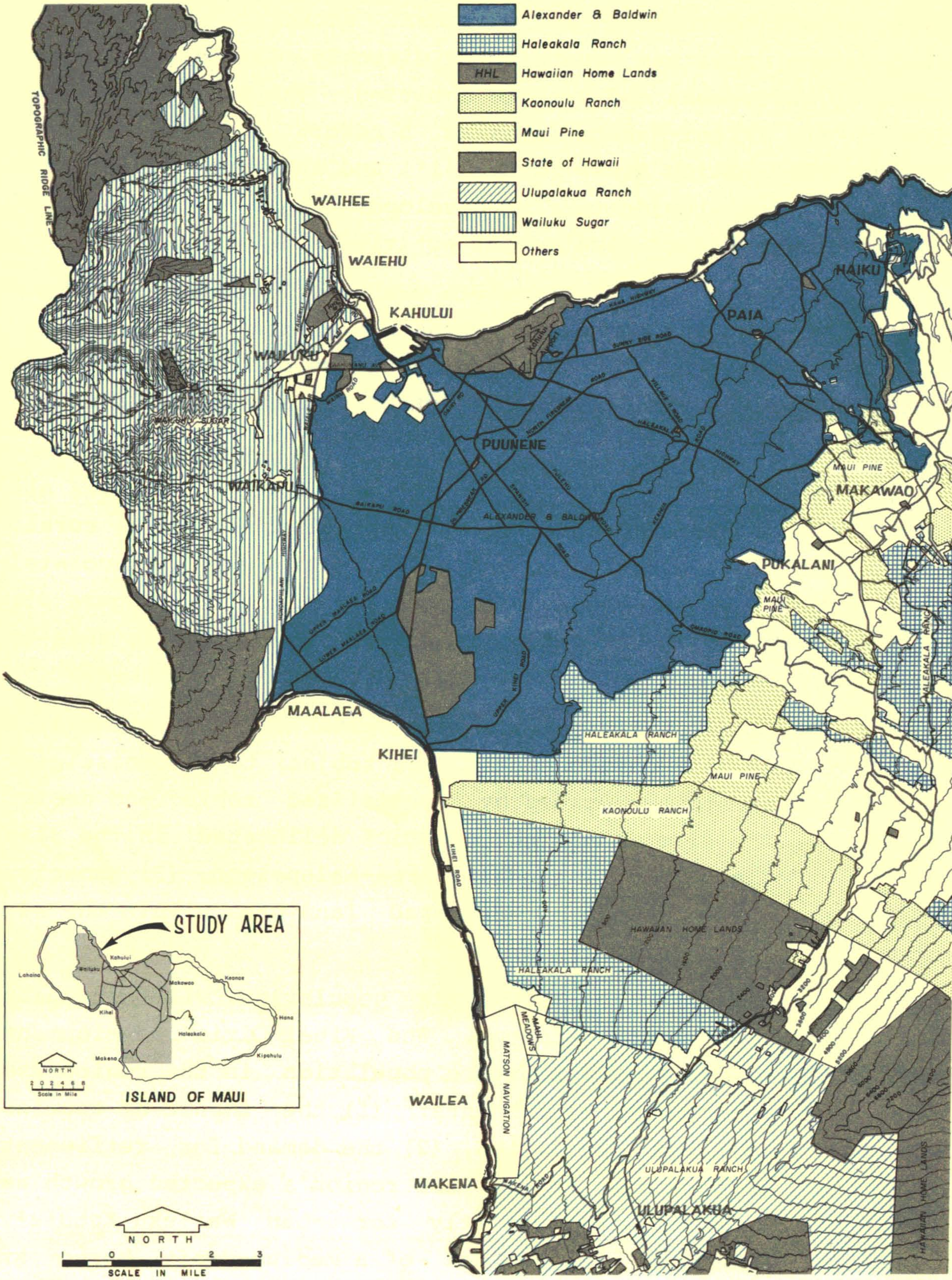
Wailuku Sugar Company owns the bulk of watershed lands on the windward slopes of West Maui. A large portion of the Central Isthmus, outside of the urban centers of Wailuku and Kahului and lands fronting Maalaea Bay, belong to HC&S (Alexander and Baldwin, Inc.). Along the coast from Kihei to Kamaole land parcels are small and ownership is scattered. The Wailea land to the south is owned by Matson Navigation Company (Alexander and Baldwin, Inc.). Lands along the coast from Makena to Ahihi Bay belong to small owners. The grazing lands mauka of the Kihei-Ahihi coastline are owned by three large ranches--Haleakala Ranch Co., Kaonoulu Ranch Co., and Ulupalakua Ranch Co., Ltd.

Almost half of the Kihei-Makena coastal lands zoned for urban use is owned by Alexander and Baldwin, Inc. A substantial acreage of beach-front property to be set aside for public recreational use is government-owned.

POTENTIAL FOR GROWTH

The Kihei-Makena area is presently composed of scattered residences and a small population of about 1,500. While large tracts of surrounding land are used for cattle raising and the growing of sugarcane, the area presently lacks the basic employment-generating industries to sustain a growing community. Land now in urban use is minimal.

There are signs, however, that the region will be increasingly subject to the dynamics of change. The recognition



LAND OWNERSHIP

Figure 2

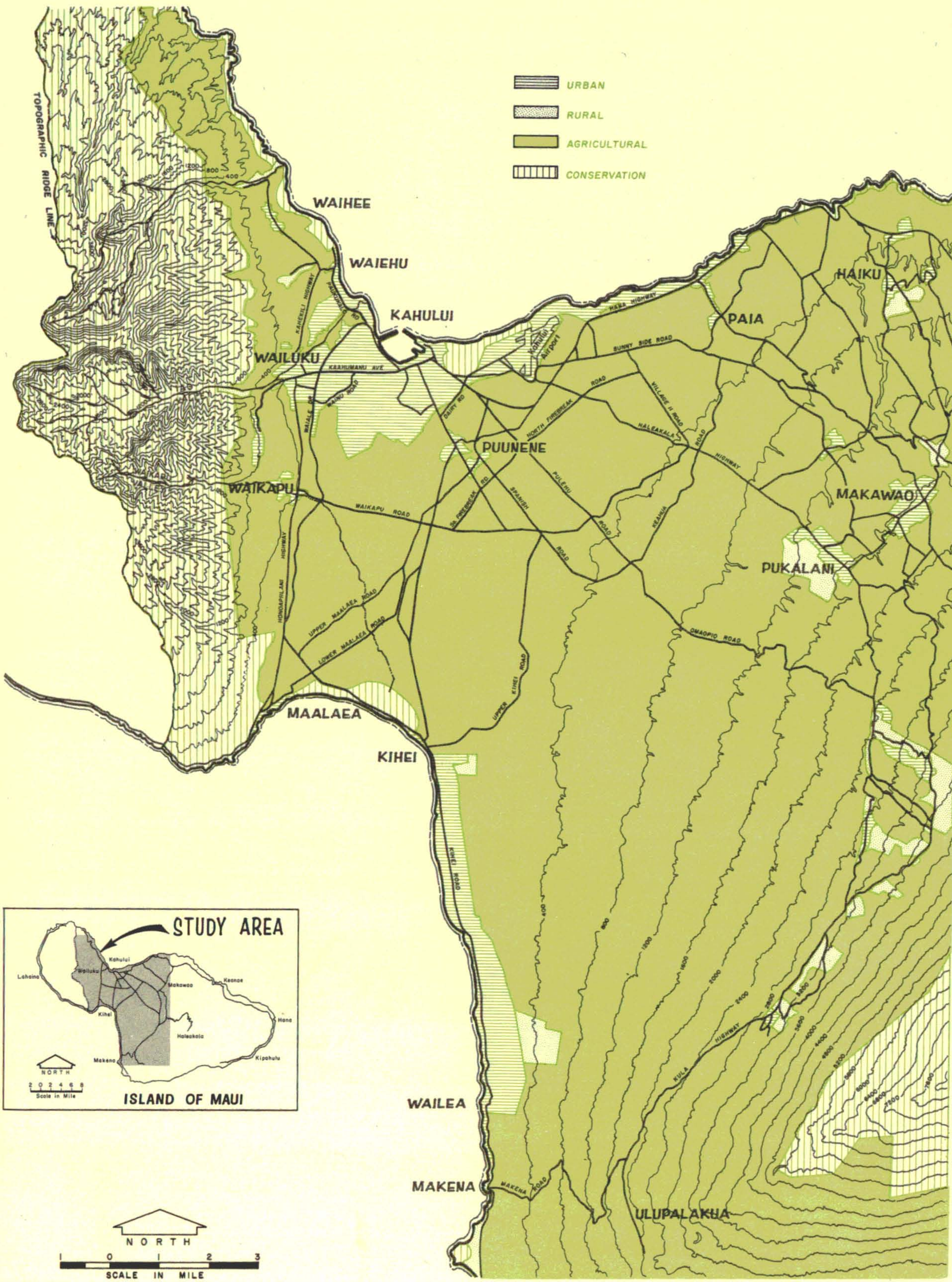
of the resort potential and attendant economic impact of the Kihei-Makena area has contributed directly to the growing interest by government and private entities. The State's designation of the Kihei-Makena area as a resort region (reference "Visitor Destination Areas in Hawaii") and subsequent government programs for statewide tourism development have motivated private interests toward development activities.

The basic guide for growth was developed by the County of Maui through its recently prepared planning report, "Kihei Civic Development Plan". The largely undeveloped lands afforded County planners a rare chance to establish firm criteria at the outset for an environment largely undespoiled.

Under the State's Land Use Law, which classifies all land in the State according to four general uses--urban, rural, agriculture, and conservation--a good portion of the coastal Kihei-Makena area has been designated for urban use (Figure 3). Within this broad urban category of use, the County is able to designate more specific land uses and development standards.

The Kihei Civic Development plan divides the region into five community environments, each subject to a precise plan of development to be guided by specialized zoning and design standards. The five planning district delineated in the plan are: (1) Maalaea, (2) Kihei Wharf Area-Kalepolepo, (3) Kamaole, (4) Wailea, and (5) Makena. Proposed land uses within the regional plan are shown in Figure 4.

A sharp rise in the area's population will accompany the expected change in economy. The Kihei Civic Development Plan's attempt to forecast future population in the region was based on three major determinants: (1) the impact of tourism and visitor-oriented facilities, (2) the demand for retirement or second family homes, and (3) the region's expected growth as a suburban community, particularly for urban Wailuku-Kahului. Also considered was the impact of a medium-draft harbor at



STATE LAND USE DISTRICTS

Figure 3

Maalaea Bay. The resulting projection of population indicates a rapid rate of growth, from the 1500 persons in 1970 to 41,300 in 1990.

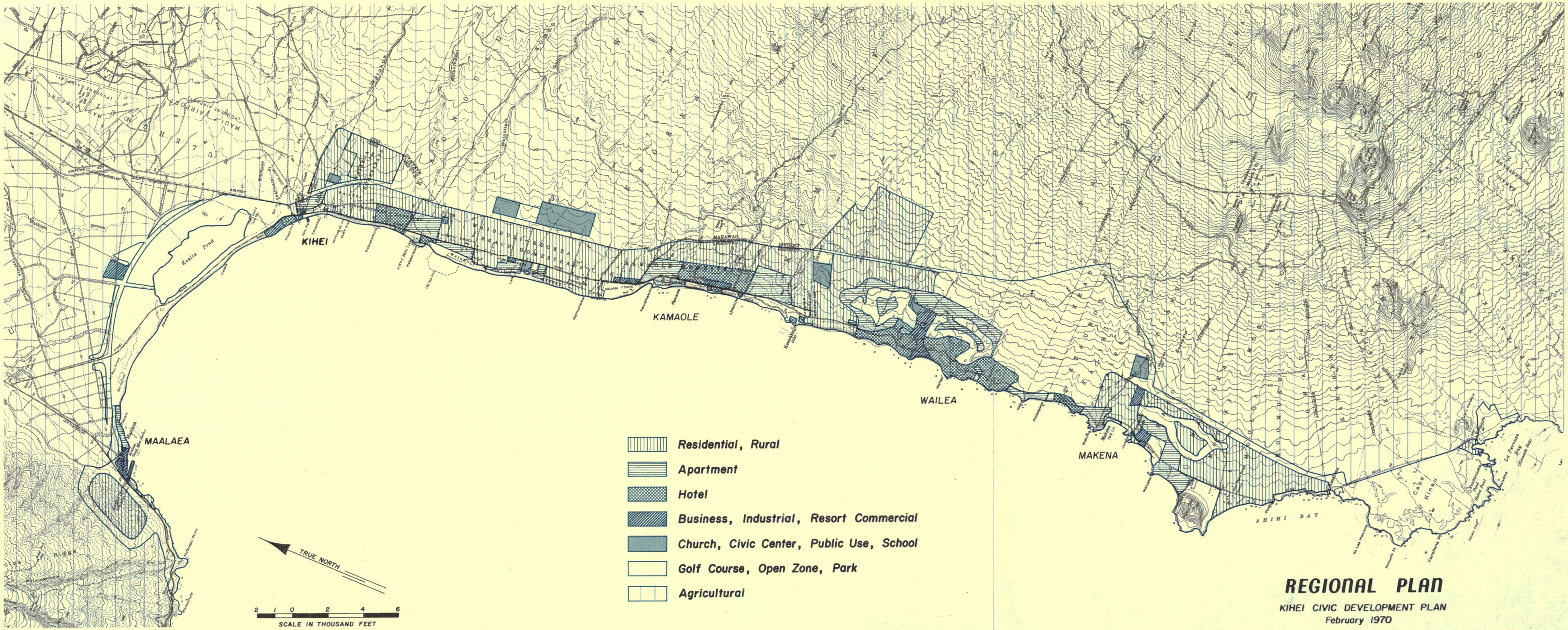

KIHEI
KAMAOLE
WAILEA
MAKENA
MAALAEA
Kealia Pond
AHIHI BAY
Residential, Rural
Apartment
Hotel
Business, Industrial, Resort Commercial
Church, Civic Center, Public Use, School
Golf Course, Open Zone, Park
Agricultural
TRUE NORTH
2 1 0 2 4 6
SCALE IN THOUSAND FEET
REGIONAL PLAN
KIHEI CIVIC DEVELOPMENT PLAN
February 1970

Figure 4

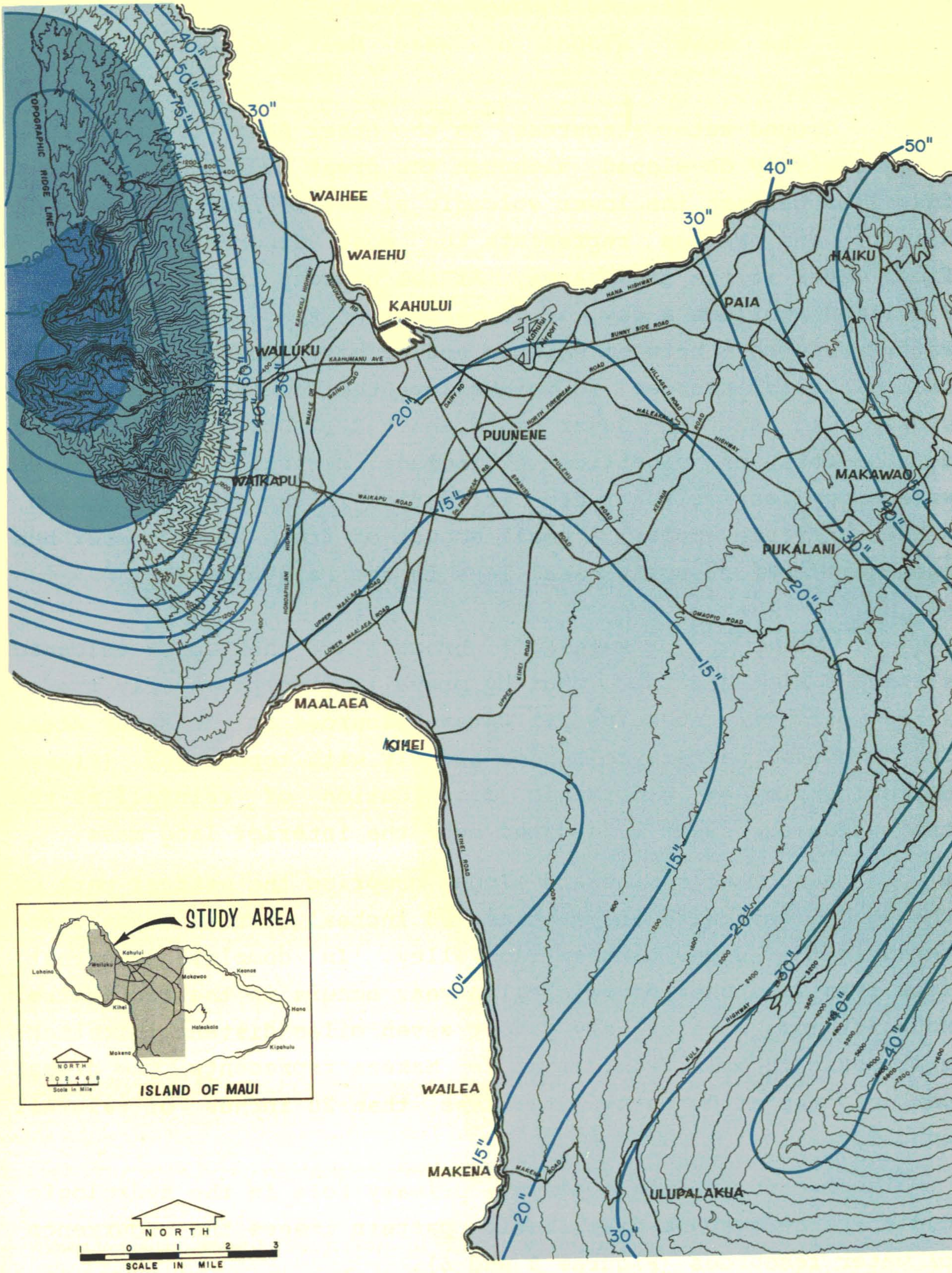
Water Resources

GENERAL

Occurrence The bulk of available water resources in the study area occurs in windward West Maui with its abundant surface waters in perennial mountain streams, its remarkably thick and extensive basal ground-water body in highly permeable basalt lava flows, and its partially developed high-level ground water bodies created by volcanic dike structures in the wet, central interior. This singular concentration of water resources in windward West Maui plays a very important role in the water supply problems of the study area.

In the central and southeast parts of the study area, namely, the Isthmus of Maui and the Kihei-Makena coastal area, respectively, available water resources consist chiefly of brackish basal ground water in East Maui lava flows. To the northeast, in the Paia-Haiku area on the northern slopes of East Maui available water resources are limited to an unexplored thin to moderately thick basal ground body which is brackish near shore, but becomes fresher inland.

Present Development The only surface water resources occur only in the perennial streams of windward West Maui and the four major streams have been extensively developed for many years as the most economical sources of irrigation water for two large sugar plantations--Wailuku Sugar Co. and Hawaiian Commercial and Sugar Co. Altogether, about 70 million gallons a day of surface water (roughly 60 percent of the estimated available streamflow) are diverted from Waihee, North and South Waiehu,



MEDIAN ANNUAL RAINFALL

Figure 5

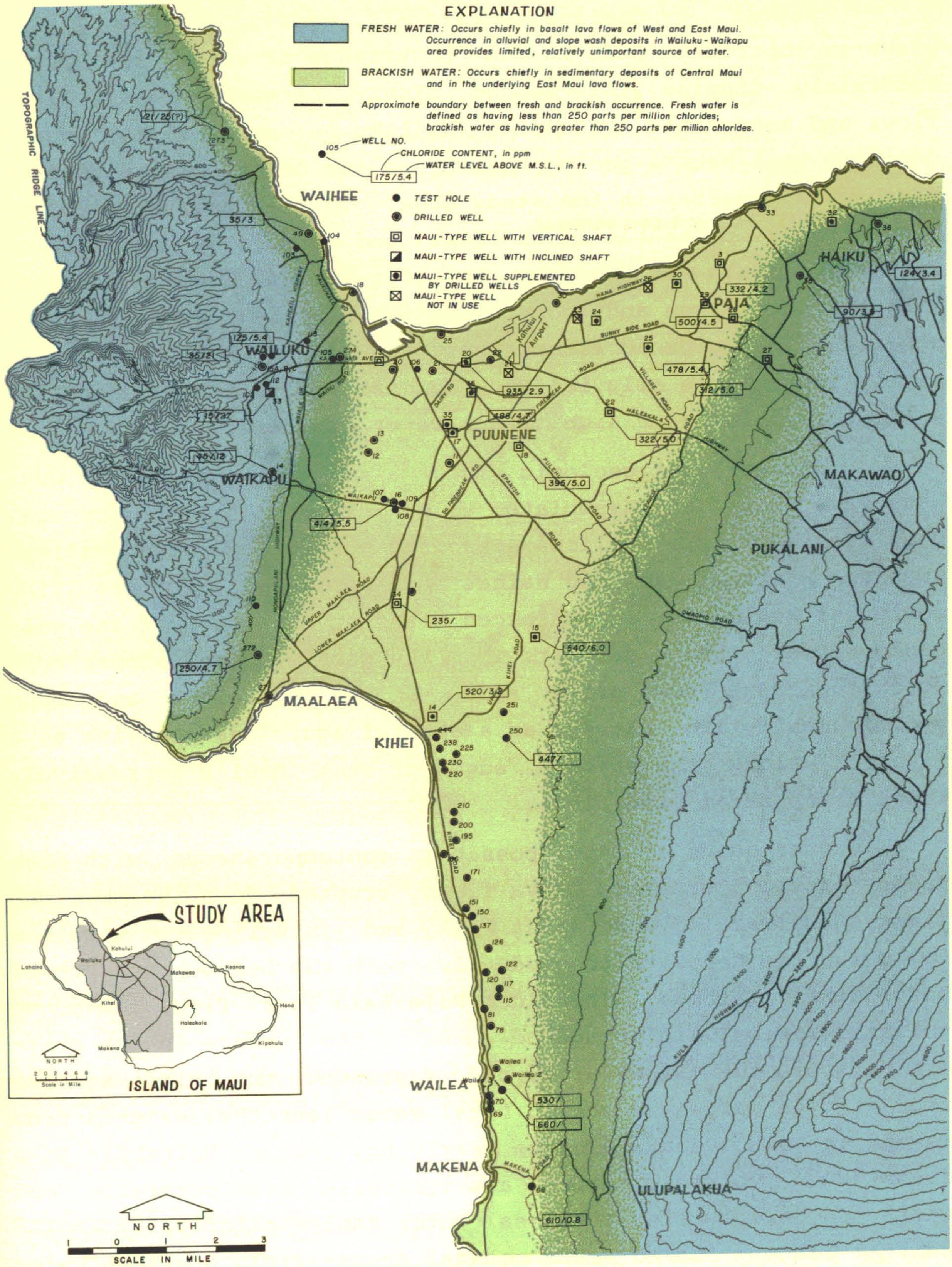
Iao, and Waikapu Streams through a gravity-flow ditch system to irrigate the lower slopes of West Maui and the lower-lying Isthmus.

Ground water resources, on the other hand, have not been as extensively developed, although the great body of basal water that lies beneath the lower volcanic slopes of West Maui between Waikapu and Waihee represents the most dependable source of fresh water in the study area. At the present time (1968), only 9 million gallons a day, or 15 percent of the estimated ground-water resources between Waikapu and Waihee, have been developed from two major sources in Iao Valley--the County's Mokuhau well source and Wailuku Sugar Co.'s Shaft 33. Other ground-water developments of significance include several major brackish water supplies for sugar cane irrigation in the central Isthmus, Kihei, and Paia areas. A small amount of fresh ground water has been developed from the basal lens in the Paia area.

Rainfall Rainfall, brought to the upper volcanic slopes of West and East Maui by prevailing northeasterly tradewinds, primarily sustains all water resources in the study area. The isohyetal pattern coincides closely with topography (Figure 5), owing to an orographic distribution of rainfall as the tradewinds are swept upward and over the interior land mass.

West Maui's windward slopes comprise the wettest part of the study area with as much as 400 inches of rain a year centered in the upper part of Iao Valley. In complete contrast, less than 20 inches of rainfall a year occurs in the low central Maui Isthmus, a relatively short seven miles distant. The ten-mile coastal area from Kihei to Makena represents the driest part of the study area with less than 20 inches of rainfall annually.

Because rainfall plays a primary role in the hydrologic cycle, its geographic distribution pattern images the occurrence of water resources (Figures 5 and 6).



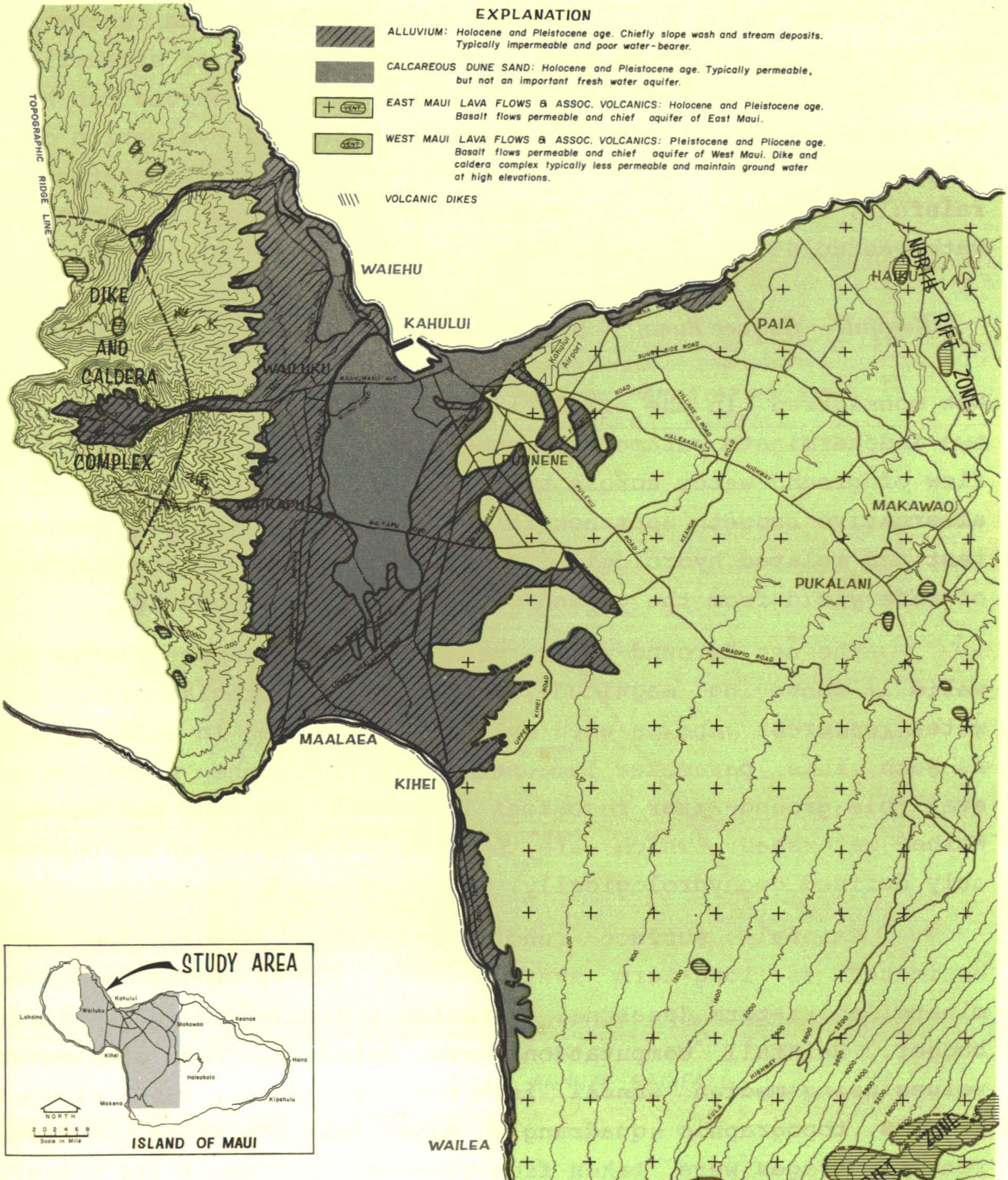
GROUND-WATER OCCURRENCE

Figure 6

Geology Similar to rainfall, geology (Figure 7) also plays an important role in the occurrence of water resources. Moderately dipping, thin-bedded, highly permeable basalt flank flows and associated volcanics (Wailuku volcanic series) which dominate West Maui's geology comprise the chief, most extensive fresh-water aquifer in the study area. To the east, gently dipping, highly permeable flank flows and associated volcanics of East Maui (Kula and Honomanu volcanic series) cover more than half the study area and constitute the principal brackish-water aquifer. In the broad Isthmus between East and West Maui, relatively impermeable alluvial and dune sediments act as a shallow aquiclude yielding no significant water supplies.

The earliest geologic history is represented by the West Maui lava flows and associated volcanics of late Tertiary age. Deep erosion a few million years ago carved out steep valleys such as Waikapu, Iao, and Waihee and deposited the resulting colluvial sediments in coalesced fans at the foot of the volcanic slopes. These deposits form the gentle upland slopes upon which sugarcane now grows from Maalaea to Waihee, and they hydrologically are classed as a general aquiclude serving as a "caprock" along the eastern edge of West Maui's impressively thick fresh basal water lens.

Subsequent to and possibly contemporaneous with deep valley erosion, numerous lava flows erupted down the western flank of Haleakala dome (East Maui) and interfingered with the colluvial fan deposits to gradually form the bedrock of much of the central Isthmus. The older Haleakala lava flows (Honomanu volcanic series) lie unexposed beneath the surface in the eastern part of the study area, and represent the chief aquifer rock for the largely brackish basal water lens that extends from Makena to Paia (Figure 6). The overlying, younger Haleakala lava flows (Kula volcanic series) are typically less permeable and where they slope below the basal water table--principally in the central Isthmus and adjacent coastal areas--yield brackish water also.



GENERALIZED GEOLOGY

Figure 7

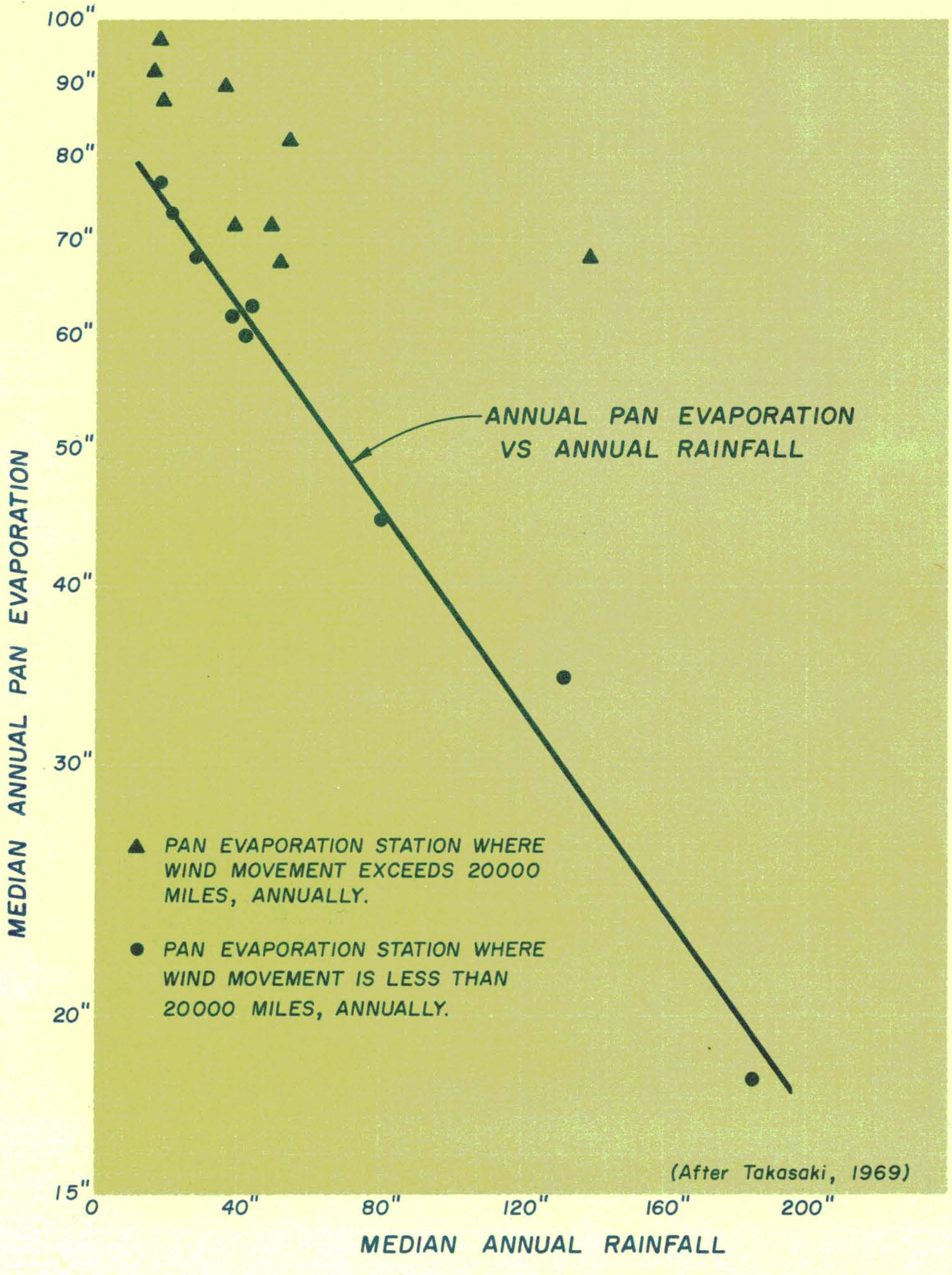
Water Budget In the study area, surface water resources can be estimated from direct measurements of streamflow. On the other hand, estimates of ground-water resources can best be approached only indirectly through a general evaluation of a simplified water budget involving the primary parameters of rainfall, surface runoff, evapotranspiration, and net ground-water percolation, for reasonably defined hydrologic areas.

Rainfall — Surface Runoff — Evapotranspiration = Ground-Water Percolation

Not considered in the simplified water budget shown above are two indeterminate parameters--subsurface lateral inflow and outflow of ground water across hydrologically defined areas. This alternative budget approach is used because available pumping test and related hydrologic records do not permit determination of safe yield from the ground-water bodies that they tap.

The net "ground-water percolation" is most useful and valid in conveying magnitude, rather than a precise value for water resources and is used only in this sense in this report. As such, this parameter is used to indicate the magnitude of available ground-water resources in the Waikapu, Iao and Waiehu-Waihee watersheds, which are the only areas that can be reasonably defined geohydrologically.

Rainfall, surface runoff, and evapotranspiration were estimated as long-term average values to eliminate indeterminate, short-term (seasonal and annual) variations in the water budget. Rainfall computations were determined from planimeter values using median annual isohyets (Taliaferro, 1959) plotted on USGS topographic quadrangle maps, 1:24,000 scale. Surface runoff averages were taken from Yamanaga and Huxel (In press), and evapotranspiration estimates were made from a correlation curve of evapotranspiration-versus-annual rainfall (Figure 8) developed by Takasaki (1969, p. 22).



RAINFALL-EVAPOTRANSPIRATION RELATIONSHIP

Figure 8

Iao Valley and town of Wailuku

Results indicate that windward West Maui, from Maalaea to Waihee, receives about 230 million gallons a day (mgd) of rainfall. Of this amount, an estimated 50 mgd (about 20 percent) returns to the atmosphere by evapotranspiration and 120 mgd (about 50 percent) becomes surface runoff in major streams. A net of 60 mgd (about 30 percent) is available to percolate deeply and recharge the dike-confined and basal ground-water systems of windward West Maui.

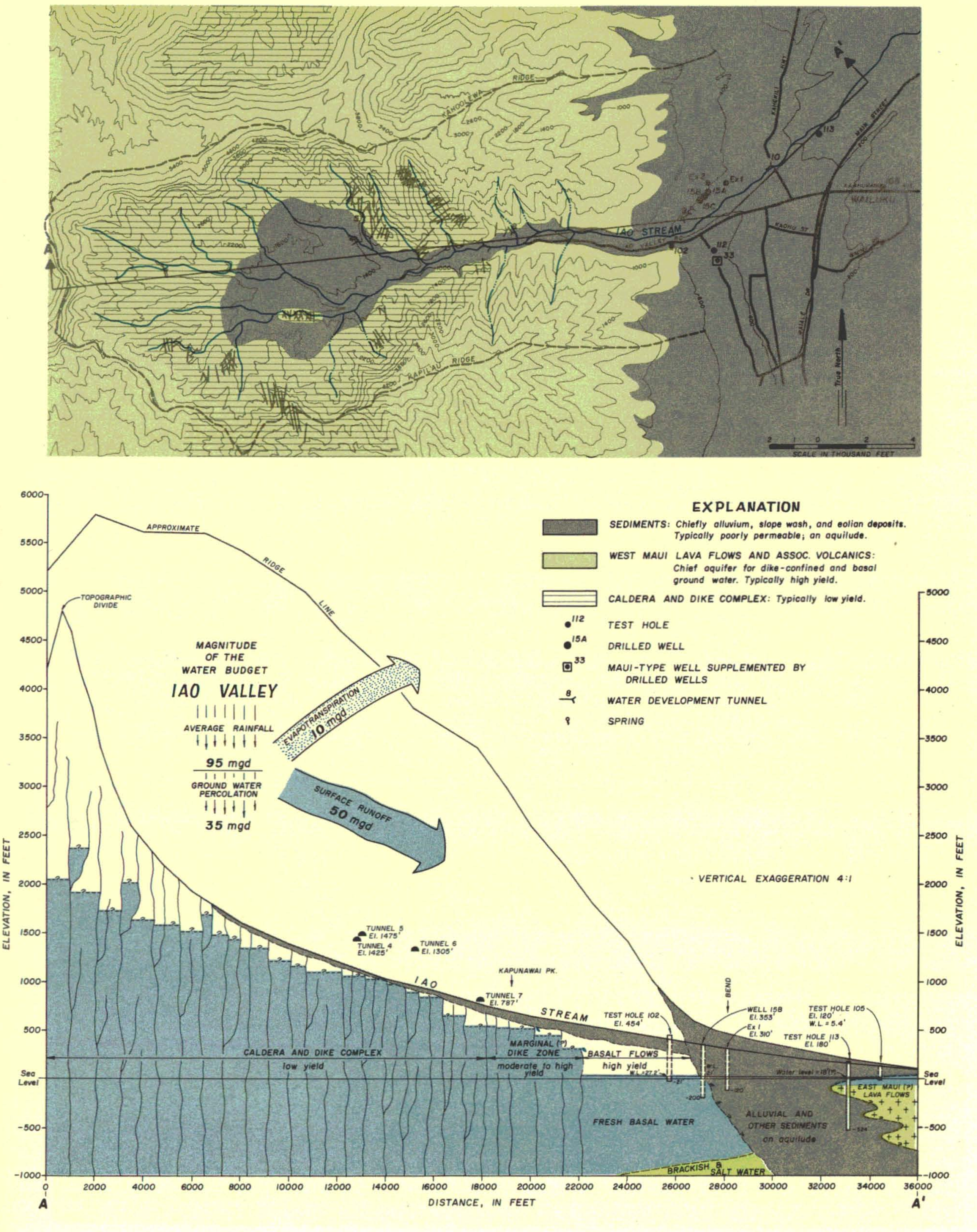
WINDWARD WEST MAUI

Iao Valley Iao Valley has the richest water budget of windward West Maui with a 95 mgd average rainfall on 9.2 square miles of permeable volcanic slopes. Of this amount, it is estimated that about 10 percent (10 mgd) returns to the atmosphere by evapotranspiration and about 50 percent (50 mgd) directly and indirectly becomes surface runoff in Iao Stream, leaving a balance of 35 mgd available for deep percolation to Iao's ground-water system (Figure 9).

Based on limited streamflow records of 1910-15, Iao Stream averages about 50 mgd. Characteristic of Hawaii's perennial mountain streams, Iao's streamflow consists of a highly variable freshet-flow component and a perennial base-flow component that is sustained during dry periods by numerous springs that discharge from dike-confined ground-water storage breached by the stream within the volcanic dike complex. Wailuku Sugar Co. diverts about 18 mgd of Iao's base flow for irrigation purposes. Freshet flows, torrential at times, however, are not captured by on-stream reservoirs and largely waste into the sea.

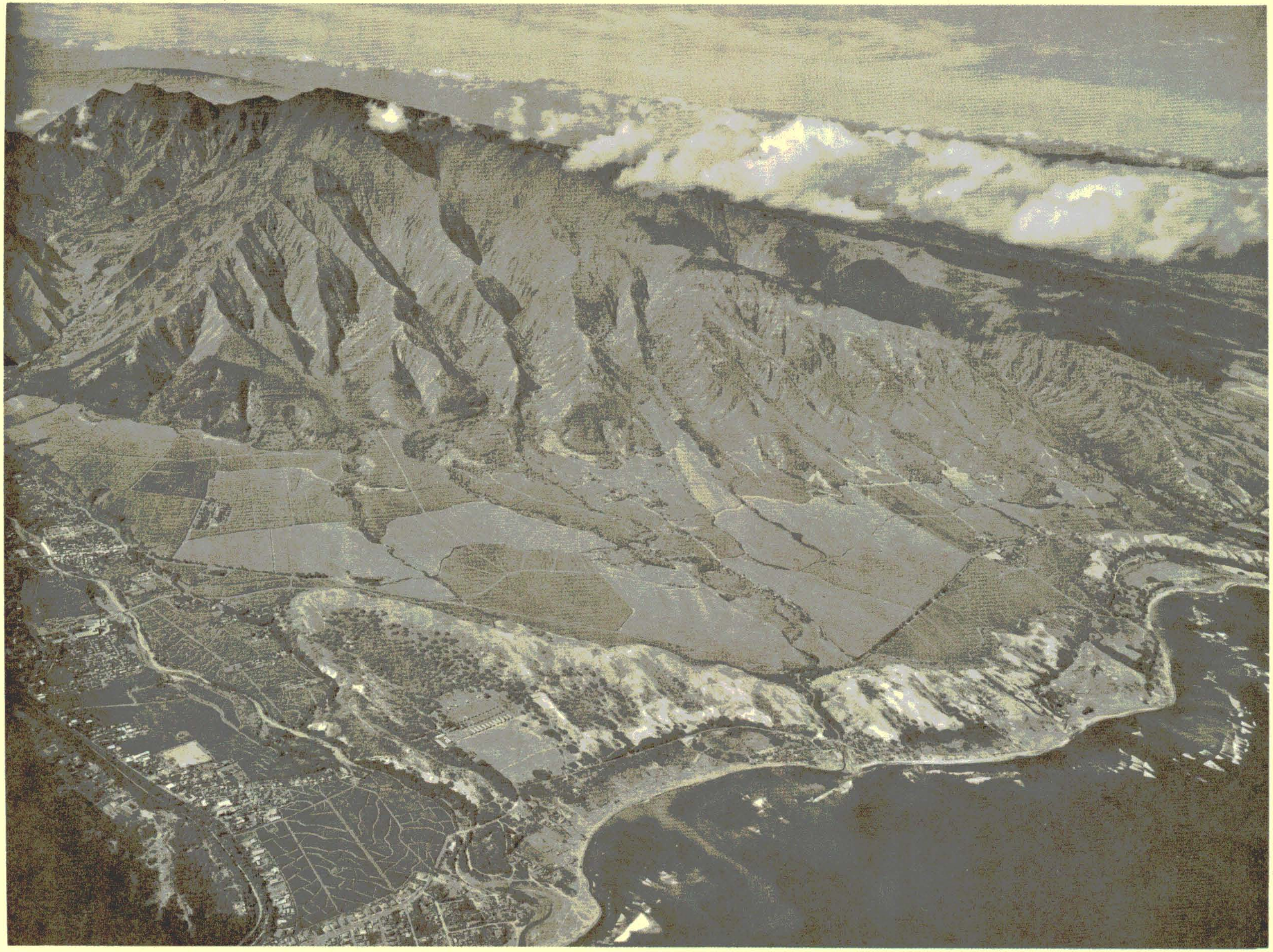
Basically, ground water in Iao Valley is sustained by the estimated 35 mgd of rainfall that directly and indirectly reaches the ground-water table through deep percolation in the upper reaches of the valley. Its occurrence as perched, dike-confined, and basal bodies, however, is largely due to geology. Perched water bodies are not significant sources of water, being locally and ephemerally sustained upon layers of ash, soil, or dense rock in heavy rainfall areas. Dike-confined water bodies in Iao Valley: (1) have been tapped by several development tunnels (Nos. 4, 5, 6, and 7, Figure 9) possessing low yields of less than a few million gallons per day; (2) occur principally in the volcanic caldera and dike complex region approximately mauka of Tunnel No. 7 in Iao Valley (elevation 787 ft.); and (3) generally can be expected to provide similar low yields due to the dense, impermeable nature of caldera lavas and the close spacing of dike structures within the dike complex. Outward from the central interior (approximately makai of Tunnel No. 7) the dike complex presumably grades into a marginal dike zone where more widely spaced dikes would permit greater ground-water storage and permeability. On this assumption, merit exists for exploration of moderate to high yield wells several thousand feet or so makai of Tunnel No. 7 (between elevations 500 and 800 feet).

Lastly, but by far the most important ground-water resource, is the basal lens that lies inland of Wailuku town beneath the alluvial and volcanic slopes. Impressively thick (20 to 30 ft. head), fresh (35 parts per million chlorides), highly permeable (10 to 20 mgd source yield), recharged by a heavy rainfall area, and protected from seaward contamination by a "caprock" of essentially impermeable colluvial fan deposits, the Iao basal lens is comparable to Honolulu's basal aquifer in magnitude and occurrence. The safe yield of Iao's basal water body has not been fully developed and cannot be estimated from existing source data. Its magnitude, however, is estimated roughly at 30 mgd, of which approximately 10 mgd is presently developed by Wailuku Sugar Co.'s Shaft 33 and the County's Mokuhau well source.

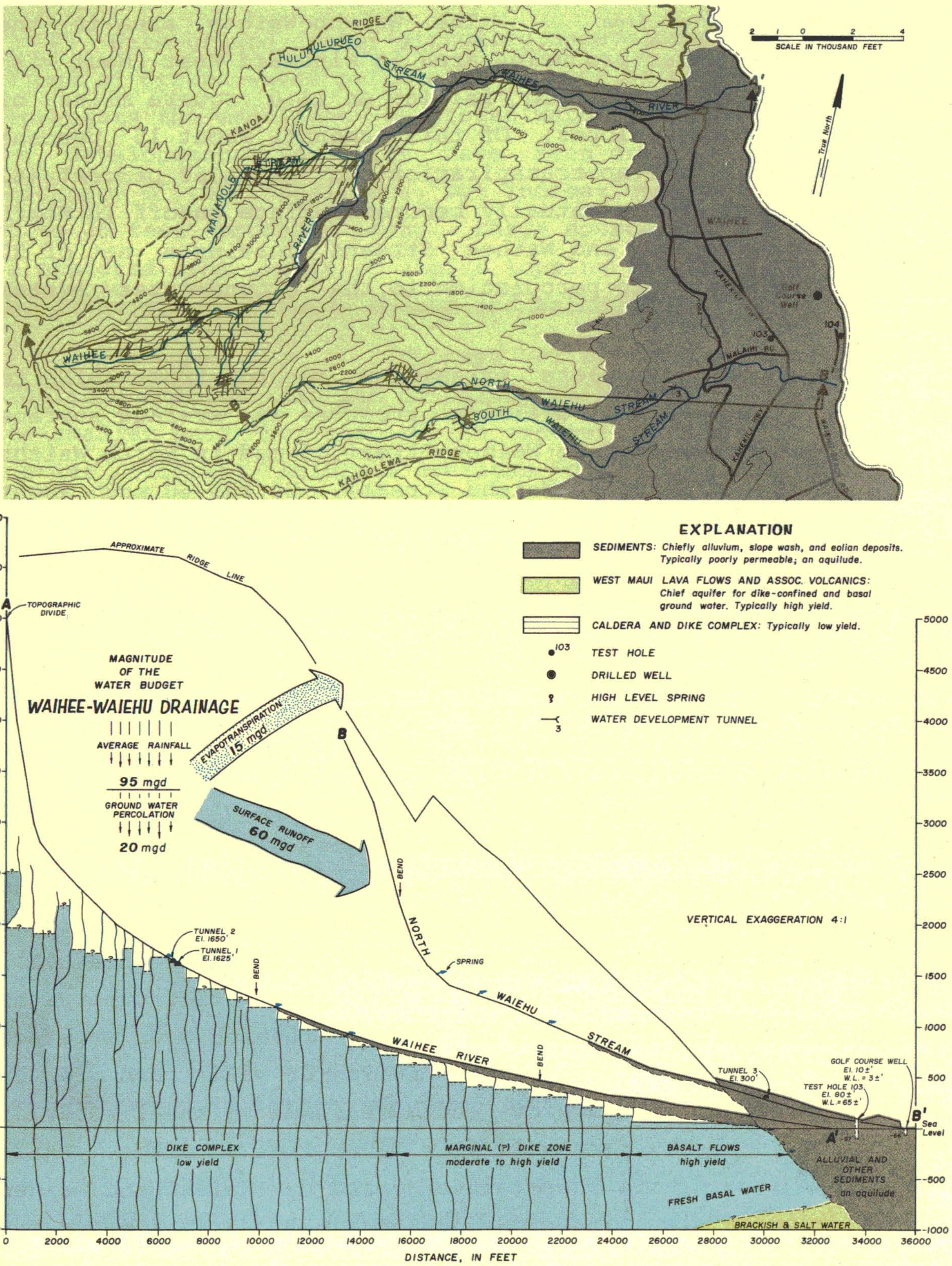


WATER BUDGET OF IAO VALLEY

Figure 9



Waiehu-Waihee area



WATER BUDGET OF WAIEHU-WAIHEE AREA

Figure 10

Waiehu-Waihee Area The Waiehu-Waihee area is the second largest water-producing area in windward West Maui with an average of 95 mgd of rain falling on 11.0 square miles of permeable volcanic slopes. Of this amount, about 15 percent (15 mgd) is lost to evapotranspiration and about 60 percent (60 mgd) immediately and eventually becomes surface runoff in North Waiehu, South Waiehu, and Waihee Streams, leaving a net of 20 mgd available for deep percolation to the ground-water system (Figure 10).

Based on incomplete streamflow records from 1910 to 1917, the Waiehu-Waihee drainage produces an average surface runoff of 60 mgd (50 mgd in Waihee Stream, 5 mgd in North Waiehu Stream, and 5 mgd in South Waiehu Stream). Of the 60 mgd, about 75 percent (46 mgd) is diverted for irrigation of sugarcane and about 25 percent (14 mgd) runs off into the sea unused (some taro crops are irrigated downstream of diversions). Wailuku Sugar Co. diverts 22 mgd from Waihee Stream and 3 mgd from North Waiehu Stream. Hawaiian Commercial and Sugar Co. diverts 18 mgd from Waihee Stream and 3 mgd from South Waiehu Stream.

The ground-water geology and hydrology is very similar to that of Iao Valley. In the upper reaches of Waihee (above elevation 800 ft.) and Waiehu Streams (above elevation 1200 ft.) abundant rainfall sustains ground water at high levels in a dike complex of intensely intruded basalts which typically provide low yields to development tunnels (Nos. 1 and 2, Figure 10). From the highest recharge levels in the interior, ground water presumably moves down gradient in cascade fashion over a series of dike compartments having lower levels of water and greater spacings, eventually reaching and sustaining a basal body of fresh water in highly permeable flow lavas free of dikes. Where dike-water levels have been intercepted by Waiehu and Waihee Streams (between elevations 900 and 1500 ft.), springs and seepages occur and collectively produce reliably constant baseflows from ground-water storage.

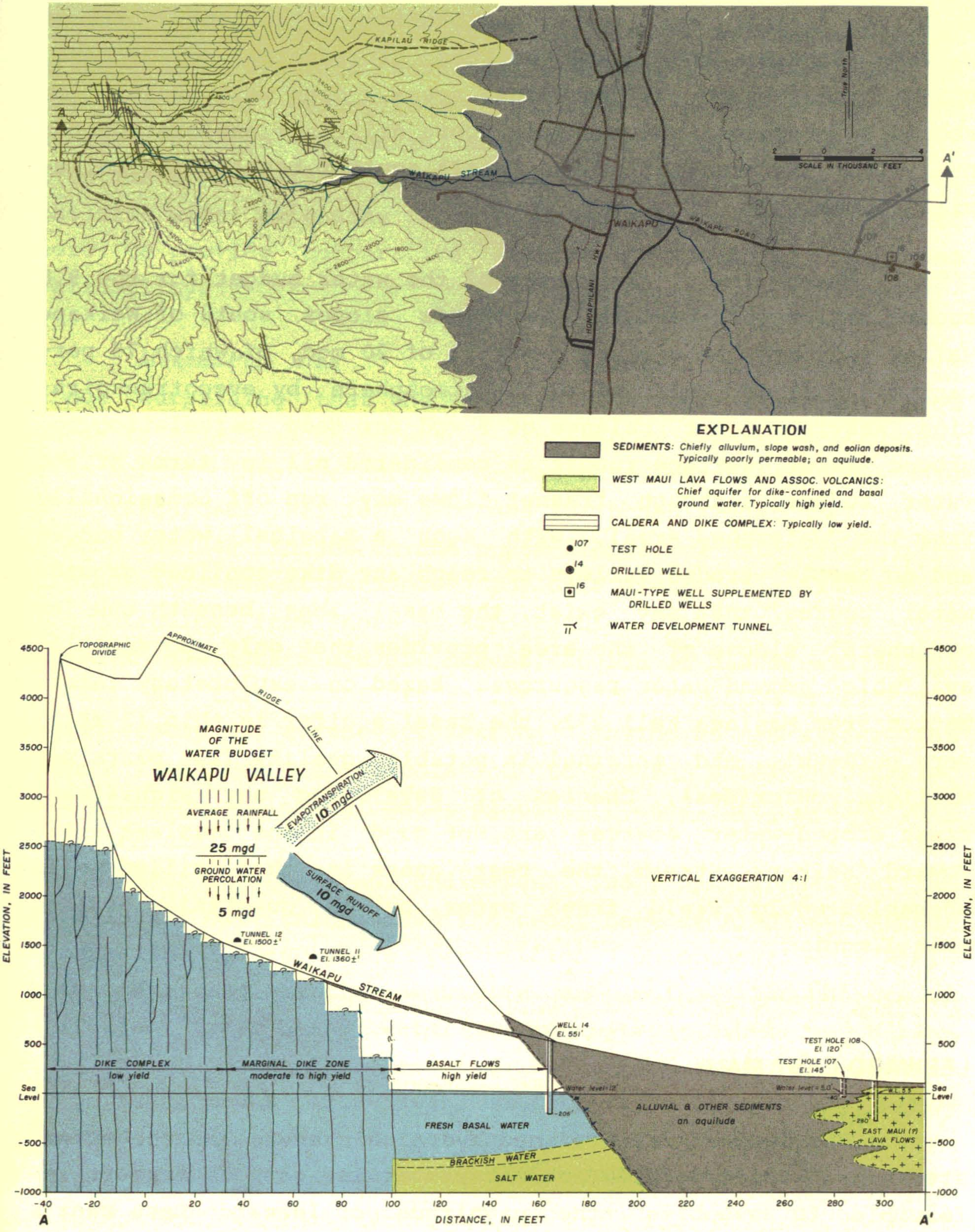
With ground water virtually undeveloped, the estimated 20 mgd of ground-water percolation in the Waiehu-Waihee drainage represents the magnitude of ground water potentially available for development. No wells have been drilled to reveal the thickness of the basal lens, but indications are that heads of 20 to 25 feet probably occur. Large sources of fresh water can be expected from wells or shafts topping the basalt flows from the lower slopes between Waiehu and Waihee.

Waikapu Valley Waikapu Valley's water budget is considerably smaller than Iao or Waiehu-Waihee, not only because of its smaller area but also of its greater evapotranspiration in a drier climate. Rainfall averages only 25 mgd (a fourth that of Iao) over 3.6 square miles of permeable volcanic slopes. Of this amount an estimated 40 percent (10 mgd) returns to the atmosphere through evapotranspiration and another 40 percent (10 mgd) becomes surface runoff in Waikapu Stream, leaving a balance of 5 mgd for deep percolation to ground water.

Based on streamflow records of 1911-1917, Waikapu's streamflow averages 10 mgd. Wailuku Sugar Co. diverts 3 mgd (essentially base flows) for sugarcane irrigation and the remaining 7 mgd is presumed to run off the watershed area, although some deep percolation to ground water probably occurs downstream.

Ground-water occurrence in Waikapu Valley (Figure 11) is similar to Iao and Waiehu-Waihee, but on a much smaller scale. This is reflected not only by the water budget but also by the 12-foot head of the basal water body explored by Waikapu Well 14. Chances of developing any significant sources of high-level, dike-confined ground water in upper Waikapu Valley are slim (for example, Tunnel 11, Figure 6) primarily due to insufficient rainfall. Because the basal aquifer north of Waikapu Stream appears to be moderately thick (12 feet head) and fresh (45 parts per million, chlorides), but anomalously poorly permeable (based solely on data from Waikapu Well 14), there is

Waikapu Valley



WATER BUDGET OF WAIKAPU VALLEY

Figure 11

merit for further basal water exploration at Waikapu (north of Waikapu Stream) to locate sources of several mgd or more. Unlike the Iao and Waiehu-Waihee areas, deep well exploration should be preceded by test-hole (core drilling) exploration for preliminary information on the basalt aquifer beneath the colluvial slopes.

Maalaea Area Estimates of the water budget for the 9.0 square miles of permeable volcanic slopes south of Waikapu Valley indicate an average rainfall of 20 mgd, of which 75 percent (15 mgd) is returned to the atmosphere by evapotranspiration, leaving a net balance of 5 mgd for deep percolation to ground water (surface runoff is considered nil in terms of the water budget, although freshet flows may run off occasionally from the watershed area). With such a marginal water budget and no deeply eroded valleys to reach any dike-confined ground-water bodies that may exist, the basal lens beneath the low peripheral slopes of the area provides the only potentially available ground-water resources. Based on exploratory information from Maalaea Well 272, the basal aquifer is thin (3 ft.), very permeable, and marginal in potable quality (250 parts per million, chlorides). Chances of developing any significant fresh ground-water sources are not good in the Maalaea area. Toward Waikapu Stream, the best guess is that drilled wells probably would yield fresh water, but in quantities of less than 1 mgd.

LEEWARD EAST MAUI

The lack of well-defined hydrologic areas and the extensive importation of surface water for irrigation make it infeasible to establish the magnitude of leeward East Maui's ground-water resources through water budget estimates similar to those for windward West Maui. However, on the assumption that the water cycle, in general, moves from mauka areas of rainfall recharge to coastal areas of discharge, it is possible to estimate simplified water budgets for unit strips of area (one mile wide) extending mauka-to-makai (topographic divide to shore) to provide comparative information on water resources availability.

Makena-Paia Area From the rainfall map (Figure 5) it is not surprising that the western slopes of East Maui, from Makena to Paia, has no perennial streams or significant surface water runoff into the ocean. Ground water represents the only water resources. Rainfall averages 10 inches a year at Kihei to no more than 40 inches on the upper slopes of Haleakala. Simplified water budget estimates for unit strips of area one mile wide extending from shore to topographic divide indicate that rainfall averages 5 mgd at Makena, 10 mgd at Kihei, and 30 mgd at Paia, but that all of it returns to the atmosphere directly or indirectly by evapotranspiration, leaving no net balance for surface runoff or deep percolation to ground water. Actually, some recharge to ground water probably occurs, but undoubtedly it is too small to sustain any fresh basal water bodies in the coastal area between Kihei and Makena. Well data shows that the basal lens a mile inland from the coast between Kihei and Makena is brackish (500-600 parts per million, chlorides), very thin (1 to 3 ft.) and chloride-sensitive to pumping. The chances of developing fresh basal water sources between Kihei and Makena are slim for distances less than two miles inland from shore (less than about 1200 feet elevation). High-level, dike-confined ground water is not known to occur and probably does not, for lack of heavy rainfall. Small, local sources of perched ground water occur on the upper slopes above Ulupalakua, but are insignificant for municipal requirements.

North of Kihei to Paia, the basal lens beneath the lower slopes of East Maui lava flows (Figure 6, Shafts 15 and 27) is brackish (300-500 parts per million, chlorides) and thin (3 to 5 feet head). Inland (at elevations greater than 500 feet) the basal water body presumably becomes fresher and thicker and because this part of the basal lens is extensive and unexplored, its potential as a major fresh water source is, at this writing (August 1970), being investigated by the drilling of an exploratory well (Figures 17 and 18).

Paia-Haiku Area Estimates of the water budget show that a one mile wide strip of area from the coast of Haiku mauka to the topographic divide receives 50 mgd of rainfall, but loses 60 percent (30 mgd) of it to evapotranspiration, for a net (surface runoff is considered nil) of 40 percent (20 mgd) available for deep percolation to ground water. This amount, compared to no net ground-water percolation for a similarly estimated unit area at Paia, suggests that ground-water recharge from rainfall increases significantly in magnitude from Haiku eastward. Not inconsistent with this comparative data is the fact that the basal lens, although thin (3.5 ft. head), is fresh (90-125 parts per million, chlorides) much closer to the coast (about one mile from shore) at Haiku than at Paia (Figure 6). In the Paia-Haiku area, about 2 miles inland from the coast (about 600 ft. elevation) fresh basal water can be developed from drilled wells yielding probably 1 mgd or more.

CENTRAL MAUI ISTHMUS

Water resources in the Central Maui Isthmus consist almost entirely of brackish basal ground water in East Maui lava flows. Rainfall contributes little or no recharge to the basal lens, being lost to evapotranspiration, and intermittent surface water runoff is insignificant in terms of the water budget. Undoubtedly, the ubiquitous basal lens is sustained chiefly by artificial recharge from excess irrigation water on sugarcane lands. Some recharge probably occurs from natural ground-water movement laterally from the East and West Maui ground-water systems, but geologic and hydrologic evidence suggests not significantly. Approximately 230 mgd (the amount of rainfall on windward West Maui, from Maalaea to Waihee) of irrigation water is imported to the Isthmus and adjacent areas from distant surface water sources in East and West Maui. Hawaiian Commercial and Sugar Co. imports 160 mgd through the East Maui Irrigation ditch system (Takasaki and Yamanaga, 1970, p. 1) for use in Central Maui; and Wailuku Sugar Co. and Hawaiian Commercial and Sugar Co., together, import about 70 mgd from West Maui sources (Yamanaga and Huxel, in press) for use in the Isthmus and on the adjacent colluvial slopes of West Maui. The net amount of irrigation water that recharges the ground-water system is not known.

Well data shows that the basal lens in East Maui lava flows is thin (5 feet head), brackish (about 500 parts per million, chlorides) and highly permeable, yielding large quantities of water to shafts (Figure 6). To test the chemical quality of the basal water, a sample of water was obtained in January, 1970, from unused Shaft 34 (Figure 6). Pertinent laboratory results by the U. S. Geological Survey were: chlorides, 300 ppm; nitrates, 23 ppm (abnormally high concentration suggests irrigation return water contamination); hardness as C_aCO_3, 328 ppm (considered very hard water); and dissolved solids, 1000 ppm (500 ppm is desirable limit for drinking water). Because it lacks potable quality and is sustained primarily by artificial recharge from excess irrigation water, the basal ground-water body in the Central Maui Isthmus is not a suitable or reliable source for municipal water.

Existing Water Facilities

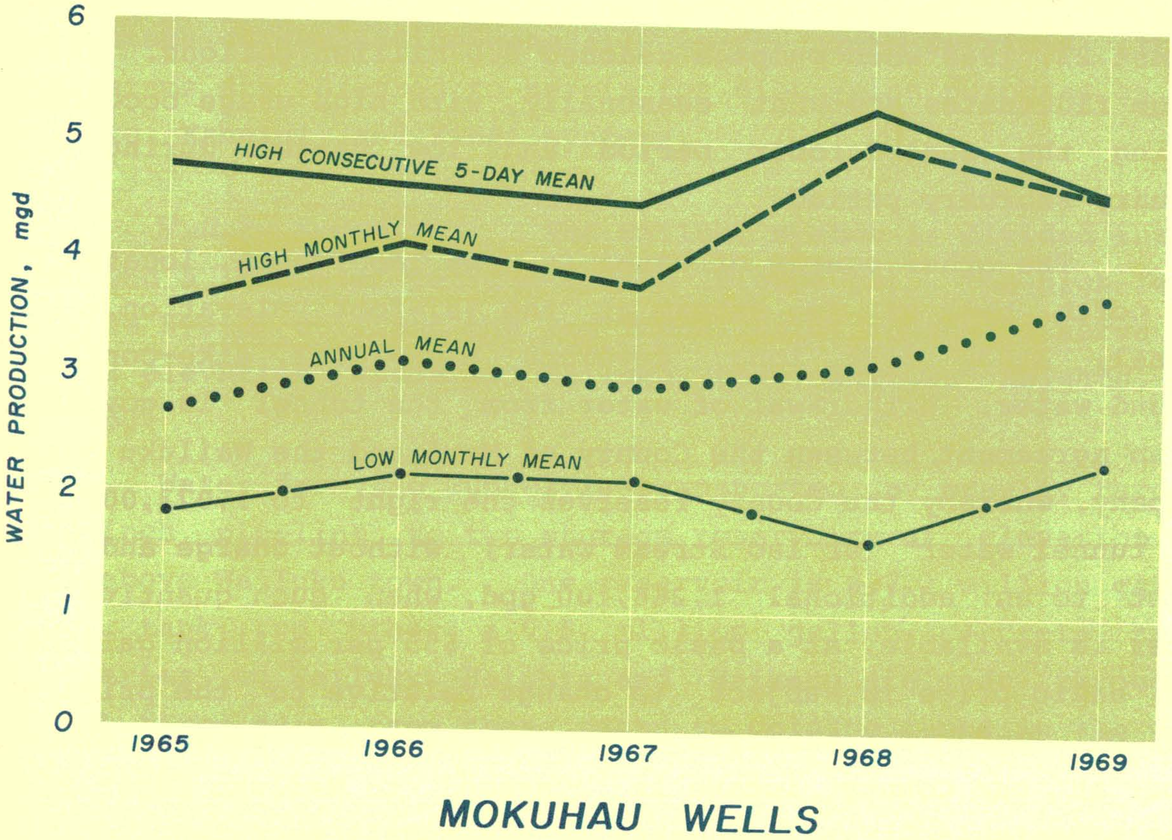
The Maui County Department of Water Supply owns and operates the domestic water system in the study area (Figure 12). The facilities presently serving the Kihei-Makena area are a part of the County's Wailuku water system, which primarily services the towns of Wailuku and Kahului and the outlying communities of Waikapu, Waiehu, and Spreckelsville, Sources of supply consist of a water development tunnel in Iao Valley and three wells at Mokuhau, just mauka of Wailuku town.

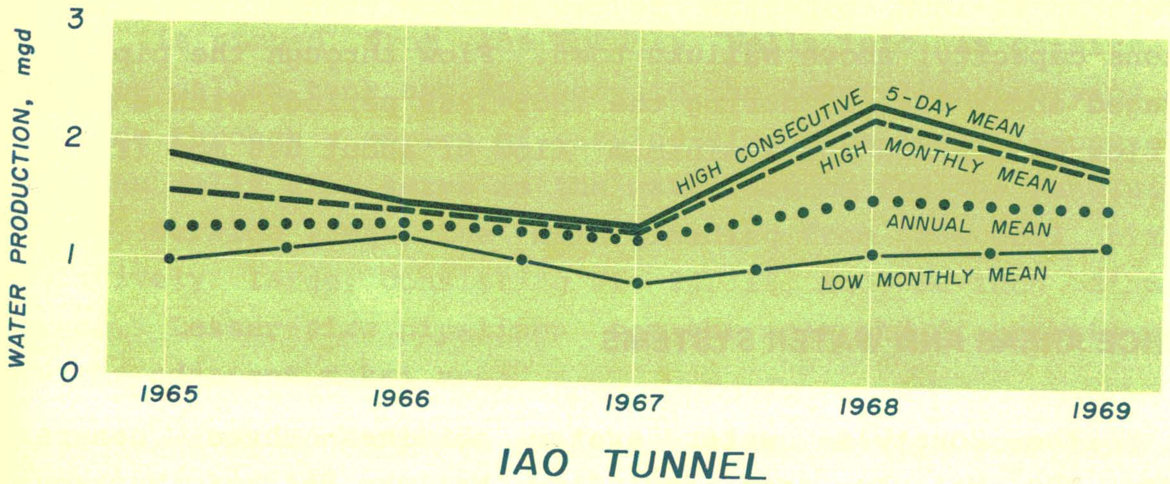
SOURCES OF SUPPLY

The system's major source of water is the Mokuhau Wells, which tap the basal ground-water aquifer underlying Iao Valley. The source consists of three wells, at the approximate 550-foot elevation, equipped with vertical turbine pumps--two of 4.0-mgd and one of 6.0-mgd nominal capacities. Two of the wells were drilled in 1954 and the third was drilled in 1966. The pumps discharge into a 1.0 million gallon steel tank with an overflow elevation of 382 feet.

Under normal use, two of the wells are operated nearly continuously, with the third held in reserve for emergencies. The safe capacity of the installation is 8 mgd and is limited by the electrical capacity of the step-down transformers used to operate the pumps. To achieve optimum operation of the pumps, the existing pumping station would need to be modified. The electrical transformer bank of 750-kva capacity, while adequate to operate both 4.0-mgd pumps simultaneously, cannot service the 6.0-mgd pump operating in conjunction with one of the 4.0-mgd pumps.

EXISTING WATER SYSTEM





WATER PRODUCTION AT MOKUHAU WELLS AND IAO TUNNEL

Figure 13

Production at the Mokuhau source has averaged 3.1 mgd, or 70 percent of the total supply, for the 1965-1969 period (Figure 13). Peak-day production during this period occurred on August 23, 1968 when pumpage reached 6.0 million gallons. Water usage fluctuates somewhat seasonally, with high usage occurring during the June-October period and low usage, during the January-February period.

The other source of water is the Iao Tunnel, located on the north bank of Iao Stream at the 787-foot elevation. The tunnel, 2,630 feet long, develops high-level, dike-confined ground water. Withdrawal of water from the tunnel is governed by an agreement, between the County of Maui and the Wailuku Sugar Company, whereby the County reserves the right to 1,073,000 gpd of tunnel water (or Iao Stream water) without charge and the right to an additional 1,266,100 gpd, when such quantity of water is available, at a basic price of $55 per million gallons. The basic price is subject to change relative to the price of fuel oil used for electric power generation. Excess tunnel water at the County intake is bypassed to Wailuku Sugar Company's Maniania Ditch just makai of the tunnel portal.

Water taken from Iao Tunnel by the County is delivered through a 12-inch pipeline to two storage tanks (2.6 million gallons capacity) above Wailuku town. Flow through the pipeline averaged about 1.4 mgd during the 1965-1969 period, with a maximum flow of 2.5 mgd and a minimum flow of about 0.6 mgd (Figure 13).

SERVICE AREAS AND WATER SYSTEMS

The County's water system services three general areas: the Wailuku area, including Wailuku Heights, Waikapu, and the Waiehu Beach area; the Kahului area; and the Maalaea-Kihei-Kamaole area. Roughly 6,300 consumers are presently being served by the system, with the greater part of the consumers situated in Wailuku and Kahului. While essentially integrated, the water system can be divided into three separate subsystems corresponding generally to the areas serviced. These subsystems are referred to herein for discussion purposes as the Wailuku, Kahului, and Kihei systems.

Wailuku System The Wailuku system is divided into a high and a low-level service system (Figure 12). The high-level service system utilizes the Iao Tunnel water source to serve the higher elevation areas of Wailuku town, Wailuku Heights, and Waikapu.

Water from Iao Tunnel is transported by gravity through a 12-inch pipeline to two storage reservoirs at elevation 507 feet above Wailuku town. One reservoir is a 2.1 million gallon steel tank; the other, a 0.5 million gallon concrete tank. Deliveries to Wailuku Heights and Waikapu are made through a 6-inch force main from these tanks to holding tanks in the service area.

The low-level service area consists generally of the makai sections of Wailuku town, including the area north of Main Street and below Central and Market Streets, and Waiehu Beach. Water is pumped from the Mokuhau Wells into an on-site 1.0-million gallon tank and delivery to the lower-lying service area is made through a series of varying-size pipelines. Because the Mokuhau Wells also serve as the water source for the Kahului and Kihei service areas, the main leading from the well site is relatively large, consisting of 24, 18, and 16-inch diameter pipes. Lesser-size pipelines tap the main and distribute water to the adjacent makai area.

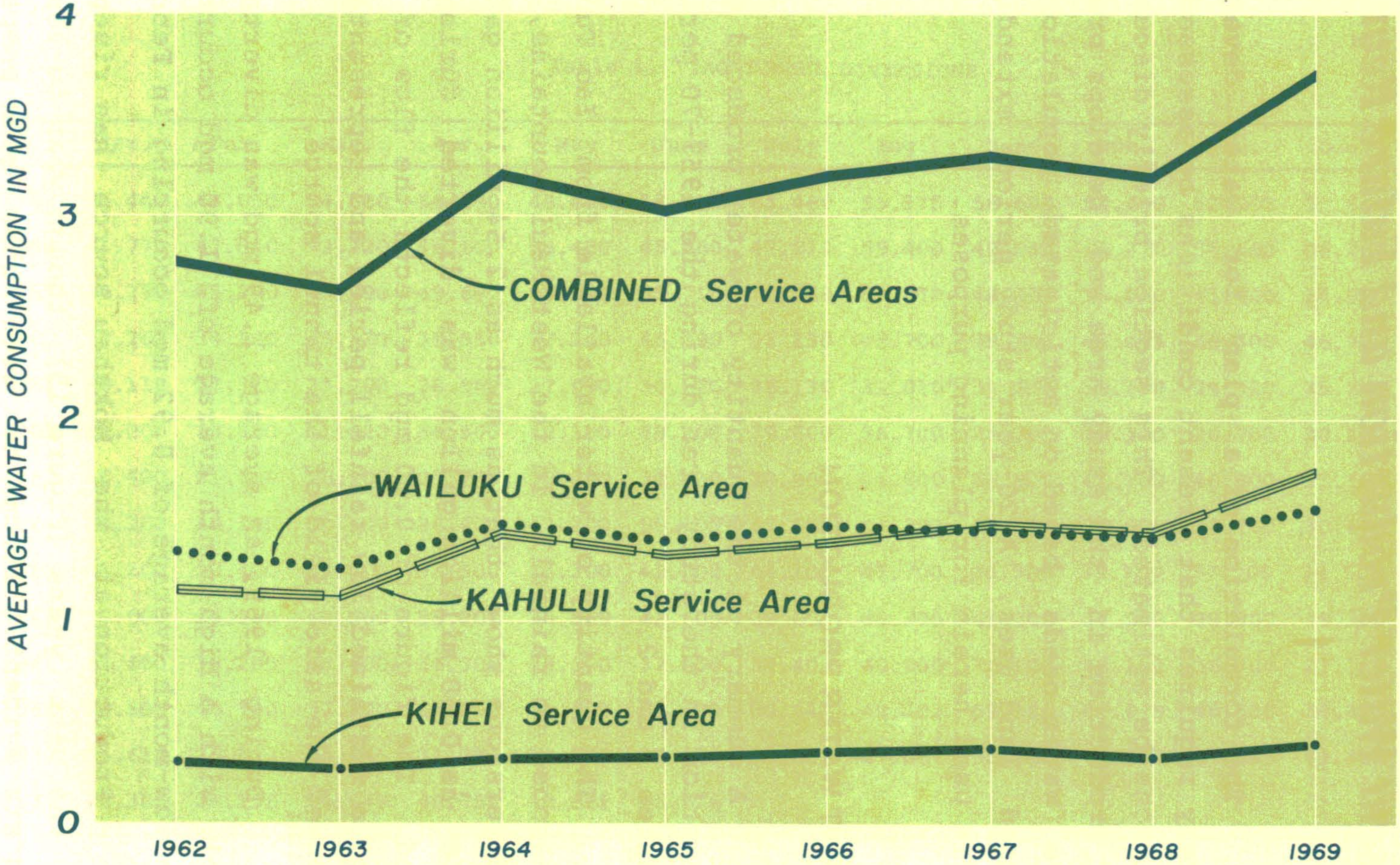
Water consumption in the Wailuku service area from June 1968 to July 1969, as reflected by sales, averaged 1.57 mgd, or about 39 percent of the total metered consumption (Figure 14).

Kahului System Water for the Kahului town and residential areas, including NASKA, Paia, and Spreckelsville, comes from the Mokuhau source and is distributed from a 2.0-million gallon concrete tank located near the junction of Waiale Drive and Waiinu Road. A 16-inch pipeline leads from the tank to the network of distribution lines in the Kahului residential area. Water for Kahului town and the airport area is delivered through 12-inch mains extending from the residential area.

Water consumption for the June 1968-July 1969 period averaged approximately 2.07 mgd, or 51 percent of the study area's total metered consumption (Figure 14).

Maalaea-Kihei-Kamaole System Water for the lee coastal communities of Maalaea, Kihei, and Kamaole comes from Mokuhau. During emergencies water can be taken from the Iao Tunnel source through valved interconnections. Water is transmitted to the communities from the outskirts of Wailuku town through an 18-inch pipeline. The 18-inch transmission line traverses the Central Maui Isthmus in the vicinity of the abandoned Puunene Airport and parallels the coastline from Kihei to Kamaole Homesteads, terminating with a 16-inch pipeline at a 1.0 million gallon concrete tank at the Wailuku-Makawao district boundary. A 12-inch force main delivers water from the concrete tank to a 72,000 steel tank farther mauka to serve the Maui Meadows residential subdivision.

Water consumption in Maalaea and Kihei averaged 0.42 mgd during the June 1968-July 1969 period, or 10 percent of the total metered consumption in the study area (Figure 14).



METERED WATER CONSUMPTION

Figue 14

Present Water Production and Future Requirements

The formulation of a plan for water development and delivery requires that present conditions be assessed and future conditions be estimated. This section briefly discusses present water production in the study area and develops projections of future water needs based on anticipated population growth and proposed land uses. A 20-year study period extending to year 1990 is used herein for planning purposes.

PRESENT WATER PRODUCTION

A summary of the quantity of water produced for domestic consumption in the study area during the 1957-70 period is shown in Tables 1 and 2.

The quantity of water available from Iao Tunnel varies in response to rainfall in the West Maui mountains, and records of diversions show that as much as 2.54 million gallons and as little as 0.60 million gallon was diverted during a one-day period. The figure of 0.60 mgd reflects the flow of the tunnel during a sustained low rainfall period and represents what might be termed the safe yield of the tunnel source.

During 1969, an average 1.49 mgd was diverted from Iao Tunnel, with a high-month average of 1.90 mgd occurring in July and a low-month average of 0.92 mgd occurring in February.

Production at the Mokuhau source has risen gradually over the past years (Figure 15), though year-to-year fluctuations are evident. It can be seen that mean pumpage has increased from 1.055 mgd in 1955 to 3.575 in 1969, or at an

Table 1. IAO TUNNEL DIVERSIONS

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1957	44.440	48.050	54.500	54.680	48.400	53.650	63.460	55.375	56.605	52.400	52.990	33.610	618.160
1958	41.770	47.810	42.220	46.100	58.480	45.860	47.930	59.400	49.030	45.270	50.660	46.200	580.730
1959	46.230	45.290	45.890	49.680	58.820	53.710	54.340	57.970	48.410	55.450	41.600	34.020	591.410
1960	39.260	34.980	33.370	39.550	37.240	46.690	53.130	48.700	58.885	41.995	46.500	46.700	527.000
1961	50.110	27.320	23.200	28.960	27.090	30.170	36.130	31.010	34.670	32.230	29.520	35.760	386.170
1962	21.200	23.380	41.420	34.500	32.100	48.200	39.600	36.700	26.300	33.300	20.700	20.200	377.600
1963	16.400	21.300	6.200	27.700	39.800	34.800	28.800	34.200	48.800	41.700	40.800	57.300	397.800
1964	28.200	26.100	30.100	36.400	43.700	50.100	47.500	41.300	45.300	39.800	34.700	30.600	453.800
1965	32.200	25.400	37.400	33.500	33.300	41.000	44.100	47.700	48.500	39.300	37.300	38.500	458.200
1966	38.000	35.300	40.800	35.200	35.800	42.600	38.600	40.700	41.300	37.000	38.800	39.300	463.400
1967	37.400	35.200	38.400	36.300	38.300	37.900	35.400	40.900	36.000	45.100	36.400	27.300	444.600
1968	28.500	44.700	37.200	44.000	31.400	55.690	80.441	49.403	59.156	44.979	46.530	38.331	560.330
1969	34.616	25.834	44.845	31.777	53.975	47.814	58.821	47.067	56.451	49.228	47.845	43.498	541.771
1970	76.302	33.176	26.049	48.752	52.661	65.616							

Table 2. MOKUHAU PUMPAGE DATA

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1957	12.946	12.946	25.027	30.979	50.951	53.888	58.100	46.329	45.184	45.850	34.179	20.391	436.428
1958	27.800	25.137	22.695	38.706	36.682	44.317	46.033	53.868	47.069	39.813	37.356	28.634	448.110
1959	22.601	24.829	38.085	39.820	50.096	52.884	61.984	55.771	54.286	56.833	33.448	30.737	521.374
1960	34.084	27.144	34.627	46.654	60.396	59.388	63.623	67.565	53.982	57.307	40.569	34.991	580.330
1961	32.585	42.683	72.626	68.507	80.272	75.347	94.937	94.171	89.276	65.382	57.632	48.550	821.968
1962	46.122	28.229	41.534	51.757	53.030	83.247	67.094	84.944	68.190	87.026	66.056	62.888	740.117
1963	58.209	43.328	2.034	5.136	6.019	35.221	47.716	72.045	80.733	55.125	51.992	69.951	527.509
1964	82.527	63.217	69.382	78.747	94.308	90.725	111.756	96.470	109.381	91.157	73.655	62.444	1,023.769
1965	64.197	51.692	72.623	67.759	78.759	111.414	101.337	108.310	111.209	84.010	67.640	64.236	983.186
1966	68.325	62.020	75.875	85.674	100.745	120.408	118.918	119.939	118.464	98.372	93.746	78.010	1,140.496
1967	65.182	60.923	72.616	73.014	100.622	107.240	98.608	99.577	108.383	118.115	86.039	70.279	1,060.598
1968	68.666	46.644	54.966	67.452	92.889	91.602	136.245	143.893	141.934	112.217	102.266	76.323	1,135.097
1969	75.195	76.309	89.375	100.474	111.917	119.168	154.200	133.794	138.867	115.087	87.733	102.876	1,304.995
1970	112.184	68.607	88.279	120.677	109.217	151.580							

average rate of 0.180 mgd per year, equivalent to an annual increase of 17.0 percent based on 1955 production.

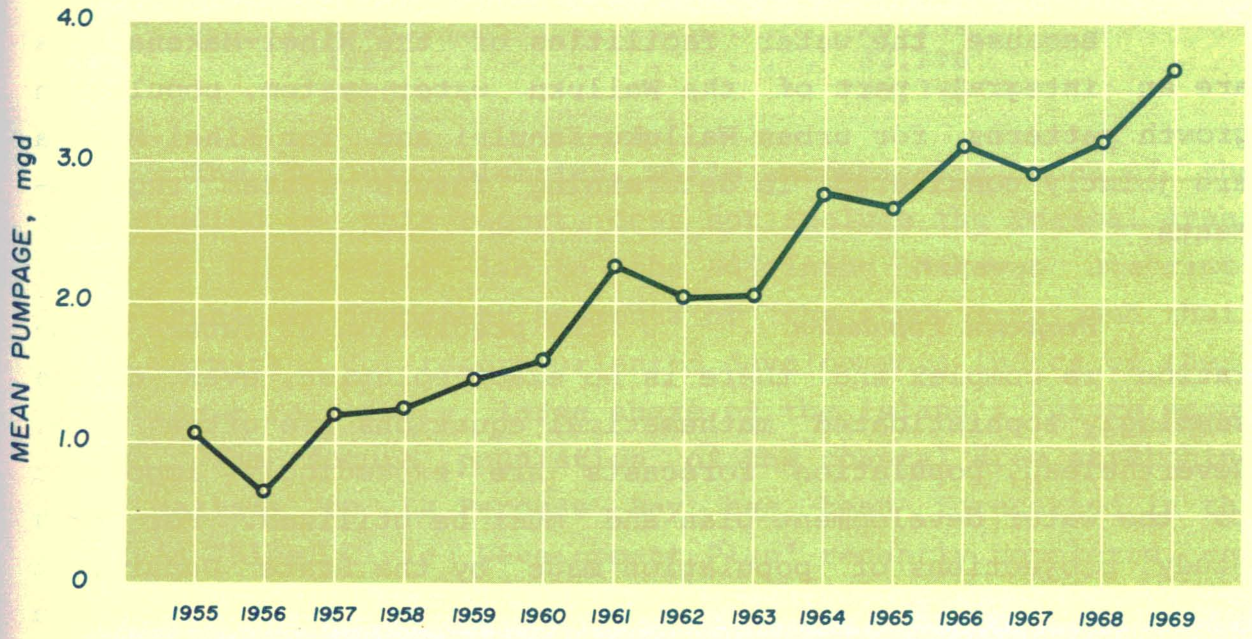


Figure 15 **MOKUHAU PUMPAGE**

A further summarized analysis of the pumping at Mokuhau is shown in Figure 13. Deviations of the values of high monthly mean and low monthly mean from the annual mean value have been closely similar during the past five years, both averaging about 35 percent. The values of high consecutive 5-day mean for each year, important from the standpoint of assessing the present water system's adequacy for sustained capacity operation and of sizing facilities for future needs, averages out to be about 1.6 times the annual mean value.

FUTURE WATER REQUIREMENTS

The basis for the design of the Kihei-Makena water system is the estimated future water requirements, extremely important in sizing the components of the system. Future population estimates permit a computation of the total water needs of the area.

Because the water facilities of the Kihei-Makena area are an integral part of the Wailuku water system, population growth patterns for urban Wailuku-Kahului and for Kihei-Makena are jointly considered in determining future system requirements.

Projected Population The prediction of future population is complex and there is no exact solution, even though seemingly sophisticated mathematical equations are often used. Nevertheless, population forecasts are exceedingly important to the water development plan and must be utilized. For this study, projections of population made by the State Department of Planning and Economic Development (covering the Wailuku District) and by the Maui County Department of Planning (covering the Kihei-Makena area) are used in estimating future water needs.

The "State of Hawaii General Plan Revision Program" population estimates, developed in 1967 and updated in November 1969, present quinquennial projections for the Wailuku Judicial District (includes Maalaea, Kihei, and Kamaole as well as Wailuku-Kahului and environs). The projections indicate an annual growth rate of 2.3 percent for the district's population. The projections were prepared by two separate methods, which were then averaged to obtain a final estimate deemed suitable for planning purposes. The first series was calculated by the "ratio method", which utilizes past trends to predict future growth. The second series was based on the assumption that a district will share in future population growth in proportion to its share of future tourism, as measured by net growth in the number of hotel units. Resulting population estimates for the Wailuku District are as follows:

Year	Estimated Population
1970	23,689
1975	24,487
1980	28,258
1985	32,296
1990	36,346

The Wailuku District, while encompassing much of the area studied in this report, does not include the coastal areas south of Kihei which lie in the adjoining Makawao District. These areas are important segments of the study area, and their being earmarked for resort-oriented developments indicates their absorbing a relatively large share of the island's future population. The future population of the coastal area stretching from Maalaea to La Perouse Bay has been forecasted in the County's "Kihei Civic Development Plan" recently completed, and discussed elsewhere in this section.

A report on the future population in the urban areas of Wailuku and Kahului was made in the County's 1962 Wailuku-Kahului planning study. This population report, prepared by economic consultant Wilbur McCann for the planning study consultant, Community Planning, Inc., predicts a population of approximately 24,000 in Wailuku and Kahului and the outlying areas by 1980. This 24,000 population closely coincides with that presented in the original projections of the State General Plan Revision Program for the corresponding area and time. Significant in the projections for the Wailuku-Kahului area is the assumption that only a moderate growth will take place and that increases would be attributable to natural causes primarily, with in-migration and out-migration in balance.

The population growth projected for the coastal Maalaea-Kihei-Makena area, on the other hand, is heavily influenced by the area's potential for tourism (Figure 4). This is reflected in the County Planning Department's recently prepared "Kihei Civil Development Plan", which predicts that the population of the coastal area will rise significantly in the next two decades from its present level of approximately 1,500 persons. Employing the "hotel-unit method" of calculating projections, the County plan envisions a resident population of 41,300 by 1990. Populations at 5-year intervals are as follows:

1970	1,500
1975	4,860
1980	11,440
1985	21,630
1990	41,300

It is to be noted that the foregoing projections of population were made for areas that are not separate entities in themselves. The Maalaea-Kihei area is common to both of the census areas for which separate projections were made and this overlap in area must be considered in using the projection figures. For this report, the use of the population figures arising from the County's Kihei planning study is considered the more appropriate for the coastal Maalaea-Kihei-Makena area, where the present rural character of the area will surely be altered by the impact of the island's visitor industry. For the Wailuku-Kahului area--urban in character, having experienced no real gain in population during the past 40 years, and believed less attractive as a tourist destination area than are other areas--the State Planning Department's projections for the Wailuku District are deemed suitable for planning purposes. The State's original projections indicated an annual growth rate of 1.3 percent as contrasted to the 2.3 percent rate of the recently revised (1969) projections. The rise in growth rate is believed attributable primarily to the expected increase in visitor-oriented activities along the Maalaea-Kihei coast.

In applying these projections, however, the State's figures need to be modified to reflect the deletion of the Maalaea and Kihei population, the accounting of which has been included in the County's Kihei Civic Development projections. If it can be assumed that the Maalaea-Kihei population projections of the 1967 State General Plan Revision Program approximates the new increases expected for the Wailuku-Kahului area under the revised 1969 projection, then it may be reasonable to let the 1967 State projections represent the expected future population of the Wailuku-Kahului area. This assumption has been followed in this report. A summary of the population figures used is included in Table 3 below.

Table 3. POPULATION PROJECTIONS FOR THE STUDY AREA

Year	Wailuku-Kahului Sub-Area*	Kihei-Makena Sub-Area**	Total
1970	21,270	1,500	22,770
1975	22,600	4,860	27,460
1980	24,030	11,440	35,470
1985	25,530	21,630	47,160
1990	27,000	41,300	~~62,300~~ 68,300

*State of Hawaii General Plan Revision Program, 1969 (as amended in text).
**Kihei Civic Development Plan, County of Maui, February 1970.

Projected Water Demand The determination of future water requirements can be obtained by relating the anticipated population with a reasonable rate of water usage per capita. An examination of past records shows that per capita usage of water in the Wailuku District amounts to roughly 180 gallons per day. By comparison, the island of Oahu averaged a daily per capita use of 188 gallons during fiscal year 1969, with the usage figure for the city of Honolulu and the suburban area being 209 gpcpd (gallons per capita per day) and 160 gpcpd, respectively.

Future water requirements for the Wailuku-Kahului and Kihei-Makena service areas based on a 180-gpcpd use rate are tabulated in Table 4 and presented graphically in Figure 16.

Also shown in the graph of Figure 16 are the water requirements of the urban-designated lands of Wailea in the service area. These requirements--prepared by the developer of the Wailea property, Alexander & Baldwin, Inc.--are predicated on areal growth occurring somewhat sooner than that anticipated under the Kihei Civic Development Plan. Alexander & Baldwin, Inc.'s average-day water requirement for Wailea in 1975 is 1.86 mgd as contrasted with the 0.88 mgd projection for the entire Kihei-Makena service area in 1975 based on the Kihei Civic Development Plan. The variation amounts to about 110 percent.

Table 4. ESTIMATED FUTURE WATER REQUIREMENTS (million gallons per day)

Year	Wailuku-Kahului		Kihei-Makena		Combined	
	Mean-Day	Max.-Day	Mean-Day	Max.-Day	Mean-Day	Max.-Day
1970	3.83	6.14	0.27	0.43	4.10	6.56
1975	4.06	6.50	0.88	1.40	4.94	7.90
1980	4.32	6.91	2.06	3.30	6.38	10.21
1985	4.60	7.35	3.89	6.22	8.49	13.58
1990	4.86	7.80	7.43	11.89	12.29	19.66

Because the distribution tanks at the service areas would provide storage limited to handling short-term demand fluctuations and fire fighting usage, the design of the water transmission facilities requires that the mains be sized to carry the maximum-day requirements. Past records show that the maximum-day requirement is about 1.6 times that of the average day. (For this determination, the mean daily value of the highest 5-consecutive-day production at the Mokuhau well source

PROJECTED MEAN WATER REQUIREMENTS

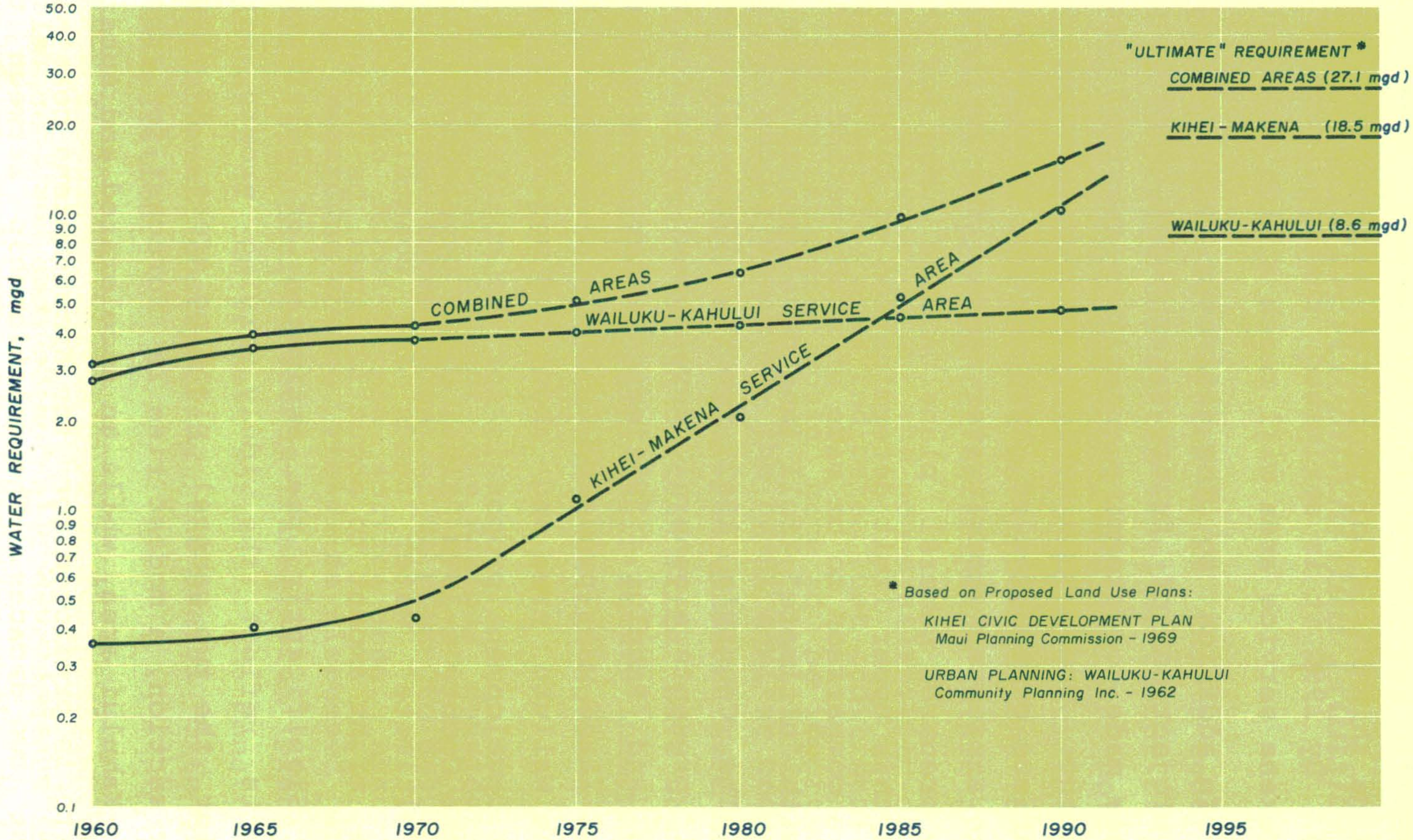


Figure 16

during the five-year 1965-1969 period was used to represent the maximum-day requirement.) Maximum-day water requirements derived on this basis for projected mean-day values are shown in Table 4. By 1990 it is estimated that delivery of water to the Kihei-Makena service area will reach a high of about 11.9 mgd.

In addition to the estimates prepared above, supplemental projections of future water needs based on proposed land uses were made to determine quantities required under full land development. Under this method, water use factors were assigned the various categories of land use on an acreage or per-room basis to arrive at total water needs. The availability of previously prepared general plans on land uses for the study area permits this upper limit determination of future water needs and allows a comparison to be made of study-period (1970-1990) water needs with "ultimate" (full land development) water needs.

The County's 1962 report, "Urban Planning: Wailuku-Kahului" presents a general development plan for the lands in Wailuku and Kahului. "Ultimate" water needs derived on the basis of land uses proposed in the plan amount to about 2.9 mgd for the Wailuku area and about 5.8 mgd for the Kahului area. Similar development proposals for the coastal Kihei-Makena area, under the County's 1970 "Kihei Civic Development Plan", indicate that "ultimate" water needs for coastal lands, including Maalaea, might amount to about 12.3 mgd, on the average.

Significantly, the estimates of "ultimate" water requirements reflect the widely varying growth pattern anticipated for the two general planning areas. As discussed in an earlier section, a modest rise is forecast for the established Wailuku-Kahului area, while an accelerated and substantial rate of growth is predicted for the Kihei-Makena coastal area during the next two decades. The relationship between this report's study-period water needs and probable "ultimate" water needs is shown in the graph of Figure 16.

Plan for Water Development and Transfer

A review of the water system as it exists today shows that the task of improving the system resolves to one of developing new sources to augment those now existing and bolstering the capacity of the present transmission mains. Evident is the general insufficiency of the present water sources and the Kihei transmission pipeline to provide for anticipated future needs.

The earlier discussion on the non-availability of water in the Kihei-Makena service area indicates that additional water required for future expansion would have to be imported, and likely sources of supply would be the basal aquifer underlying leeward East Maui just north of Kihei and windward West Maui in the vicinity of Wailuku. Though certain sites have been earmarked as possible sources of supply, their future incorporation into the overall water system would hinge on the outcome of preliminary explorations.

This section will present the various considerations that entered into the formulation of a plan to develop and deliver water to the Kihei-Makena service area. Assumptions have been made regarding source yield, as discussed in the earlier sections. Alternative source-Transmission plans were compared on the basis of the present worth of the construction, pumping, and replacement costs during the useful life of each structure or installation.

The plans discussed herein provide for needs which have not yet materialized, and because not all developments are required at once or at the same time, the plan would be implemented as needs arise. A precise schedule of year to year development was not considered necessary, but a general order of priority was established.

SOURCE DEVELOPMENT

Because surface water resources in the study area are already extensively developed for irrigation use by the sugar plantations, new source developments for municipal purposes are directed toward the use of ground water. Hydrologic and geologic considerations indicate the availability of a good supply of basal water at or near Iao Valley, with lesser amounts available in the Waiehu-Waihee area and at Waikapu Valley. Ground water of good quality is not widespread in the Central Maui Isthmus, which is largely of alluvium and believed to be replenished with percolated irrigation water. The aquifer beneath the slopes of leeward East Maui is largely unexplored and its potential as a major water source is currently being investigated by the drilling of an exploratory well. Elsewhere in the study area, along the Kihei-Makena coast, potable ground water in sufficient quantities is believed lacking, due in main to the small recharge from low rainfall on the mauka slopes.

The following possible sites for new ground-water developments to augment the existing Iao Tunnel and Mokuhau Wells are examined in some detail herein: (See Figure 17 for numbered site locations.)

Site 1 - Upper Kihei
Site 2 - Waikapu
Site 3 - Kepaniwai Park in Iao Valley
Site 4 - Happy Valley
Site 5 - Waiehu

The prospects of encountering developable amounts of potable water at the four sites in West Maui are good, while at the mauka Kihei site such prospects are somewhat speculative.

POSSIBLE SITES FOR SOURCE DEVELOPMENT

Figure 17

Site No. 1 - Upper Kihei From an economic viewpoint, a water source situated close to its service area is desirable. The present importation of water at the Kihei-Makena service area from Iao Valley involves a transmission main of approximately 11 miles across the Maui Isthmus. This pipeline can deliver up to about 3.0 mgd, after which rate a supplemental line would have to be installed to provide the balance of the total 12 mgd maximum-day demand expected by 1990. The availability of an adequate source of potable water somewhere within or near the service area would obviate the installation of such a long supplemental pipeline.

Present data on ground-water explorations show that only brackish water can be expected to be encountered along the coastal area from Kihei to the southern limit of the study area. Wells to recover potable water would have to be drilled farther mauka, but the slope rises so rapidly inland that the great depth of such wells would make them too costly.

Near the Isthmus and up the western slope of Haleakala the chances of locating good quality water is expected to be somewhat better. There is, however, little information to definitively assess the character of the underlying aquifer. Hawaiian Commercial & Sugar Co.'s Shaft 15 (Figure 6) located about two miles back of the abandoned Puunene Airport at elevation 303 feet is currently being pumped at a rate close to 20 mgd. The chloride content at this source is about 550 ppm. Water produced at Shaft 14 at elevation 26 feet near the Kihei shore area has a chloride content of about 700 ppm.

To learn more about the quality and quantity of developable water farther inland, the State is presently drilling an exploratory well at the approximate 600-foot level along Waiakoa Road. The site lies in the land district of Pulehunui and is about 1.75 miles mauka of Shaft 15. Should good quality water be available in sufficient amount, the source's incorporation into the Kihei-Makena water is advised.

Site No. 2 - Waikapu A review of the ground-water potential in the general area of Wailuku suggests the drilling of an exploratory well in Waikapu to take advantage of the location's shorter distance to the Kihei service area. It is believed that wells drilled in Waikapu will encounter developable amounts of water, with yields increasing with distance up the mountain slope. The chances of encountering a high-production well, however, would be less than those of encountering such a well closer to Iao Valley.

A possible site lies at the 500-foot elevation about midway between Waikapu and Wailuku towns. Wells at this site are expected to pass through the alluvial plain of the Maui Isthmus and penetrate the permeable West Maui basalt somewhere near sea level. Wells located at lower elevations would encounter the basalt aquifer at progressively greater depths, with a corresponding increase in the possibility of salt water intrusion with pumping, and this may limit the rate at which water may be withdrawn. The yield of the aquifer at this site is estimated to be about 10-12 mgd.

Site No. 3 - Kepaniwai Park in Iao Valley Wells tapping dike-confined ground water in Iao Valley are possible sources of additional water for Wailuku's high-level service area. The base yield of Iao Tunnel is not sufficient for future requirements and it is believed that devloping the structure further would not increase its yield materially.

About 2 mgd of water could be developed through wells drilled at the County's Kepaniwai Park site. These wells would extend to a depth of about 200 feet. The pumped water would be delivered to the makai Iao tanks through the existing 12-inch pipeline from the Iao Tunnel. The output of the wells, when coupled with that from Iao Tunnel, would provide a firm delivery of about 3 mgd to the upper Wailuku service area. This is the projected quantity required near the end of the study period for the area.

Water from the wells, because of its being derived from a high-level aquifer, would be less costly to develop, from a pumping-cost standpoint, than that obtained from the deep wells at Mokuhau. Further, its cost from the same standpoint would be less than the basic price of $55.00 presently being charged for Iao Tunnel water taken above that quantity granted without charge.

Site No. 4 - Happy Valley The drilling of additional wells at the Mokuhau site is not being contemplated. While present water quality is good, an analysis of recent records of chloride levels shows that salinity encroachment may become a problem at higher sustained withdrawals.

Considered as a possible new well site is an area on the mauka slopes of Happy Valley about 0.5 mile distant from the existing Mokuhau Wells. While the new wells would tap the same aquifer as the Mokuhau Wells, the distant between the two sites should minimize to safe levels the effects of interference during pumping.

As the character of the underlying geology at the proposed site is expected to be similar to that at Mokuhau, there would exist at this site an element of risk in tapping the basalt at an economical depth beneath the mantle of alluvium. The siting of the wells to a mauka location to lessen the chances of encountering the basalt lavas way below sea level and resulting in higher-cost wells and a possible problem in saltwater encroachment must be weighed against the siting of the wells to a makai location to reduce pumping lift. It should be noted that the 1950 Department of Water Supply's test well No. 1 along Mokuhau Road did not reach the basalt at all, and that the Mokuhau Wells found the basalt near sea level. Wells drilled at the Happy Valley site should be located near the 500 to 550-foot level. At this level the alluvium-basalt interface should be reached at or above sea level.

Site No. 5 - Waiehu Barring the availability of good quality water in sufficient quantity from areas nearer to the Kihei-Makena service area, the development of ground water in Waiehu is suggested. Fed by ample rainfall, the permeable lavas along the windward West Maui slopes constitute an excellent source of potable ground water.

At this site, the yield is expected to be plentiful, interference from other wells would not be a problem, and the aquifer at sea level would almost surely be of basalt. The site's extreme distance from the area of service is an obvious disadvantage, however.

TRANSMISSION ROUTES

The present 18-inch transmission pipeline supplying water to the Kihei-Makena service area is expected to be supplemented with another pipeline when future demand exceeds the present pipeline's capacity. In the event future requirements cannot be satisfied from sources in the proximity of the service area and new supplies need to be imported from windward West Maui, two general alternative routes could be used to transmit water from the source area to the service area. The major difference between these two routes is the alignment followed in traversing the Isthmus. One route follows the present pipeline. The other follows the present pipeline up to Waikapu town, then diverts toward Maalaea and continues along Honoapiilani Highway until the latter's intersection with Kihei Road, and then follows Kihei Road toward a reunion with the existing pipeline at Kihei. While the latter Maalaea route entails an additional distance of 1.3 miles, it eliminates for a large part (approximately 11,000 feet) any new pipeline needed from the present transmission pipeline to service Maalaea. After discussions with the County Department of Water Supply, it was decided jointly that the Maalaea alignment would be incorporated in this study's development proposals.

ALTERNATIVE DEVELOPMENT PLANS

The several new sources of supply may be incorporated into the present system by means of various alternative schemes. Two schemes were developed in some detail, as follows:

Alternative 1: Development of New Source in Kihei

Alternative 2: Development of New Source in Windward West Maui

Basic to both plans would be (1) the provision of an additional source of supply for the Wailuku high-level service system, and (2) the enlargement in electrical capacity at the existing Mokuhau pumping station. The augmentation of the Iao Tunnel with another supply source is designed to provide the additional water that will be required in the Wailuku high-level service area. Under the present agreement governing the use of Iao Tunnel water, only 1,073,000 gpd is guaranteed as a firm supply; additional water can be purchased only when it is available.

Three courses of action may be followed in meeting the needs of the high-level service area:

(1) Continued purchasing of available surplus Iao Tunnel water from Wailuku Sugar Company.

(2) Development of dike-confined ground water in Iao Valley.

(3) Booster pumping of water from Mokuhau Wells.

The first course of action is disadvantaged by the fact that water yield isn't entirely dependable and quantities may be insufficient for future needs. Too, the basic price of $55 per million gallons is subject to escalation.

The second course of action has possibilities, but is hampered by unknown conditions which may make it infeasible. The risks, though, are not great and can be eliminated through preliminary drillings. This course's apparent advantages lie in its higher dependability as a source as compared with surplus tunnel flows and in its lesser pumping cost as compared with obtaining Mokuhau water. With respect to the latter, the cost advantage in the new source would be negated if ground water is not encountered at a high level or if aquifer yield is poor. Present estimates indicate costs of capital recovery and operation and maintenance of a new source to be competitive with the cost of purchased water if aquifer yield is at least 2 mgd and water stands no deeper than about 350 feet from ground level.

The third course of action can be implemented straightforwardly, but operational costs can be expected to be high, as Mokuhau water is essentially basal water that needs to be lifted from sea-level.

As the other basic improvement to the present water system, the enlargement of the electrical capacity of the Mokuhau pumping installation would increase the reserve capacity at the site by 25 percent (from 8 mgd to 10 mgd). This increase is predicated on the belief that the Mokuhau aquifer is capable of sustaining additional pumpage. Additional power transformers would provide the desired increase in the electrical capacity of the station. (Power is purchased under the primary power schedule, which requires rental or customer installation of transformers.)

Alternative 1: Development of New Source in Kihei

This plan presupposes the availability of an adequate quantity of water at the site of the exploratory well currently being drilled in upper Kihei near the 600-foot level. The maximum-day water requirement for the Kihei-Makena area by 1990, as estimated, is 11.9 mgd. Of this amount, 3.0 mgd is available for delivery to the area via the present transmission main from the Mokuhau source. The balance of the water required would be furnished by deep wells drilled in upper Kihei.

Without benefit of definitive figures, pending the collection of data from the exploratory well presently being drilled, estimates of probable aquifer yield were made to prepare a water supply and transmission plan that could be implemented in the event a good supply of potable water is shown to exist. A peak capacity of 9 mgd--corresponding to the above balance of supply required for the service area, and representing an average production rate of 5.6 mgd--was used as the yield potential of the Kihei source.

Under this plan, a field of three wells would produce the required 9 mgd peak supply; a fourth well would stand by for emergency use. Initially, two wells would be drilled; additional wells would be drilled as the need arises. An 18-inch supply line would deliver water from the well site to Kamaole Homesteads in the service area, following a route generally along Waiakoa Road.

An obvious advantage under this plan is the unnecessity of a costly transmission main across the Maui Isthmus. This advantage would adequately offset the disadvantage of the higher pumping lift required at the site as compared with those at possible sites near Wailuku.

Alternative 2: Development of New Source in Windward West Maui

Under this plan of development, additional wells would be drilled in windward West Maui at possible Sites 2 (Waikapu), 4 (Happy Valley), or 5 (Waiehu). These wells would provide the additional water required when consumer demands exceed the combined capacity of the existing Mokuhau Wells and Iao Tunnel. On the basis that 3.0 mgd will be available for delivery to Kihei-Makena from the Mokuhau Wells, the proposed new wells at Sites 2, 4, or 5 would be called upon to furnish a maximum-day requirement of 9.0 mgd.

Of the three possible new well sites, priority development of the Waikapu site (Site No. 2) is recommended. Two 3.0 mgd capacity wells would be drilled initially; one would serve as a standby. Three additional wells of like capacity would be drilled later when required.

If, for some reason, the site at Waikapu proves infeasible, the Happy Valley site would then be explored. The yield of this site is estimated to be ample for the 9.0 mgd maximum-day pumpage desired. In the event the yield is found to be substantially less and prospects for obtaining the desired quantity through wells drilled farther up the slope are poor or economically infeasible, the development of the Waiehu site could then be considered.

The increase in supply brought about by the drilling of the new wells at the aforementioned sites would be accompanied by a corresponding increase in the capacity of the transmission mains. The present pipeline across the Maui Isthmus and along the Kihei-Makena coastline would be left intact, and supplemental parallel lines would be added incrementally as water requirements progressively increase.

RECOMMENDED PLAN OF DEVELOPMENT

The evaluation of the two alternative schemes of water development and transmission shows that the scheme proposing the full development of the Upper Kihei source possesses an obvious economic advantage over the other. The Kihei source's proximity to the coastal service area, however, is offset by the possibility of a restricted yield and this constitutes a major shortcoming under this plan. The current exploratory drilling at the Kihei source site would provide the information required for a more accurate assessment of aquifer potential.

The scheme proposing the development of additional sources in windward West Maui, while a costlier alternative, offers a program that involves less speculative courses of action. Importantly, the sites considered for possible source development are amenable to further development, embracing an aquifer that is believed capable of sufficiently providing the additional supply needed.

A consideration of the hydrologic and economic factors involved points out the desirability of consolidating both schemes, with some flexibility retained to allow for contingencies. This approach is recommended herein. Basically, the recommended plan of development proposes (1) the implementation of the Kihei source-based scheme if the results of the current site exploration prove favorable, and (2) the alternative implementation of the windward West Maui source-based scheme if the exploration proves otherwise. Under the latter scheme, the Waikapu source site would be accorded priority development.

The recommended plan of development can be implemented under two separate project programs, with the elements of each being initiated when the need arises. One program involves the improvements proposed for the Wailuku high-level service area. The other program involves the improvements proposed for the Kihei-Makena service area.

Program I: Improvements to Wailuku High-Level Service System

As mentioned earlier, the problem of initiating source developments for the Wailuku high-level service area hinges on the adequacy of the present Iao Tunnel supply to meet future needs, especially during extended periods of low rainfall, and the economics of developing a new source in preference to the continued purchasing of when-available tunnel water. Long-term considerations favor the County's developing a new high-level source near Kepaniwai Park.

Recommended at the outset is the drilling of an exploratory well at Kepaniwai Park to ascertain the site's potential as a supply source. For this study it is assumed that the exploratory drilling will encounter dike water at approximately 350 feet below ground surface and the aquifer would be capable of yielding about 2.0 mgd. Under this assumption, the exploratory well would comprise the initial of two wells to be drilled at the park site. The combined yield of the tunnel "free" water and the two wells would amount to roughly 3.0 mgd. or slightly more than the 2.8 mgd requirement projected for the high-level service area. Under this tunnel-well arrangement, the drilling and equipment of a standby well would not be necessary as tunnel water can be purchased during periods of emergency.

It should be noted that the existing 12-inch main from the Iao Tunnel to the makai tanks has a capacity of 4.5 to 5.0 mgd, precluding the need for a new transmission line for the Kepaniwai Park well supply. Also, because of existing system interconnections beyond the Iao Tanks, any water surplus to the needs of the upper Wailuku area can be allowed to be bypassed to lower Wailuku or Kahului. A pressure-sustaining valve installed near the Waiale Drive-Waiinu Road intersection would accomplish this bypass.

As an alternative measure in the event high-level ground water cannot feasibly be developed, it is recommended that the present practice of purchasing tunnel water be continued and that a booster pumping unit be installed in the Wailuku system to permit the delivery of Mokuhau water to the Iao Tanks during periods of high consumption or emergency.

The improvements proposed under this program are listed below.

a. Kepaniwai Park Wells in Iao Valley

(1) one 1.0-mgd exploratory well and pump at Kepaniwai Park, including test pumping. If results of above well prove satisfactory,

(2) additional 1.0-mgd well and pump, electrical and mechanical equipment and controls, and connection to existing 12-inch Iao supply line.

b. Alternative Booster-Pumping of Mokuhau Well Supply

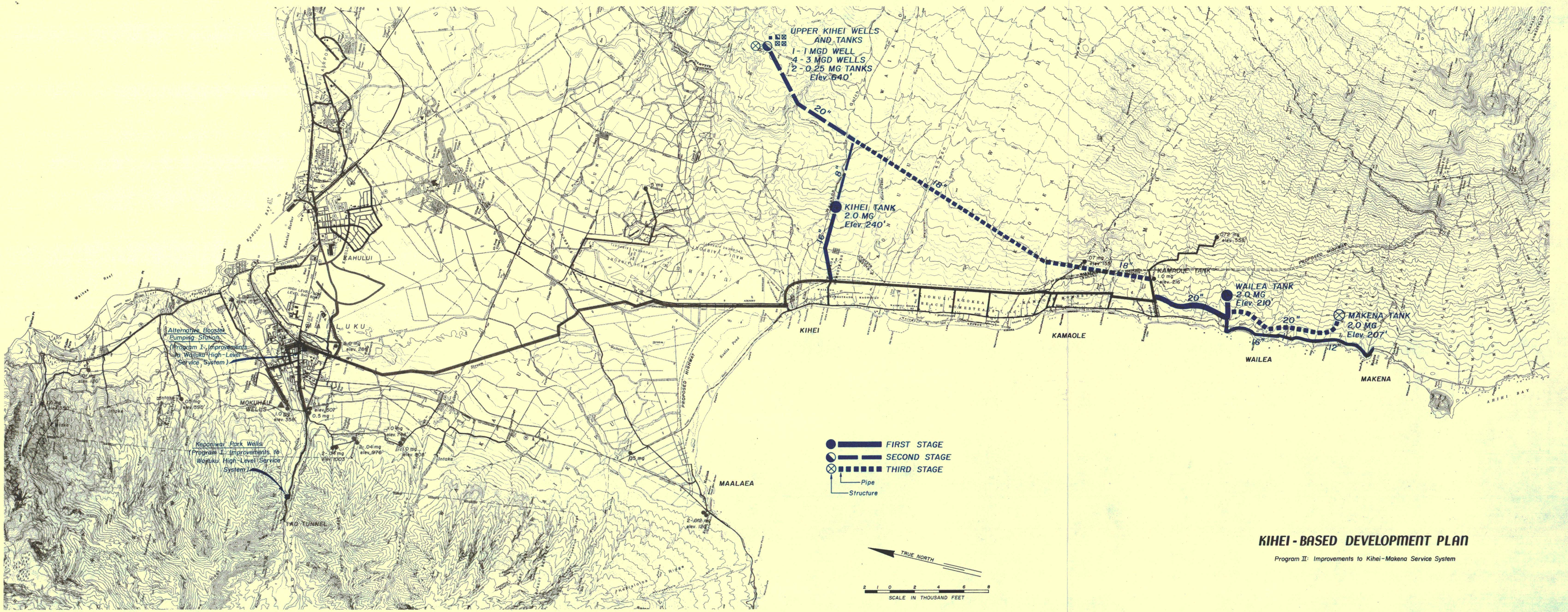
(1) in-line booster pumping unit along Main Street trunkline from Iao tanks.

Program II: Improvements to Kihei-Makena Service System

As earlier noted, the development of the Upper Kihei site as the primary source of supply for the Kihei-Makena service area is tentatively proposed. Should data collected from the current exploration at the site show this proposal unsuitable, the alternative development of the windward West Maui sites would be pursued.

The proposed development plans incorporating the Waikapu, Happy Valley, and Waiehu source sites, when considered separately, are similar in many respects. All utilize the same basis for the design of the system features and involve like facilities, with differences confined primarily to pipeline diameters and lengths. For this reason, only the Waikapu based plan is discussed in some detail.

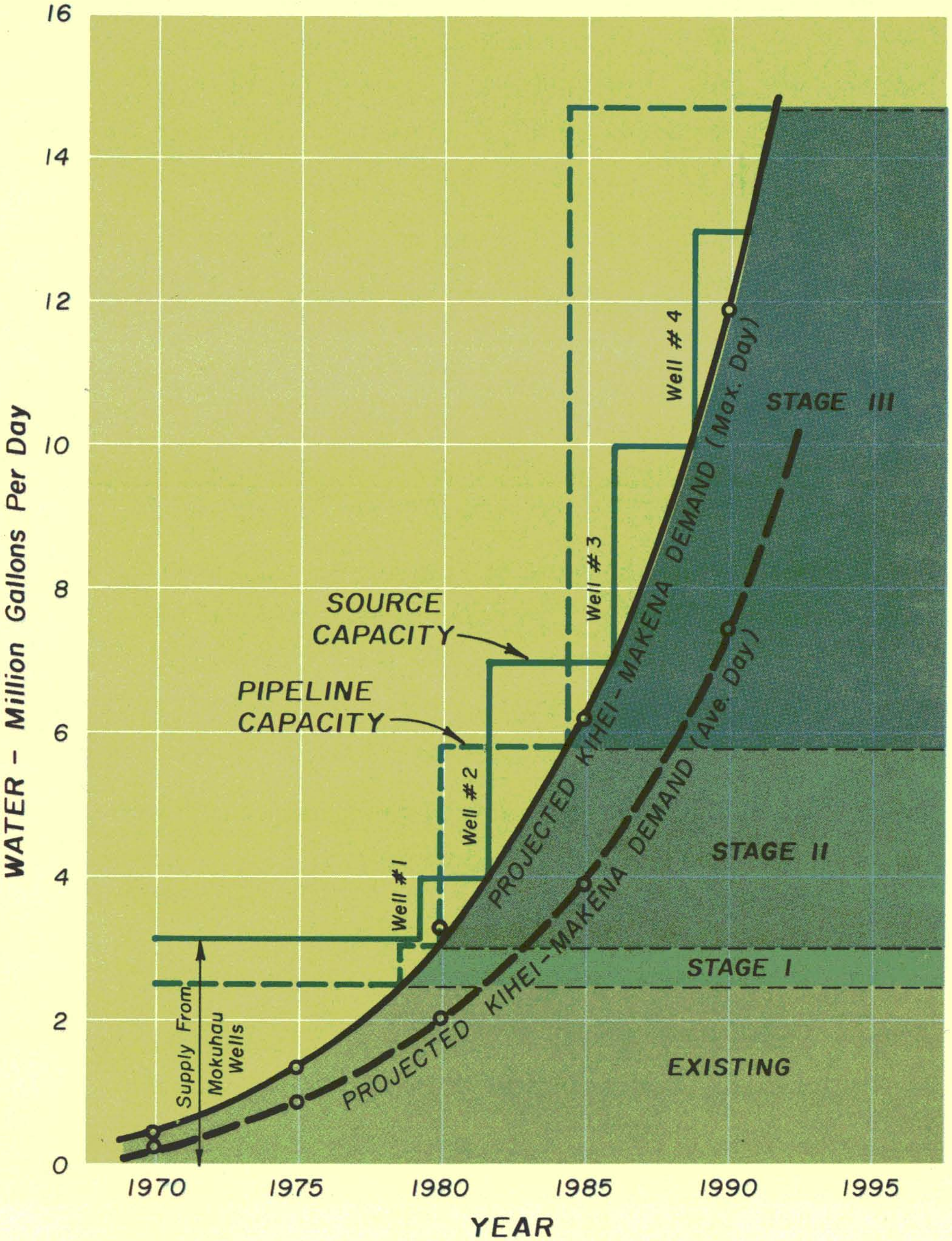
a. Kihei-Based Development Plan (Figure 18) As the primary source of supply for the coastal service area, the proposed Kihei wells would furnish a minimum peak supply of 9.0 mgd by 1990, with the balance of the 11.9 mgd peak-day projected requirement being imported from the Wailuku area. An estimated



KIHEI - BASED DEVELOPMENT PLAN

Program II: Improvements to Kihei-Makena Service System

Figure 18



CONSTRUCTION STAGING FOR KIHEI-BASED DEVELOPMENT PLAN

Figure 19

four wells (1 standby) each yielding a peak 3.0 mgd would provide the necessary supply. From a control tank at the well site a 20/18-inch gravity pipeline would make deliveries to tanks in Kihei, Kamaole, Wailea, and Makena. This pipeline would roughly follow the existing Waiakoa Road alignment, and hook up with the present service area trunkline at Kamaole Homesteads.

The relatively high elevation difference between the control tank at the well site and the distribution tanks farther makai would, during the earlier years when demands are low, allow the delivery of water by gravity to the upper service areas proposed at Wailea and Makena. As overall area demands increase over the years, however, booster pumping would be needed to augment deliveries to the upper levels.

The Mokuhau Wells would continue to supply the lower Wailuku, Kahului, and Maalaea areas. The present 18-inch transmission main across the Isthmus would also continue to deliver the balance of the Mokuhau supply to the Kihei area, with flow expected to be limited to about 3.0 mgd, as earlier mentioned.

The Kihei-based developed plan consists of improvements in three stages (figure 19) as follows:

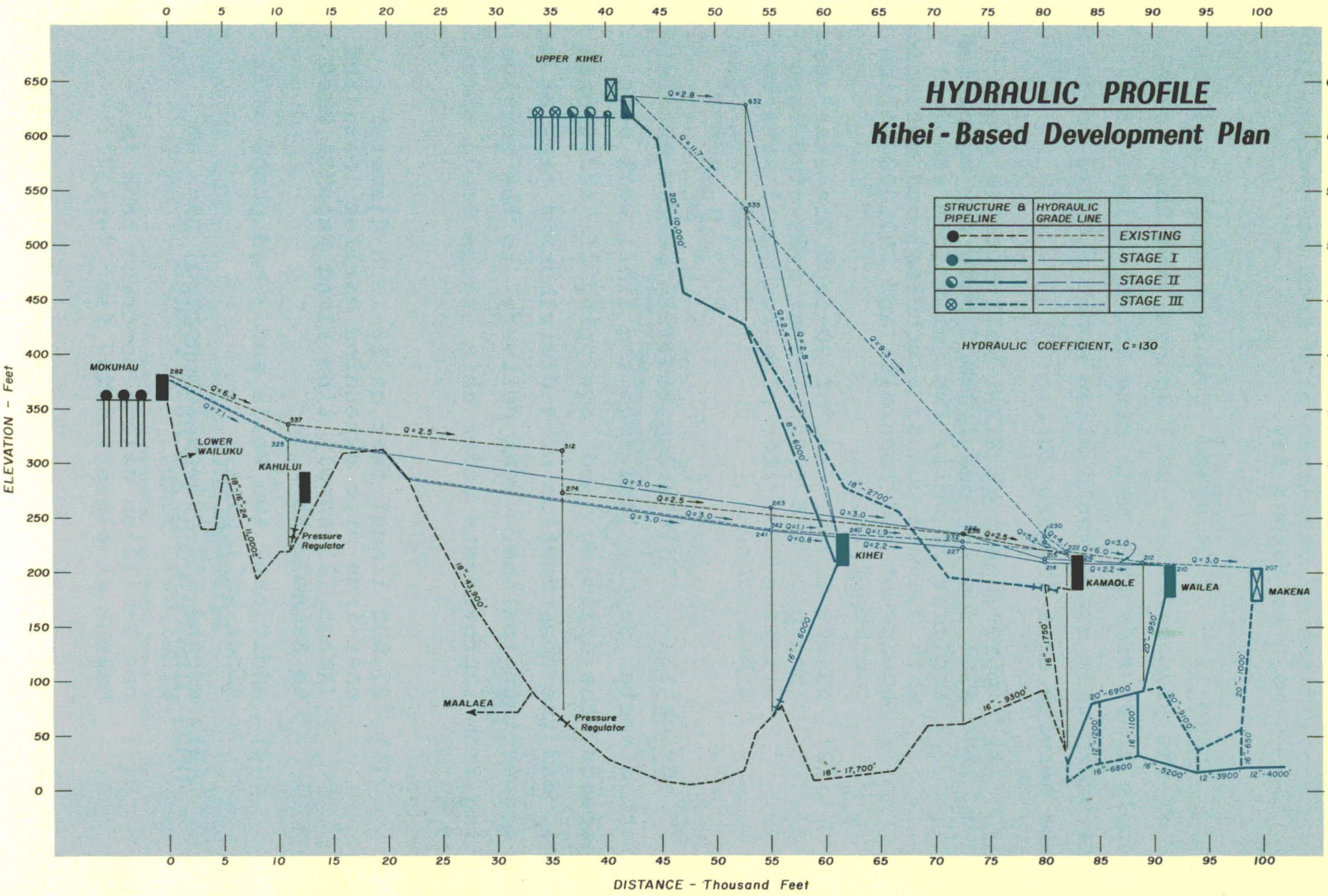
<u>Stage I</u> - This stage consists of storage improvements in the service area to permit improved system flows and pressures and to provide reserve supplies for contingencies. Also included is a spur pipeline to Makena Bay.

(1) one 2-million gallon concrete tank in Kihei at elevation 240 feet (spill).

(2) 6,000 lineal feet of 16-inch diameter cast-iron pipe from new Kihei tank to existing main.

(3) one 2-million gallon concrete tank in Wailea at elevation 210 feet (spill).

(4) 8,900 lineal feet of 20-inch diameter cast-iron pipe from new Wailea tank to existing main.



HYDRAULIC PROFILE: KIHEI-BASED DEVELOPMENT PLAN

Figure 20

(5) 6,300 lineal feet of 16-inch diameter cast-iron pipe and 7,900 lineal feet of 12-inch diameter cast-iron pipe from new Wailea tank main to Makena Bay.

Stage II - This stage consists of the initial development of the proposed Kihei well source, and the installation of a supply line from the well site to the Kihei tank. Improvements under this stage would allow about 5.8 mgd to be delivered to the service area (Figure 20).

(1) improvements at Kihei well site (elevation 620± feet): one 1.0-mgd pump for completed exploratory well; two wells (one standby) with 3.0-mgd pumps; electrical and mechanical equipment and controls; and 250,000-gallon control tank.

(2) 10,000 lineal feet of 20-inch diameter cast-iron pipe and 6,000 lineal feet of 8-inch diameter cast-iron pipe from well site to Kihei tank.

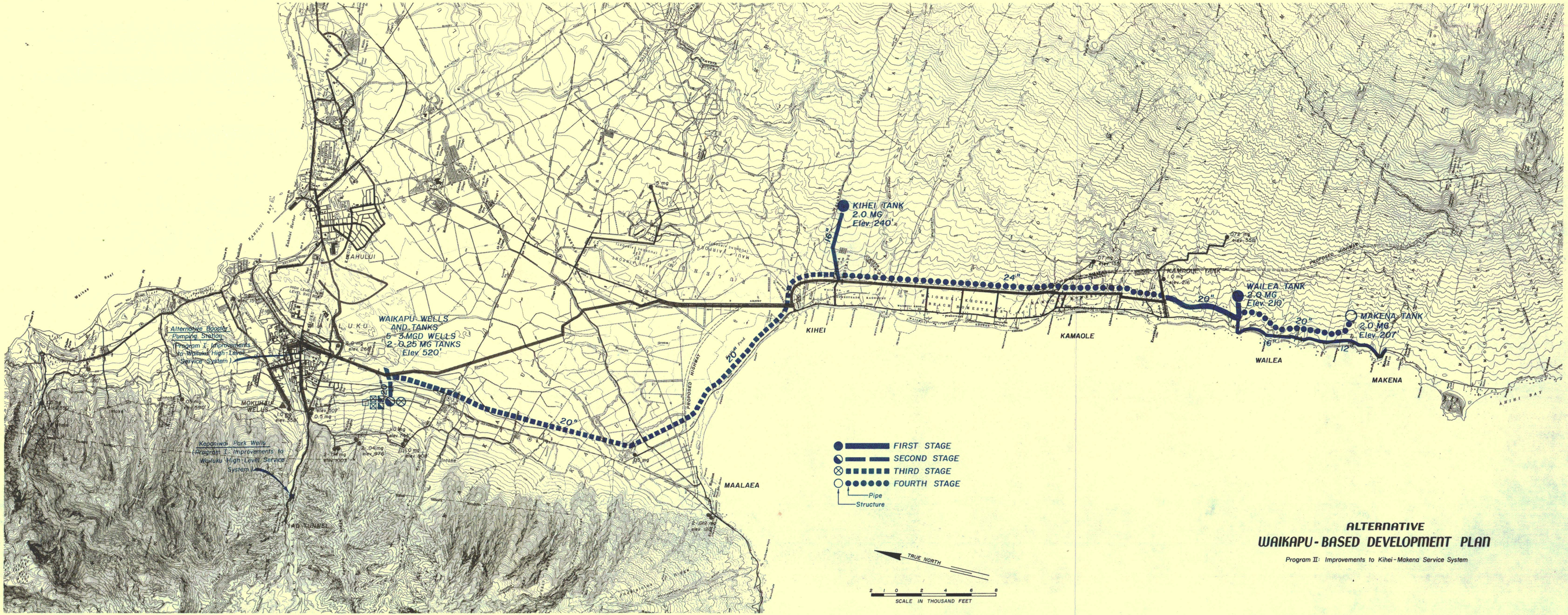
Stage III - This stage consists of the extension of the 20-inch diameter supply line from the Kihei well site to Kamaole Homesteads, the drilling and equipping of additional wells at Kihei, and the construction of a distribution tank at Makena and its connecting pipeline. Peak delivery to the service area resulting from improvements under this stage would amount to 14.7 mgd.

(1) 27,000 lineal feet of 18-inch diameter cast-iron pipe extending earlier installed (stage II) supply line along Waiakoa Road to Kamaole tank.

(2) additional two wells and 3-mgd pumps at Kihei well site.

(3) second 250,000-gallon control tank at Kihei well site.

(4) one 2-million gallon concrete tank in Makena at elevation 207 feet (spill).



ALTERNATIVE
WAIKAPU-BASED DEVELOPMENT PLAN

Program II: Improvements to Kihei-Makena Service System

Figure 21

(5) 10,100 lineal feet of 20-inch diameter cast-iron pipe from new Makena tank to main in Wailea.

b. Alternative Waikapu-Based Development Plan. (Figure 21). Like the preceding Kihei-Based Development Plan, this plan proposes the development of basal ground water in Waikapu to furnish a minimum peak supply of 9.0 mgd by 1990, supplementing the approximate 3.0 mgd supply from the Mokuhau Wells. Five 3-mgd wells (1 on standby) would be drilled near the 500-foot level and water pumped from these wells would be transmitted by gravity through a combination 20-inch diameter pipeline across the Isthmus via Maalaea to Kihei. A 24-inch diameter pipeline paralleling the present 18-inch diameter pipe would continue toward Kamaole, where a 20-inch diameter pipeline would continue further to Makena. Distribution storage tanks would be constructed at Kihei, Wailea, and Makena.

Implementation of the proposed plan would proceed in stages (Figure 22) as follows:

Stage I - This initial stage consists of the construction of distribution storage tanks at Kihei and Wailea and the installation of their connecting pipelines, including a spur line to Makena Bay. Improvements under this stage of development would provide no noticeable increase in the supply over the approximate 3.0 mgd deliverable to the service area from the Mokuhau source at present (Figure 23).

(1) one 2-million gallon concrete tank in Kihei at elevation 240 feet (spill).

(2) 6,000 lineal feet of 16-inch diameter cast-iron pipe from new Kihei tank to existing main.

(3) one 2-million gallon concrete tank in Wailea at elevation 210 feet (spill).

(4) 8,900 lineal feet of 20-inch diameter cast-iron pipe from the new Wailea tank to existing main.

(5) 6,300 lineal feet of 16-inch diameter cast-iron pipe and 7,900 lineal feet of 12-inch diameter cast-iron pipe from new Wailea tank main to Makena Bay.

Stage II - This stage consists of the drilling and equipping of the initial three wells at the Waikapu site and the installation of a supply line from the well site to the existing transmission main along Honoapiilani Highway. Under this stage, peak delivery of supply to service area, at Kihei, would increase to 4.4 mgd.

(1) improvements at Waikapu well site (elevation 500± feet): three wells with 3-mgd pumps, electrical and mechanical equipment and controls, and 250,000-gallon control tank.

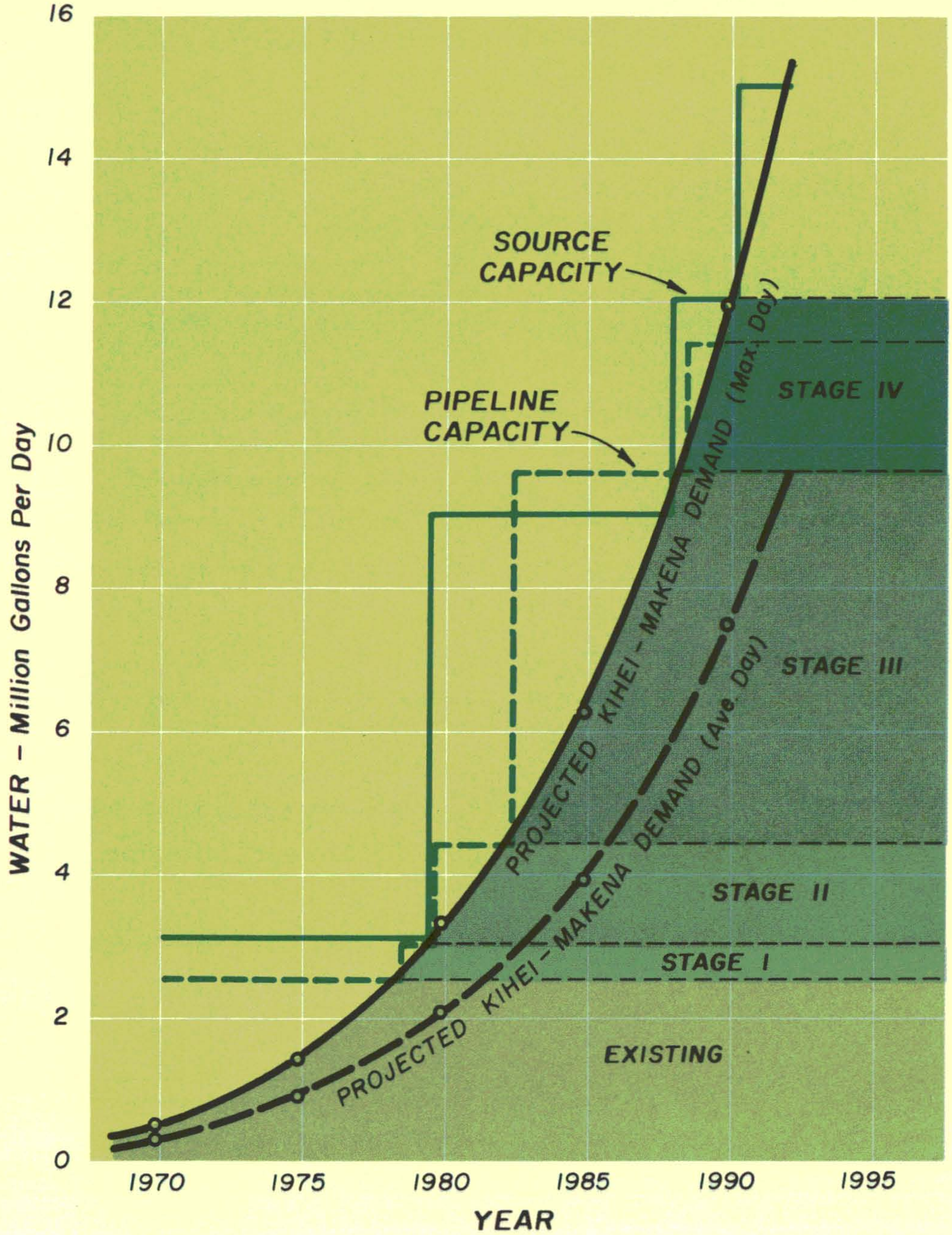
(2) 1,800 lineal feet of 20-inch diameter cast-iron pipe and 1,200 lineal feet of 18-inch diameter cast-iron pipe from Waikapu well site to existing 18-inch diameter main on Honoapiilani Highway.

Stage III - This stage consists of the drilling of an additional well at Waikapu and the installation of a supplemental transmission main across the Isthmus to Kihei via Maalaea. Peak delivery under this stage would amount to 9.6 mgd.

(1) one additional well with 3-mgd pump at Waikapu well site.

(2) 45,000 lineal feet of 20-inch diameter cast-iron pipe from Waikapu to Kihei.

Stage IV - This stage consists of the construction of a distribution storage tank at Makena and its connecting pipeline, the installation of a supplemental main from Kihei to Kamaole Homesteads, and the drilling of an additional well and the construction of a second 250,000-gallon control tank at the Waikapu well site. Peak delivery under this stage would amount to 11.4 mgd or 12.0 mgd, depending on whether the two transmission mains across the Isthmus are operated separately or conjunctively.



CONSTRUCTION STAGING FOR ALTERNATIVE WAIKAPU-BASED DEVELOPMENT PLAN

Figure 22

(1) one 2-million gallon concrete tank in Makena at elevation 207 feet (spill).

(2) one additional well with 3-mgd pump at Waikapu well site.

(3) one 250,000-gallon control tank at Waikapu well site.

(4) 10,100 lineal feet of 20-inch diameter cast-iron pipe from new Makena tank to main in Wailea.

(5) 27,000 lineal feet of 24-inch diameter cast-iron pipe from Kihei to Kamaole Homesteads.

COSTS

The capital costs of construction and annual costs including operation has been estimated for each planned stage using 1970 price levels. Engineering and contingencies have been included as 15 percent of capital cost. Annual costs have been estimated assuming a project life of 50 years and an interest rate of 6.0 percent. A 15-year replacement period for pumping installations has been used.

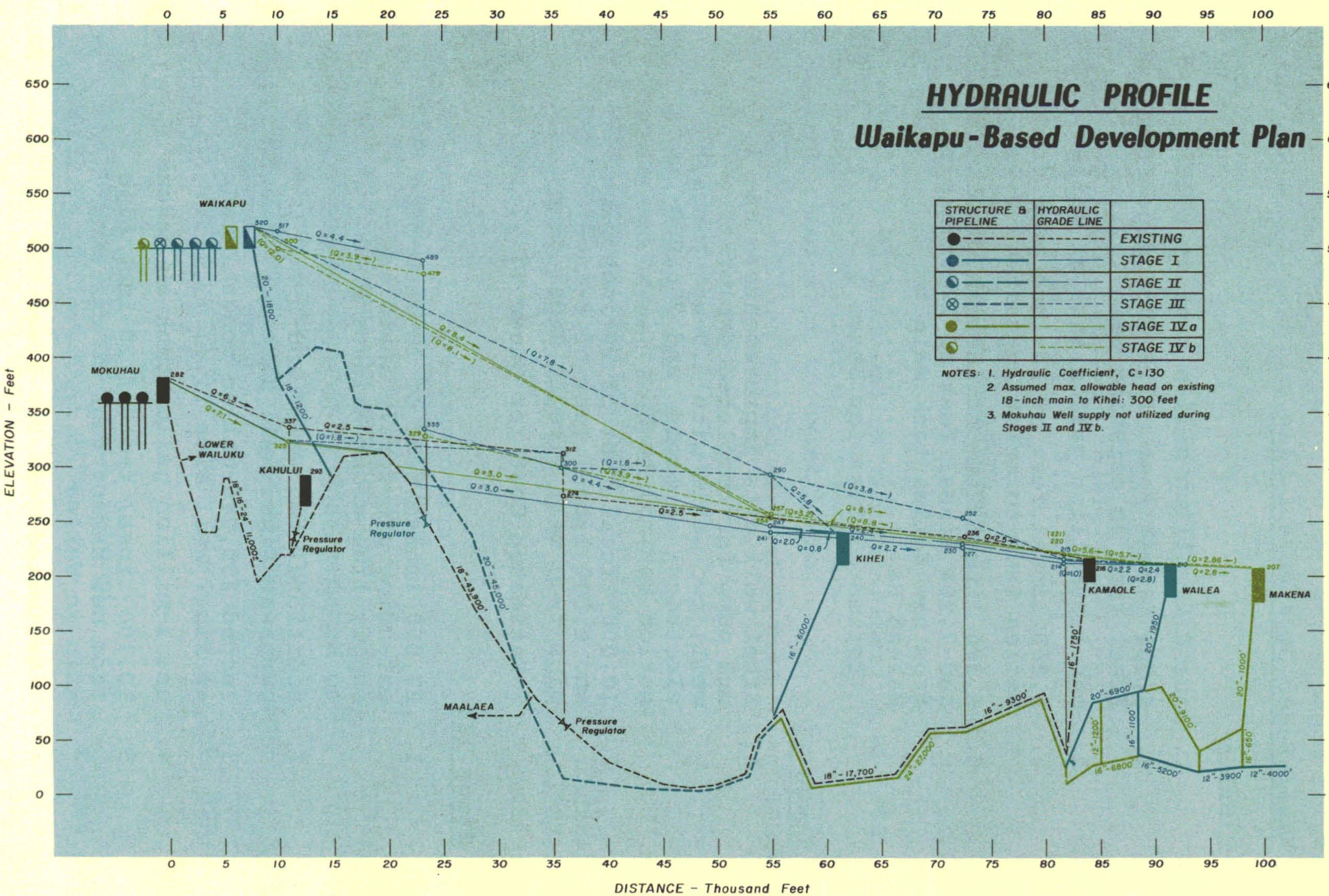
A summary of the estimated construction costs for the proposed plan is presented in the following, by programs and stages.

Program I: Improvements to Wailuku High-Level Service System

A. Kepaniwai Park Wells

1. one exploratory well and 1.0-mgd pump at Kepaniwai Park, including test pumping	$ 96,000
2. additional well and 1.0-mgd pump, electrical controls, and connecting pipeline	108,000
Total Estimated Cost	$204,000

B. Alternative Booster-Pumping of Mokuhau Well Supply (in-line 1.0-mgd booster pumping unit) ...... $ 33,000



HYDRAULIC PROFILE: ALTERNATIVE WAIKAPU-BASED DEVELOPMENT PLAN

Figure 23

Program II: Improvements to Kihei-Makena Service System

A. Kihei-Based Development Plan

Stage I

1.	one 2.0-million gallon tank at Kihei....	$ 460,000
2.	6,000 lineal feet of 16-inch pipe from Kihei tank to existing main	172,500
3.	one 2.0-million gallon tank at Wailea...	460,000
4.	8,900 lineal feet of 20-inch pipe from Wailea tank to existing main	355,000
5.	6,300 lineal feet of 16-inch pipe and 7,900 lineal feet of 12-inch pipe from new Wailea tank main to Makena Bay	335,000
	Estimated Cost for Stage I	$1,782,500

Stage II

1.	Kihei well site improvements: one 1.0-mgd pump for completed exploratory well, two wells with 3.0-mgd pumps, electrical controls, and 250,000-gallon control tank	$ 405,000
2.	10,000 lineal feet of 20-inch pipe and 6,000 lineal feet of 8-inch pipe from well site to Kihei tank	478,000
	Estimated Cost for Stage II	$ 883,000

Stage III

1.	27,000 lineal feet of 18-inch pipe extending previously installed supply line along Waiakoa Road to Kamaole tank	$ 930,000
2.	additional two wells and 3-mgd pumps at Kihei well site	265,000
3.	second 250,000-gallon control tank at Kihei well site	83,000
4.	one 2-million gallon tank at Makena	460,000
5.	10,100 lineal feet of 20-inch pipe from new Makena tank to existing main in Wailea	406,000
	Estimated Cost for Stage III	$2,144,000
	Total Estimated Cost for Three Stages	$4,809,500

The total annual costs including amortization of the capital cost and the cost of operation and maintenance for each stage of the above proposed plan have also been estimated and are reported below.

Stage	Total Annual Cost
I	$144,020.00
II	$221,140.00
III	$427,120.00

B. Alternative Waikapu-Based Development Plan

Stage I

1.	one 2.0 million gallon tank at Kihei....	$ 460,000
2.	6,000 lineal feet of 16-inch pipe from Kihei tank to existing main	172,500
3.	one 2.0 million gallon tank at Wailea ..	460,000
4.	8,900 lineal feet of 20-inch pipe from Wailea tank to existing main	355,000
5.	6,300 lineal feet of 16-inch pipe and 7,900 lineal feet of 12-inch pipe from new Wailea tank main to Makena Bay	335,000
	Estimated Cost for Stage I	$1,782,500

Stage II

1.	Waikapu well site improvements: three wells with 3.0-mgd pumps, electrical equipment and controls, and 250,000-gallon control tank	$ 532,000
2.	1,800 lineal feet of 20-inch pipe and 1,200 lineal feet of 18-inch pipe from well site to existing transmission main......................	114,000
	Estimated Cost for Stage II	$ 646,000

Stage III

1.	one additional well with 3.0-mgd pump at Waikapu well site	$ 144,000
2.	45,000 lineal feet of 20-inch pipe from Waikapu to Kihei	1,810,000
	Estimated Cost for Stage III	$1,954,000

Stage IV

1.	one 2.0-million gallon tank at Makena...	$ 460,000
2.	one additional well with 3.0-mgd pump at Waikapu well site	11,000
3.	one 0.25-million gallon control tank at Waikapu well site	83,000
4.	10,100 lineal feet of 20-inch pipe from Makena tank to main in Wailea	408,000
5.	27,000 lineal feet of 24-inch pipe from Kihei	1,426,000
	Estimated Cost for Stage IV	$2,388,000
	Total Estimated Cost for Four Stages..	$6,770,500

The total annual costs including amortization of the capital cost and the cost of operation and maintenance for each stage of the above alternative plan are given below.

Stage	Total Annual Cost
I	$144,020.00
II	$245,220.00
III	$421,170.00
IV-a	$641,360.00
IV-b	$683,260.00

References

Cox, D. C., 1951, Lowland ground water development prospects in and north of Iao Valley, Wailuku, Maui: Administrative report to Maui County Waterworks Board (now Department of Water Supply), 11p.

Herschler and Randolph, March 1962, Ground Water Development at Wailuku, Maui.

Maui County Planning Commission, February 1970, Kihei Civic Development Plan, Kahului, Maui.

Maui County Planning and Traffic Commission, 1962, Urban Planning: Wailuku-Kahului, Kahului, Maui.

State of Hawaii Department of Planning and Economic Development, 1967, State of Hawaii General Plan Revision Program: Population Projections, Honolulu, Hawaii.

State of Hawaii Department of Planning and Economic Development, November 24, 1969, Interim Revisions of Population Projections in the State General Plan, (Memorandum) Honolulu, Hawaii.

Takasaki, K. J., Hirashima, G. T., and Lubke, E. R., 1969, Water resources of windward Oahu, Hawaii: U. S. Geological Survey Water Supply Paper 1894, 119 p.

Takasaki, K.J. and Yamanaga, G., 1970, Preliminary report on the water resources of northeast Maui: Division of Water and Land Development Circular C60, 41p.

Taliaferro, W.J., 1959, Rainfall of the Hawaiian Islands: Hawaii Water Authority (now Division of Water and Land Development), 394 p.

Yamanaga, G. and Huxel, Jr., C. J., (in press), Preliminary report on the water resources of the Wailuku area, Maui: Division of Water and Land Development.