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of Engineers

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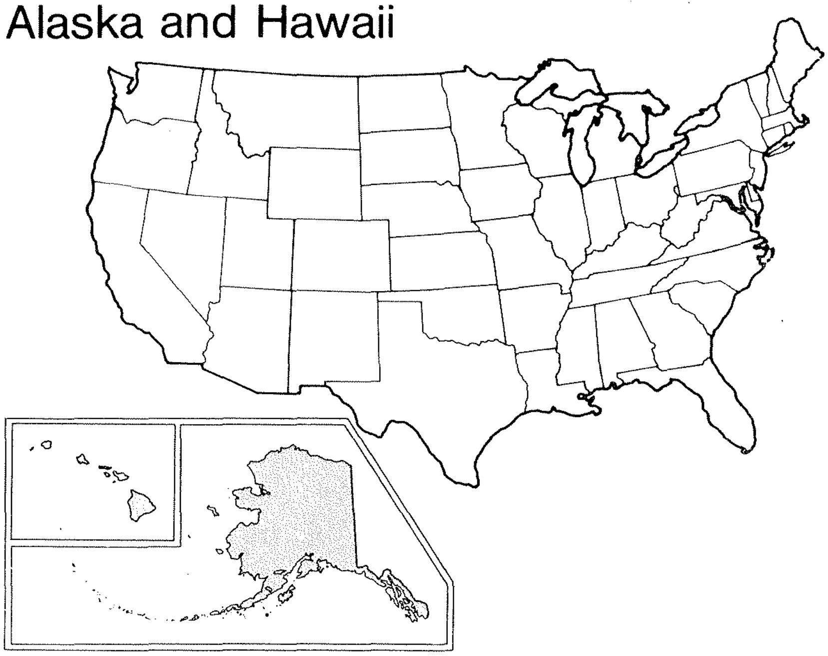
Hydroelectric Power
Resources Study

Volume XXIII
September 1981

Regional Assessment:
Alaska and Hawaii



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This volume briefly describes existing conditions (physical, social, economic) affecting electric supply and demand in the states of Alaska and Hawaii. It discusses the existing electric energy system and the role of hydropower therein. Projections of electrical supply and demand through the year 2000 are discussed. The hydropower resources, developed and undeveloped, of the region are evaluated and a regional ranking of specific projects and sites which are recommended to be studied in further detail is presented. The public involvement in the planning process is described.

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FROM ELECTRONIC REPRODUCTION PREPARED BY
HAWAII STATE ENERGY OFFICE

U.S. Army Corps of Engineers

National Hydroelectric Power Study
Regional Report: Volume XXIII
Hawaii

September 1981

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Chapter 1
REGIONAL OBJECTIVES

Currently and in the foreseeable future, the Hawaii region will be almost wholly dependent upon imported petroleum products for generation of power in the public utility system. The purpose of this regional study is to document the role of hydroelectric power in the Hawaii region, both currently and in the foreseeable future. The report will not recommend projects for authorization of construction by the Corps of Engineers. However, the report will present information on those potential projects which should be considered for continued study consistent with the following objectives:

1. Increase the energy self-sufficiency of the region.

2. Assess the physical potential for increasing hydroelectric power capability and generation.

3. Determine the potential for increasing hydroelectric generating capacity by development of new sites and by adding generating facilities to existing water resource projects.

4. Assess the general environmental and socioeconomic impacts of hydroelectric power development.

5. Provide for maximum feasible utilization of the energy potential derived from the region's water resources.

Chapter 2
EXISTING CONDITIONS

2.1 GENERAL AREA DESCRIPTION

For the National Hydroelectric Power Study, the Hawaiian Archipelago constitutes the Hawaii Region. The Hawaiian Archipelago extends some 1,523 miles over the North Pacific Ocean, between the islands of Midway on the west and Hawaii on the east. The archipelago consists of a chain of mountaintop islands, islets, pinnacles and reefs, all rising thousands of feet from the ocean floor. A large part of the Pacific Ocean surrounding Hawaii has depths from 16,000 to 20,000 feet. Except for Midway Island, the archipelago is under the jurisdiction of the State of Hawaii, the 50th State admitted to the Union, the 47th in geographic area and 40th in population. Midway has no potential for hydropower development, so the study area following comprises only the State of Hawaii.

The State's eight principal islands (with their areas in square miles) are Niihau (73), Kauai (553), Oahu (608), Molokai (261), Lanai (140), Kahoolawe (45), Maui (729), and Hawaii (4,038). These islands form a 400-mile-long arc at the southeastern end of the archipelago and comprise more than 99 percent of the region's land area. Of the eight islands, Kahoolawe is barren, uninhabited and under military control; Niihau is privately owned and little developed. The other six islands of Kauai, Oahu, Molokai, Lanai, Maui, and Hawaii, therefore, constitute the principal study area. The island of Oahu, which is the third largest in land area, is the social, cultural, economic, and military center of the State. The study region is shown on Figure 2-1.

The islands and mountains that constitute the Hawaiian Archipelago have been built almost entirely by volcanic activity. Each island is the top of an enormous volcanic mountain, modified by stream and wave erosion and minor amounts of organic growth. The geology is predominantly igneous, with lava basalts and sporadic occurences of pyroclastics comprising the majority of the rock types. The decomposition of lava and pyroclastics results in the residual, lateritic soils found blanketing most of the islands.

Constant erosion has changed the topography of the islands from huge, gently sloping volcanoes to dissected and incisioned cliffs, valleys and basins. The topography of many of the drainage areas is characterized by relatively steep stream courses and steep, rugged basaltic formations. As a result, the streams generally do not meander as they traverse alluvial areas. In areas of the State which are geologically youthful, few if any perennial streams are found. For example, on the island of Hawaii, 710 intermittent streams reach the sea along three-fourths of the coastline, a distance of about 225 miles.

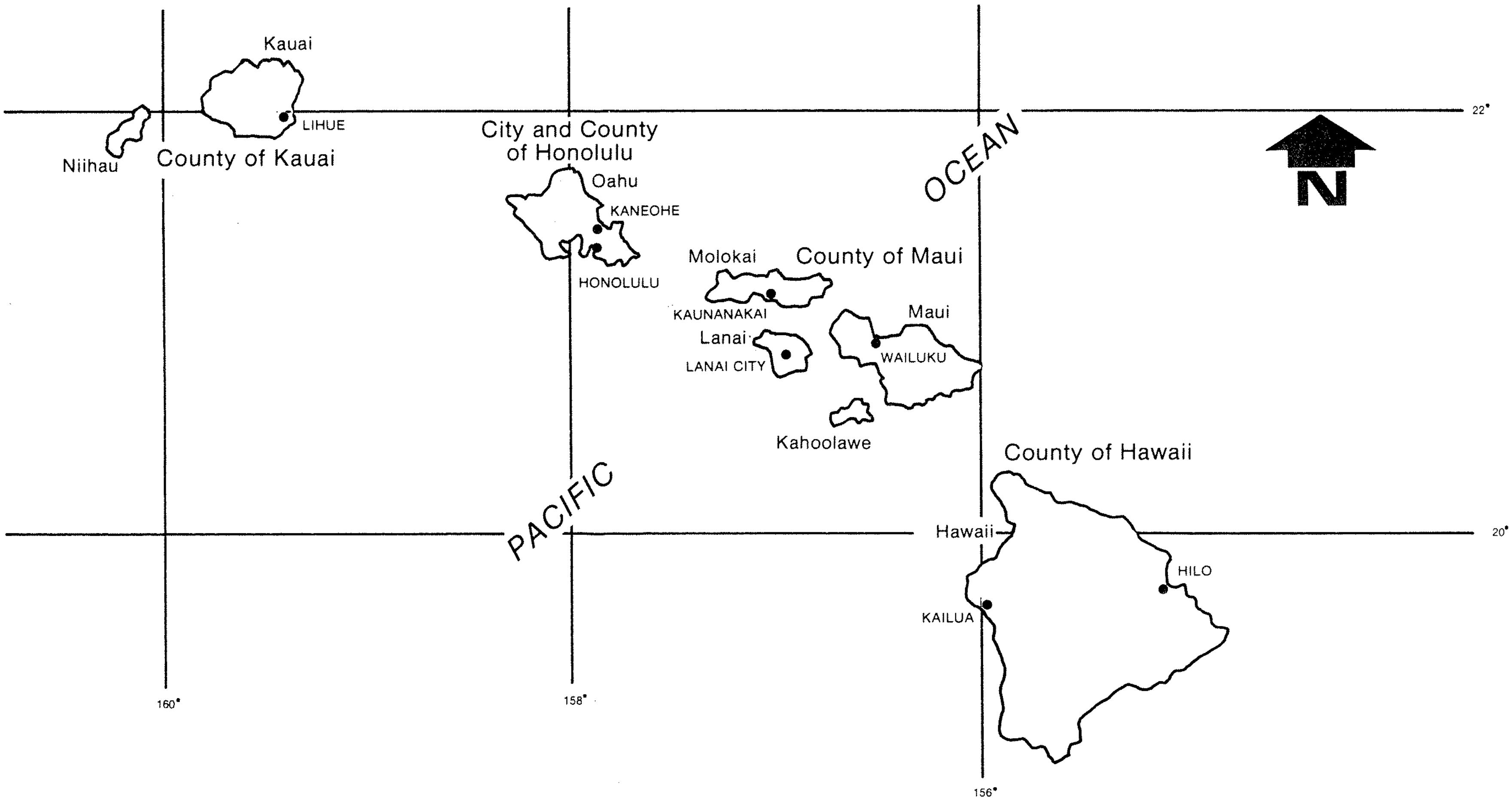

Figure 2-1
LOCATION MAP-STATE OF HAWA II

2.2 CLIMATOLOGY AND HYDROLOGY

In general, the climate of the Hawaiian Islands is characterized by a two-season year (summer and winter), mild and uniform temperature, strikingly marked geographic differences in rainfall, generally humid condition, and by a general dominance of tradewind flow from the northeast. During the five-month summer from May through September, tradewinds prevail 80 to 95 percent of the time. During the seven-month winter from October through April, the prevalence of the tradewinds decreases to 50 to 80 percent. Although the trade-winds produce most of the annual rainfall over the Hawaiian Islands, it is during the absence of these winds that most of the flood-producing rainfall occurs. In particular, storms from the south which are known as "Kona" storms produce the damaging floods in Hawaii. These storms usually occur during the winter months.

Much of the rainfall in Hawaii results from orographic effects of the northeast tradewinds, the most prominent feature of air circulation in the islands. However, major storms are almost always associated with a migratory low pressure area accompanied by widespread heavy rain and southerly winds. In the open ocean, at the latitude of the Hawaiian Islands, the average annual rainfall is approximately 25 inches. The actual average at 70 inches indicates about 45 inches of rainfall is orographically extracted from moisture-bearing air. These effects are evident from the annual rainfall maps, which show the tremendous depths of rainfall deposited in mountainous areas and the large variation in rainfall between the mountain and coastal areas. In many mountainous areas of the State these depths exceed 240 inches. At Mt. Waialeale, on Kauai, the average annual rainfall totals 486 inches.

The average rainfall is often highly variable from one year to another. Even in areas where the rainfall is very high and the monthly averages are all above 10 inches, the rainfall of some months may vary by 200 to 300 percent from one year to another and there may be some months with only 1 or 2 inches of rain. With such a high variability of rainfall, it is inevitable that there are occasional droughts. Drought conditions are prevalent when the winter rain fails. Although such a deficit of winter storms can affect any portion of the State, the impact is severest over the normally dry areas dependent chiefly on these winter rains. In these localities, the small amount of rainfall that occurs during the usually dry summer season is insufficient to prevent severe drought.

Steep streams extending from mountainous rainfall belts to the shoreline are characteristic of the topography and relatively small geographic area of the Hawaiian Islands. There are no large watershed areas with complex stream systems comparable to continental areas, but only relatively small drainage basins, usually consisting of one principal stream with minor tributaries. As most streams have only a few branches generally located in their upper reaches, the water quickly finds its way to the sea. As a result, streamflows are generally very flashy in nature. Minimum flows may consist principally of groundwater seepage and spring discharges. Maximum flows result from heavy rains and reflect the rapid surface runoff typical of Hawaii's mountainous areas.

2.3 ECONOMICS OF AREA

Hawaii is a prosperous state with growing population and economy. Between 1950 and 1978, the total resident population increased by over 79 percent, from 500,000 to 897,000. The gross state product increased tenfold during this same period, from $900 million to $9 billion. The three largest contributors to the State's economy are tourism, Federal expenditures, and agriculture. The bulk of agricultural activity is in the production of sugar and pineapple. The most rapid growth in the past decade has been in the tourist industry. Tourist arrivals increased from 243,216 annually in 1959 to 3,670,309 in 1978. Visitor expenditures have grown by an average of over 17 percent annually since 1959, when they amounted to $109 million. Estimated 1978 visitor expenditures were over $2 billion. While visitor expenditures increased by a factor of 20 over this period, defense expenditures only tripled. The trend in tourist industry growth will probably continue, although at a slower pace, together with the State's economy in general.

Hawaii's locational advantages and climate are apparent to the visitor industry and the military establishment. Its mid-Pacific location also has important trade and finance implications. The island of Oahu has about 81 percent of the population of the State, and includes the major military installations. Oahu also has a considerable agricultural and food processing industry and the largest regional tourist destination area, Waikiki beach. The other islands, sometimes referred to as the Neighbor Islands, do not have as diversified an economic base. In the past their economies have centered on agriculture and attendant food processing but, employment in these two sectors has been on the decline. The growth in the tourist industry, however, has stimulated the Neighbor Islands economies as well as the State's economy.

The 1970 Census recorded a labor force of 346,859 of which 337,595 (49,785 in the military) were employed. Between 1940 and 1970 the number of employed persons almost doubled. During this same period, agricultural employment fell from 55,000 to 13,000. By occupation, one out of every six workers is classified as either professional or technical. Activities in the 1970 employment with large number of workers are services (82,000), government (70,000), retail trade (50,000), and manufacturing (31,000). Labor union membership was estimated at 82,000 in 1970.

From a cursory viewpoint, it may appear that the Hawaiian Islands are insulated from other economies in the mid-Pacific area and should exhibit stable employment. On the contrary, growth in the tourist industry and strategic shifts in military deployment link Hawaii's economy to other Pacific Basin economies and to the global military situation.

Information from U. S. Census of Population reports indicates that the number of employed persons in the State grew at over 2 percent a year during the decade of the 1950's and increased to an annual rate of over 3 percent during the 1960's. This State growth pattern strongly reflects the average annual growth rate of about 3-1/3 percent experienced by the City and County of Honolulu for both decades. The Counties of Hawaii, Maui, and Kauai have had a somewhat different experience. During the decade of the fifties, these counties experienced a continuing decline of employment in the agricultural sector, which resulted mainly from the impact of mechanization. Though this decline in agricultural employment still continues, the development of a significant tourist industry in these counties has expanded employment over the past decade.

2.4 MAJOR ENERGY USERS

Hawaii derives 92 percent of its energy from petroleum. Table 2-1 shows consumption of petroleum in Hawaii by basic industry.

Table 2-1
HAWAII PETROLEUM CONSUMPTION BY BASIC INDUSTRY, 1976

User Category	Percent of Total
Air Transportation	27.4
Ground Transportation	15.6
Water Transportation	3.5
Military Transportation	8.4
Military (Other)	9.2
Industrial/Commercial	14.9
Residential	13.1
Other	7.9
Total	100.0

Source: State Energy Office consultant's unpublished report.

Combined transportation is by far the largest energy consuming industry. Two of Hawaii's largest industries stand out in this table; tourism, which is Hawaii's largest industry, accounts for the majority of the 27 percent consumed by air transportation and a significant portion of the 16 percent used by ground transportation; the military establishment, which is a major industry in Hawaii, accounts for almost 18 percent of the total petroleum consumption. Table 2-2 shows the major civilian energy users in Hawaii. The two largest users, overseas airlines and residents (home and car), consume more than half of the State's energy. One quarter of the State's petroleum consumption is for electricity generation.

In 1976, about half of the State's electrical energy was consumed by residential users. Other major electrical energy users included retail (7.3%), hotel (6.7%), institutions (5%) and manufacturing (4.8%). The consumption of electricity for the State and four major islands is summarized in Table 2-3. As displayed in that table, users on the island of Oahu consumed 85.2 percent of the State's total electricity, while users on the islands of Hawaii, Maui, and Kauai consumed 6.6, 5.5 and 2.7 percent, respectively. Consumption of electricity on the island of Molokai amounts to less than one-half of 1 percent of the State's total and is therefore excluded.

Table 2-2
HAWAII'S CIVILIAN ENERGY USE

(Billion BTU's)

End Users	Direct Deliveries	Electrical Utilities	Civilian and PX Service Sta.	Gas Mfrs. and Distributors	Total	Percent of Total
Overseas airlines	56,128.9	ND	64.0 1/	ND	56,192.9	29.5
Residents: home & car	ND	30,548.7	18,237.0	2,286.0	51,071.7	26.8
Agriculture, incl. process	7,673.0	371.9	160.0	ND	8,204.9	4.3
Overseas waterborne	8,056.4	ND	50.0	ND	8,106.4	4.3
Commercial and industrial	2,636.0	2,941.0	0.0	2,343.0	7,920.0	4.2
Wholesale/retail	ND	4,562.4	1,406.0	ND	5,968.4	3.1
Local airlines	5,349.6	ND	31.0 1/	ND	5,380.6	2.8
Hotel	ND	4,362.7	128.0	ND	4,490.7	2.4
Oil company use	3,861.9	ND	ND	ND	3,861.9	2.0
Construction	2,592.2	ND	1,194.0	ND	3,786.2	2.0
Institutions	ND	3,101.9	401.0	ND	3,502.9	1.8
Other (uses identified)	6,259.2	15,778.4	3,639.0	78.0	25,754.6	13.5
Unidentified uses of gasoline 2/	0.0	0.0	6,359.0 2/	0.0	6,359.0	3.3
Total	92,557.2	61,667.0	31,669.0	4,707.0	190,600.2	100.0

Source: "Energy Use in Hawaii", Department of Planning and Economic Development, State of Hawaii, Nov. 1977.

Notes: ND - Not defined as an end user by fuel or energy distributors.

1/ - Airlines allocated between domestic and foreign and local airlines on same proportion as direct deliveries.

2/ - Unidentified uses of service station deliveries amount to 20.0 percent of the total motor gasoline and include usage by non-taxed federal, state, and county vehicles, ambulances, and motorcycles.

Table 2-3

ELECTRICAL CONSUMPTION FOR FOUR MAJOR ISLANDS SUMMARIZED ON THE BASIS OF KWH USED,1976 1/

(Thousands of kWH)

User Category	Total		Oahu	Hawaii	Maui	Kauai
	Amount	Percent				
Residential	2,726,795	48.7	2,368,525 5/	158,403	143,145	56,722
Retail	406,338	7.3	346,153	32,695	22,681	4,809
Hotel	374,141	6.7	261,933	49,506	39,129	23,573
Manufacturing	268,623	4.8	259,955	3,940	3,458	1,270
Institutions	277,728	5.0	246,471	15,788	8,455	7,014
Communications	153,240	2.7	133,845 6/	6,457	6,304	6,634
Food processors	99,399	1.8	76,225	6,161	16,413	600
Street lighting	98,619	1.7	74,457	16,088	5,804	2,270
Agriculture	30,288	0.5	10,019	11,714	3,990	4,565
Military	8,917	0.2 2/	(730,000)2/	- 3/	- 3/	8,917 4/
Other	1 152,561	20.6	992,891	60,737	59,472	39,461
Total	5,596,649	100.0	4,770,474	361,489	308,851	155,835
Percent	100.0		85.2	6.6	5.5	2.7

Source: State Energy Office consultant's unpublished report.

Notes:

1/ Molokai not included above amounted to 17,769 kWh in 1975, which would add 0.3 percent to total of all islands.

2/ For Oahu, military accounts are included in above breakdown.

3/ Military on Hawaii and Maui relatively insignificant.

4/ Kauai military separately reported; not distributed by user category as done for Oahu.

5/ Includes military housing and base operations. On Maui and Hawaii military use is not a significant factor.

6/ On Oahu includes military bases devoted to communications.

2.5 FUTURE DEVELOPMENT

Forecasts of regional demographic and economic growth are taken from the OBERS Series E projection [3]. Series E refers to the latest detailed regional and national projection of population, employment, and earnings up to the year 2000. Projections are for the Bureau of Economic Analysis (BEA) economic area 173, encompassing all of the islands in the State of Hawaii, and are summarized in Table 2-4.

Although the OBERS population projections are somewhat low, projections of earning and income are useful to show the relative magnitude of earnings in various industrial sectors. OBERS forecasts average annual growth in earnings and total personal income at 3.5 and 3.6 percent, respectively, between 1970 and 2000. Trade, services, and government sectors are expected to have the highest industrial sector earnings. Per capita income in Hawaii was higher than the national average in 1970, and is expected to remain so throughout the forecast period. The disparity between the national average and Hawaii per capita incomes is expected to decrease over time. Between 1970 and 2000, per capita income is expected to grow at 2.5 percent annually.

Table 2-4

PROJECTED POPULATION, INCOME AND MAJOR SECTOR EARNINGS(OBERS)

HAWAII (BEA AREA 173)
(Constant 1976 Dollars)

	YEAR			
	1980	1985	1990	2000
	(Earnings in million $)			
Agriculture	107	110	114	128
Mining	0	0	0	0
Construction	317	370	432	580
Manufacturing	255	295	342	455
Transportation utilities	329	399	483	697
Trade	549	643	752	1,035
Finance	262	324	400	598
Services	712	896	1,127	1,721
Government	1,211	1,443	1,721	2,431
Total Earnings	3,741	4,483	5,372	7,646
Total Personal Income	4,555	5,502	6,645	9,575
Total Population (thousands)	847	911	979	1,085
Per Capita Income ($)	5,375	6,042	6,791	8,823
Per Capita Income Relative To U.S.	1.12	1.11	1.10	1.08

Source: 1972 OBERS Projections, Regional Economic Activity on the U.S., Series E Population, U.S. Department of Commerce, Bureau of Economic Analysis, 1974.

Note: Sum of sector earnings may not equal the total because of discrepancies in OBERS data.

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1. Department of Planning and Economic Development, State of Hawaii, 1977, Energy Use in Hawaii.

2. U.S. Army Engineer District - Honolulu, 1977, Hydroelectric Power, Plan of Study, Harbors and Rivers in Hawaii.

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Chapter 3
EXISTING ENERGY SYSTEMS

3.1 EXISTING ENERGY SYSTEMS EXCLUDING HYDROPOWER

Nuclear

There are no nuclear power plants in the State of Hawaii. The technology for producing power on a commercial basis from the fission process is well developed but is economical only in large-scale units. Even the smallest commercial reactors are too large for integration into the region's electrical systems before the turn of the century.

Oil

Hawaii derives 92 percent of all energy from petroleum. More than half of it is used for transportation in the form of jet fuel and gasoline. About 25 percent of it is used for the generation of electricity.

There are a total of five utility companies servicing the main populated islands. All of the companies are investor-owned but are regulated by the State Public Utility Commission. Each of the islands is served by independent power systems. There is no interconnection of power between the islands. The utility companies are:

Island	Company
Oahu	Hawaiian Electric Company (HECO)
Hawaii	Hawaii Electric Light Company (HELCO)
Kauai	Kauai Electric Division of Citizens Utility Company (KED)
Maui-Lanai	Maui Electric Company (MECO)
Molokai	Molokai Electric Company (MOECO)

The largest company in the State is Hawaiian Electric Company (HECO). Two companies on neighbor islands, Maui Electric and Hawaii Electric Light, are wholly owned subsidiaries of HECO. The island of Lanai is serviced by Maui Electric but the generating plant and most of the distribution lines are owned by the privately-owned Dole Company.

These five oil-burning utilities generated 6,541 GWh of electricity in 1978, 90.5 percent of the State's total electric power. The major generating equipment in Hawaiian Electric Company's system is designed to burn residual fuel oil. Even with today's critical oil situation, oil remains Hawaii's most economical source of energy. Alternative energy sources including biomass (chiefly the sugarcane waste, bagasse), wind, geothermal energy, refuse, and ocean thermal energy conversion (OTEC) will be developed to reduce dependence on oil. However, in the foreseeable future, oil is expected to be the main source of electrical energy.

Coal

Major economic and environmental problems will be encountered if petroleum fuels are to be replaced by coal. Coal is expensive in Hawaii because it must be imported from overseas. In addition, for large-scale seaborne transport of coal to power plants in Hawaii, a new ocean bulk handling system, port facilities, unloading and storage areas, and a surface transportation system from dockside to generation plant would have to be built at a large investment cost. The environmental problems would arise from the fact that, because of the higher impurities content, control of environmentally unacceptable pollutants such as sulfur dioxide and particulates is more difficult, and large quantities of ash require disposal.

Waste Material

Hawaii obtains about 7 percent of its energy by burning waste material. Electrical generation in the State of Hawaii was first begun in the sugar mills to power the processing of sugar and has evolved along with these agriculture-based origins. Power is produced by the agricultural processing power plants by burning a residual product of sugarcane, bagasse. In 1978, private companies generated 687 GWh of electrical energy, mainly from bagasse, or 9.5 percent of the total electric energy generated in the State, which was 7,228 GWh in that year. In 1978, bagasse supplied 38 percent of the electrical energy of the island of Hawaii and 23 percent of the island of Kauai. A 12 MW bagasse power plant was completed in 1980, forming an integral part of the Lihue Sugar Plantation facilities in Kauai. The power plant, built under a cooperative agreement among Foster-Wheeler Corporation, AMFAC and Kauai Electric, will annually produce 55.6 GWh of electrical energy. Refuse is another potential source of energy. The City and County of Honolulu is considering implementation of a solid refuse treatment plant. If constructed, the power plant is expected to produce 48 MW of power, totalling 4 percent of Hawaiian Electric's installed capacity.

Geothermal Energy

Natural heat from the earth shows great long-range potential for Hawaii's energy future. Economic comparisons generally show that geothermal energy is competitive with conventional energy sources. High-temperature water can be used for power generation, while water in the intermediate temperature range may find application in manufacturing processing, desalting of sea water, and agriculture. Geothermal environmental problems are relatively minor; potentially, there could be some impact in the form of noxious gases, noise from exhaust steam, ground subsidence, and water contamination.

Practically all potential developable geothermal energy is located in the Island of Hawaii. Although the amount of recoverable geothermal energy is still unknown, a test well (HGP-A) was drilled 6,450 feet into the eastern rift of Kilauea volcano on Hawaii Island in 1976 to explore geothermal potential. Construction of a 3 MW geothermal power plant to utilize the steam from HGP-A, which is funded by the Department of Energy, began in January of 1980. The Hawaii Electric Light Company has agreed to purchase at least 2

MW of energy for the first two years the generator operates. The first production of electricity from geothermal energy is scheduled for mid-1981. If huge reservoirs are found yielding greater energy than is needed on the Island, breakthroughs in undersea transport of energy will be necessary before power can be transmitted to the other islands. Hawaiian Electric Company is currently investigating the feasibility of placing undersea power transmission cables between the islands.

Wind

Enormous amounts of energy are contained in the persistent trade winds that sweep the Hawaiian Islands. Wind power is a renewable natural energy resource and has the advantage of generating no noxious substances. It shows excellent potential for providing a significant percentage of the future energy requirements of Hawaii. The best wind locations in the Hawaiian Islands include Kahuku on Oahu, Kahua Ranch on Hawaii Island, West Molokai, and McGregor Point on Maui. A 200-kW wind machine has been built at Kahuku, partially funded by the U.S. Department of Energy. The model MOD-OA machine used here was built and erected by Westinghouse Electric Corporation. Hawaiian Electric has an agreement with Windfarms Ltd. to purchase 80 MW of wind generated electricity which is expected to be on line in three to four years.

Ocean Thermal Energy Conversion (OTEC)

Hawaii has warm surface water and deep cold water near shore the year round. The technology of OTEC would use this thermal energy differential to produce electricity. Should OTEC systems become a practical reality, Hawaii could become energy selfsufficient. A small demonstration plant, Mini-OTEC, has proved successful and produced 50 kW of electricity. Commercial OTEC's would range in capacity from 200 MW to 400 MW at an estimated power generation cost of as low as 4 cents per kWh. However, problems of marine fouling of equipment and transmission of the electric energy remain to be overcome. In addition, recent funding limitations of the Federal government will severely constrain future applied research and development of OTEC.

Summary

In the State of Hawaii electric power is generated on the six developed islands of Oahu, Hawaii, Kauai, Maui, Lanai and Molokai. Each of the islands has its own electrical system, and there is no interconnection of power transmission lines between the islands. Most of the State's power is generated by the oil-burning utility companies. In 1978, these companies generated 92.4 percent of the electric power (excludes hydropower). The remaining 7.6 percent was generated mainly by the sugar companies for their own consumption.

All electric power on the island of Molokai is generated by the Molokai Electric Company. On the island of Oahu, Hawaiian Electric Company generated 98 percent of electric power in 1978. The remaining 2 percent of the island's total electricity was produced by three sugar companies; Oahu, Waialua, and California and Hawaii. On the other major islands private companies generate a much more significant portion of the electric power; in 1978, private companies produced 47.2 percent of the total nonhydropower on the island of Hawaii, 27.4 percent on the island of Kauai, and 18.4 percent on the islands of Maui and Lanai. Table 3-1 displays the capacity and energy generation of the existing electric system.

Table 3-1
ELECTRICAL POWER CAPACITY AND ENERGY GENERATED HAWAII, 1978

	Entire System 1/			NonHydroelectric 2/		
		Percent of Total			Percent of Total	
	Total	Utility	Private	Total	Utility	Private
Oahu Island						
Installed capacity, MW	1,236	98.0	2.0	1,236	98.0	2.0
Energy generated, GWh	5,723	98.0	2.0	5,723	98.0	2.0
Hawaii Island						
Installed capacity MW	163	65.0	35.0	159	64.5	35.5
Energy generated, GWh	558	54.9	45.1	527	52.8	47.2
Kauai Island						
Installed capacity MW	106	59.0	41.0	98	63.4	36.6
Energy generated, GWh	299	61.4	38.6	253	72.6	27.4
Maui and Lanai Islands						
Installed capacity MW	142	59.3	40.7	137	61.5	38.5
Energy generated, GWh	619	67.4	22.6	589	81.6	18.4
Molokai Island						
Installed capacity MW	7	100.0	-	7	100.0	-
Energy generated, GWh	29	100.0	-	29	100.0	-
State of Hawaii						
Installed capacity MW	1,654	88.9	11.1	1,637	89.6	10.4
Energy generated, GWh	7,228	90.5	9.5	7,121	92.4	7.6

Notes:

1/ "State Energy Plan", Department of Planning and Economic Development, State of Hawaii, September 1980.

2/ Derived from Table 3-2

3.2 ROLE OF EXISTING HYDROPOWER WITHIN EXISTING ENERGY SYSTEM

Relationship of Hydropower Within Existing System

Hydropower facilities were originally installed to supplement the needs of the plantation industry. Only three islands now have developed and operating hydropower plants. These are Maui, with 7.1 MW installed capacity; Kauai, with a 7.9 MW capacity; and the island of Hawaii, with 4.2 MW capacity. Of the 20 operating and retired hydropower plants on the islands, 18 are owned by sugar plantations for their own industrial use, and two are owned by a utility company. Only 13 hydropower plants are operating in the State. Their total installed capacity is 19.2 MW, producing an average energy of 107.1 GWh per year. Hydropower accounted for 1 percent of the State's total electric power in 1978. An inventory of hydropower plants in the islands is shown in Table 3-2.

Hawaii Electric Light Company, Inc. (HELCO), the utility which serves the island of Hawaii, is a subsidiary of HECO. HELCO is also the only utility company that operates hydropower plants. The plants are located near Hilo, the largest area of consumption. The hydropower plants operated by the sugar plantations are largely part of irrigation systems, and power generation is dependent to some extent on seasonal rainfall and crop irrigation priorities.

Marketing and Regulations

There is no electric reliability council in the State of Hawaii. The State is not serviced by a Federal power marketing agency since there is no Federal power marketed in Hawaii. However, any potential Federal power marketing activities will be performed by the U.S. Department of Energy. Currently there are no hydropower plants in the State licensed by the Federal Energy Regulatory Commission (FERC). Licensing is required for nonfederal development in the following cases: (1) development is on an historically navigable stream or a stream which could reasonably be improved for navigation; (2) development is on Federal land; or (3) energy is transmitted interstate. FERC has enacted a new rule to permit owners of small hydropower projects (5 MW or less) to apply for exemption of licensing requirements provided the site is not on Federal land and does not require construction of a new dam.

Hydropower facilities operated by utility companies are regulated by the Public Utilities Commission (PUC) of the State of Hawaii under the Department of Budget and Finance. The PUC does not regulate the hydropower plants owned by sugar companies if the sole use is industrial. However, when sugar companies sell excess power to utilities for public consumption, the rates must be approved by the PUC.

Parameters Governing Use of Existing Hydropower

Hydraulic turbines do not perform well when actual flow is substantially different from the design flow. In Hawaii, since most of the runoff comes during the winter months (November through March) existing turbines are not

Table 3-2
EXISTING HYDROELECTRIC PLANTS

Island and location	Stream	Owner	Owner class	Static head (feet)	Installed capacity (kW)	Average Annual Energy (GWh)	First year operated
Hawaii							
Wainaku Mill	Maili	HCPC ✓	P	200	60*	----	Pre-WW II
Puueo	Wailuku	HELCO ✓	I	400	2,250	19.0	1918
Waiau	Wailuku	HELCO ✓	I	322	1,100	9.2	1921
Papaikou Mill	Honolii	HCPC ✓	P	207	150*	----	Pre-WW II
Hakalau Mill	Hakalau/Kolekole	HCPC ✓	P	265	75*	----	Pre-WW II
Paauhau	Lo. Hamakua Ditch	PASC ✓	P	473	150*	----	N.A.
Honokaa	Lo. Hamakua Ditch	HOSU ✓	P	415	800	3.0	N.A.
Union	Kohala Ditch	KOSC ✓	P	565	500*	----	1940
Hawi	Kohala Ditch	KOSC ✓	P	371	350*	----	1923
Maui							
Kauaula	Kauaula	PIMC ✓	P	535	500	2.0	1918
Paia	Wailoa Ditch	HACS ✓	P	260	800	2.8	1912
Kaheka	Wailoa Ditch	HACS ✓	P	660	5,800	25.0	1924
Kauai							
Wainiha	Wainiha	MBSC ✓	P	565	3,600	24.0	1906
Waimea	Waimea	KESC ✓	P	265	1,000	5.0	1954
Waiawa	Kahoana	KESC ✓	P	275	500	1.9	1907
Hydro Kaumakani	Makaweli	OLSC ✓	P	211	500	3.1	1920
Alexander Res	Wahiawa	MBSC ✓	P	700	1,000	2.1	1928
Malumalu	Waihohonu	MBSC ✓	P	150	128*	----	1919
Lower Lihue	North Wailua & Iliiliula Ditches	LIPC ✓	P	206	800	5.0	1941
Upper Lihue	North Wailua & Iliiliula Ditches	LIPC ✓	P	247	500	3.1	1930

Source:

1. "Alternate Energy Sources for Hawaii", Hawaii Natural Energy Institute, University of Hawaii, and Department of Planning and Economic Development, State of Hawaii, February 1975.
2. Input from owners, 1979-1980.
3. Energy generation estimated by the Pacific Ocean Division, U.S. Army Corps of Engineers.

Abbreviations:

HELCO - Hawaii Electric Light Co., Ltd
PASC - Paauhau Sugar Co.
HOSU - Honakaa Sugar Co.
KOSC - Kohala Sugar Co.
PIMC - Pioneer Mill Co., Ltd.
HCPC - Hilo Coast Processing Co.
HACS - Hawaiian Commercial & Sugar Co.
MBSC - McBryde Sugar Co., Ltd.
KESC - Kekaha Sugar Co., Ltd.
OLSC - Olokele Sugar Co., Ltd.
GRFC - Grove Farm Co., Ltd.
LIPC - Lihue Plantation Co.
N.A. - Not Available
I - Investor-owned utility
P - Commercial or Industrial Firm

* Denotes inactive sites

being fully used. Because of relatively small drainage basins having only one principal stream with minor tributaries, streamflows are low, highly variable, and largely unregulated. Hydropower plant capacities are small, usually operated on run-of-river streamflows. Most hydropower plants were installed by the plantations in their irrigation ditches. In addition, in contrast to most mainland installations, practically all of the existing projects are characterized as high head, low discharge facilities and utilize impulse-type (Pelton) turbines.

During the past decade many hydropower plants were deactivated or abandoned. In certain instances, sugar plantations owning plants went out of business; in other cases, turbine/generator equipment no longer performed effectively. However, some plants could be reactivated and there is potential for increasing the capacity of currently active plants. The prospect for reactivation is enchanced by certain recent developments:

a. Sharply rising petroleum prices make hydropower economically attractive.

b. There is an increasing interest among the plantations to sell energy as a prime source of revenue.

c. The implementation of the Public Utility Regulatory Policies Act (PURPA) of 1978 mandating regulatory agencies to establish energy rates based on avoided petroleum costs assures hydropower producers of receiving a fair market price. This has spurred plantations to take a second look at their existing and new alternative energy systems.

d. There is a growing recognition that the combination of wet-season hydropower and dry-season bagasse could produce year round firm power for possible sale to a utility.

References

1. Department of Planning and Economic Development, State of Hawaii, 1977, Energy Use in Hawaii.

2. Department of Planning and Economic Development, State of Hawaii, 1980, State Energy Plan.

3. Federal Power Commission, Bureau of Power, 1966, Planning Status Report; Hawaii River Basins.

4. Hawaii Natural Energy Institute, University of Hawaii, and Department of Planning and Economic Development, State of Hawaii, 1975, Alternate Energy Sources for Hawaii.

5. Pacific Analysis Corporation, 1977, An Inventory and Analysis of the Electrical Energy Industry in the State of Hawaii (prepared for the U.S. Army Corps of Engineers).

Chapter 4
DEMAND SUMMARY

Forecasts of electricity demand have been made by the State of Hawaii (Table 4-1) and Hawaiian Electric Company and Kauai Electric Division (Table 4-2). Another forecast was made in a study by Harza Engineering Company for the Institute for Water Resources, U.S. Army Corps of Engineers (Table 4-3 [1, 2]. In that study, three projections of electricity demand were developed for use in assessing the regional market for hydropower. Projection I was derived from forecasts made by the utilities [5]. Projection II was derived from the forecast made by the Institute for Energy Analysis (IEA) at the Oak Ridge National Laboratory in May 1977 [3]. Projection III was based on the "Consensus Forecast of U.S. Electricity Demand" [4]. From these three projections, a "median" forecast was selected and is considered to be representative of future power and energy demand of the State. The OBERS population forecasts are adjusted to reflect the latest census [4].

4.1 Capacity

The peak demand for all the utility companies in the State of Hawaii was 1,120 MW in 1978, up from 726.6 MW in 1969. The total utility-installed capacity increased from 862 MW in 1968 to 1,470 MW in 1978 which was 88.9 percent of the total installed capacity in the State. Table 4-4 shows the peak load and installed capacity from 1968 to 1978. The majority of the peak load occurs on Oahu. However, Oahu's share of the total peak load in the State decreased from 86.4 percent in 1969 to 81.9 percent in 1978. This is attributable to the faster growth of the Neighbor Islands during the past decade. Installed capacity on Oahu constituted 84.2 percent of the State's total capacity in 1968. This percentage has reduced to 81.3 in 1978.

Hawaii's peak demand now occurs in winter and it is expected to continue doing so in the future. According to Harza's projection, the peak demand between 1978 and 1985 is likely to grow at an average annual rate of 4.5 percent from 1,100 MW to 1,500 MW. After 1985, annual growth in peak demand is likely to be about 4.0 percent until 1990, then 3.6 percent through the end of the century. The peak demand is expected to be 2,600 MW in 2000.

Utilities projected peak load is somewhat lower. As shown in Table 4-2, it will only be 2,127 MW in 1998. This projection does not cover Molokai Electric Company which constituted less than 0.5 percent of the total peak load for the utility companies in 1978. Also shown in Table 4-2 are the utilities projected generating capacities. The planned additions are presented in Table 4-5. The Neighbor Islands are expected to exceed Oahu's rate of growth in the next two decades. Projected peak load and installed capacity for Oahu in 1998 are 70.9 and 71.0 percent of the State's total, respectively. These percentages are considerably lower than 1978. Maui is projected to have the most significant gain in peak load; from 7.0 percent in 1978, to 18.1 percent in 1998, and in generating capacity from 5.7 percent in 1978 to 16.8 percent in 1998. Kauai, the island with the most

Table 4-1
STATE PROJECTED ELECTRICAL ENERGY DEMAND FORECAST, HAWAII, 1980-2005

Year	Oahu		Hawaii		Maui, Lanai, Molokai		Kauai		State	
	Energy (GWh)	Avg. Ann. Growth Rate (%)	Energy (GWh)	Avg. Ann. Growth Rate (%)	Energy (GWh)	Avg. Ann. Growth Rate (%)	Energy (GWh)	Avg. Ann. Growth Rate (%)	Energy (GWh)	Avg. Ann. Growth Rate (%)
1980	5,057	-	435	-	509	-	187	-	6,187	-
1985	5,350	1.13	522	3.71	799	9.45	230	4.26	6,900	2.21
1990	6,213	3.04	604	2.98	1,071	6.04	272	3.38	8,159	3.41
1995	6,767	1.72	677	2.31	1,285	3.72	297	1.81	9,027	2.04
2000	7,466	1.99	720	1.23	1,395	1.65	306	0.58	9,887	1.84
2005	8,345	2.25	771	1.39	1,497	1.42	314	0.54	10,926	2.02

Source: "State Energy Plan," Department of Planning and Economic Development, State of Hawaii, September 1980.

Table 4-2

PUBLIC UTILITIES PROJECTED PEAK LOAD AND GENERATING CAPACITIES, HAWAII 1979-98

YEAR	HECO		HELCO		MECO		KED	
	Peak Load(mw)	Capacity (mw)	Peak Load(mw)	Capacity (mw)	Peak Load(mw)	Capacity (mw)	Peak load(mw)	Capacity (mw)
1979	906	1209	87	124	87	99	36.5	62.1
1980	994	1350	90	124	95	112	38	62.1
1981	1022	1350	93	124	103	112	39.6	74.1*
1982	1049	1350	97	124	112	125	41.2	74.1
1983	1077	1350	100	124	121	138	42.8	74.1
1984	1106	1350	103	127	131	151	44.4	74.1
1985	1136	1350	107	141	141	164	46.1	74.1
1986	1163	1420	110	141	152	164	47.7	74.1
1987	1191	1420	114	141	165	190	49.3	74.1
1988	1220	1420	118	141	178	203	50.9	74.1
1989	1249	1489	122	155	192	216	52.6	82.1
1990	1278	1489	127	155	207	229	54.2	82.1
1991	1307	1559	131	155	224	255	55.8	82.1
1992	1336	1559	136	168	242	268	57.4	82.1
1993	1365	1729	140	168	261	294	59.1	92.1
1994	1395	1729	145	168	282	307	60.7	92.1
1995	1426	1729	150	182	305	333	62.3	92.1
1996	1453	1729	156	182	329	359	63.9	114.3
1997	1481	1729	161	196	355	398	65.6	114.3
1998	1509	1799	167	196	384	424	67.2	114.3

* Kauai Electric Division will have contract purchase power from Lihue Plantation amounting to 12 MW in 1981; thus, planned additions by the public utility itself are not projected to occur until 1989.

SOURCE: Official HECO and KED projections, 1979.

Abbreviations:

HECO - Hawaiian Electric Company	MECO - Maui Electric Company
HELCO - Hawaii Electric Light Company	KED - Kauai Electric Division of Citizens Utility Company

Table 4-3
HARZA PROJECTED POWER DEMAND FORECAST, HAWAII 1978-2000

	1978	7-year Growth Rate 1/ %	1985	5-year Growth Rate 1/ %	1990	5-year Growth Rate 1/ %	1995	5-year Growth Rate 1/ %	2000	5-year Growth Rate 1/ %
Population (Thousands)	897.	1.7	1007.0	1.4	1080.0	1.0	1135.0	1.0	1193.0	1.3
Projection I										
Per Capita Consumption (MWh)	7.5	1.8	8.6	1.7	9.3	2.1	10.3	2.1	11.5	1.9
Total Demand (Thousand GWh)	6.8	3.5	8.6	3.1	10.0	3.2	11.7	3.1	13.7	3.2
Peak Demand (GW)	1.1	3.7	1.4	3.0	1.7	3.2	1.9	3.1	2.3	3.3
Projection II										
Per Capita Consumption (MWh)	7.5	2.6	9.0	2.6	10.3	2.6	11.7	2.6	13.3	2.6
Total Demand (Thousand GWh)	6.8	4.3	9.1	4.0	11.1	3.6	13.2	3.6	15.8	3.9
Peak Demand (GW)	1.1	4.5	1.5	4.0	1.8	3.6	2.2	3.6	2.6	4.0
Projection III										
Per Capita Consumption (MWh)	7.5	4.3	10.3	4.0	12.5	3.3	14.7	3.2	17.2	3.8
Total Demand (Thousand GWh)	6.8	6.2	10.3	5.5	13.5	4.3	16.7	4.2	20.5	5.2
Peak Demand (GW)	1.1	6.4	1.7	5.4	2.2	4.3	2.8	4.2	3.4	5.2
Median Projection										
Per Capita Consumption (MWh)	7.5	2.6	9.0	2.6	10.3	2.6	11.7	2.6	13.3	2.6
Total Demand (Thousand GWh)	6.8	4.3	9.1	4.0	11.1	3.6	13.2	3.6	15.8	3.9
Peak Demand (GW)	1.1	4.5	1.5	4.0	1.8	3.6	2.2	3.6	2.6	4.0
Margin (Percent)			25.0		25.0		25.0		25.0	
Resources To Serve Demand (GW)			1.9		2.3		2.7		3.3	
Load Factor (Percent)	69.5		68.7		69.0		69.0		69.0	

1/ The Growth Rates Are Average Annual Compounded Rates Over The Period.

Source: "The Magnitude and Regional Distribution of Needs for Hydropower, The National Hydropower Study: Phase II - Future Electric Power Demand and Supply," Harza Engineering Company, Report Prepared for the U.S. Army Corps of Engineers, 1980.

Table 4-4

HISTORICAL INSTALLED CAPACITY AND PEAK LOAD, HAWAII 1968-1978

Year	HECO		HELCO		MECO		KED		MOECO		Total	
	Peak Load(MW)	Capacity (MW)	Peak Load(MW)	Capacity (MW)	Peak Load(MW)	Capacity (MW)	Peak Load(MW).	Capacity (MW)	Peak Load(MW)	Capacity MW)	Peak Load(MW)	Capacity (MW)
1968	567	725.9	40	57.2	28	50	17.8	22.3	-	6.6	-	862
1969	628	725.9	44.8	57.2	31	50	19.6	22.3	3.2	6.6	726.6	862
1970	680	873	51	60.8	34	40	21.9	22.3	3.7	6.6	790.6	1,002.7
1971	726	873	56.8	60.8	39	42.8	24.3	22.3	3.7	6.6	849.8	1,005.5
1972	780	963	61.8	71.8	43	48.3	27	22.3	3.7	7.9	915.5	1,113.3
1973	815	1,068.4	66	73.8	48	60.6	29.4	39.9	4.1	7.9	962.5	1,250.6
1974	838	1,209.4	69	102.3	55	60.6	29.4	39.9	3.9	7.9	995.3	1,420.1
1975	854	1,209.4	71	103.6	60	72.9	31.9	39.9	4.3	7.9	1,021.2	1,433.7
1976	896	1,209.4	78	124.3	67.2	72.9	31.7	39.9	4.5	7.9	1,077.4	1,454.4
1977	911	1,209.4	80.5	124.3	73.1	79.1	33.7	62.1	4.8	6.9	1,103.1	1,481.8
1978	917	1,209.4	83.3	124.3	78.7	85.2	35.9	62.1	5.1	6.5	1,120	1,487.5

Sources:
1. "An Inventory and Analysis of the electric Energy Industry in the State of Hawaii," Pacific Analysis Corporation, Prepared for the U.S. Army Corps of Engineers, Pacific Ocean Division, 29 March 1977.
2. State of Hawaii Data Book 1977-79.
3. State of Hawaii Public Utilities Commission's Record.

Abbreviations:

HECO - Hawaiian Electric Company
HELCO - Hawaii Electric Light Company
KED - Kauai Electric Division of Citizens Utility Company
MECO - Maui Electric Company
MOECO - Molokai Electric Company

Table 4-5

PLANNED ADDITIONS TO ELECTRIC GENERATING CAPACITY, PUBLIC UTILITIES, HAWAII 1979-98

(Megawatts)

	Location of Planned Additions				
	Oahu	Hawaii		Maui	Kauai
	Kahe	Waimea	Ke-ahole	Maalaea	Lihue
1979				14	
1980	141			13	
1981					
1982				13	
1983				13	
1984		3		13	
1985			14	13	
1986	70				
1987				26 (2 units)	
1988				13	
1989	69		14	13	8
1990				13	
1991	70			26 (2 units)	
1992			13	13	
1993	170			26 (2 units)	10
1994				13	
1995			14	26 (2 units)	
1996				26 (2 units)	22.2
1997			14	39 (3 units)	
1998	70			26 (2 units)	

Source: Official HECO and KED projections, 1979.

Note: Kauai Electric Division will have contract purchase power from Lihue Plantation amounting to 12 MW in 1981. Thus, planned additions by the utility are not projected to occur until 1989.

hydropower potential, is expected to remain at 3.2 percent in peak load and grow slightly from 4.2 percent in 1978 to 4.5 percent in 1998 in generating capacity.

4.2 ENERGY

The electric energy sold by the utilities in the State of Hawaii for 1978 was 6,005 GWh, increased from 3,104 GWh in 1968. This corresponds to an average annual growth rate of about 6.8 percent. Electricity data for all utility companies from 1968 to 1978 are presented in Table 4-6.

The "median" electric energy demand in Hawaii as projected by Harza, is expected to grow from a projected 6,800 GWh in 1978 to 9,100 GWh in 1985, an average annual growth rate of 4.3 percent. The electric energy demand is expected to grow to approximately 15,800 GWh by the year 2000, an average annual growth rate of 3.9 percent between 1978 and 2000. The island of Oahu currently consumes the largest portion of electrical energy generated. The island of Maui is expected to have an accelerated growth in demand because of its expanding tourist industry.

Projections by the State are based on the assumption that conservation measures, such as improved efficiency in appliances, will be adopted. As a result, an average annual growth rate of 2.3 percent from 1980 to 2005 is shown. This projection also reflects the anticipated consumption levels for electricity regardless of the primary energy source utilized for electric generation.

In 1978, Hawaii's annual load factor was 69.5 percent. The annual load factors for the Hawaiian Electric Company and its subsidiaries, Hawaii Electric Light Company and Maui Electric Company, increased from 57.7 percent in 1970 to 62.3 percent in 1977. From projected peak and energy demand forecasts by the utilities, future load factors are expected to average 69 percent.

Table 4-6
HISTORICAL ELECTRICITY DEMAND, HAWAII, 1968-78
(GWh)

	Utility					
Year	HECO	HELCO	KED	MECO	MOECO	Total
1968	2,728	166	78	119	13	3,104
1969	3,004	186	90	126	14	3,420
1970	3,276	214	103	146	15	3,754
1971	3,601	247	112	186	16	4,162
1972	3,943	279	121	197	17	4,557
1973	4,189	302	132	221	17	4,861
1974	4,393	320	136	243	17	5,109
1975	4,555	333	149	275	18	5,330
1976	4,762	363	156	316	19	5,616
1977	4,911	377	167	353	23	5,831
1978	5,025	394	179	382	25	6,005

Sources: 1. "An Inventory and Analysis of the Electric Energy Industry in the State of Hawaii," Pacific Analysis Corporation, Prepared for the U.S. Army Corps of Engineers, Pacific Ocean Division, 29 March 1977.
2. State of Hawaii Data Book 1977-79.

Abbreviations:

HECO - Hawaiian Electric Company
HELCO - Hawaii Electric Light Company
KED - Kauai Electric Division of Citizens Utility Company
MECO - Maui Electric Company
MOECO - Molokai Electric Company

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1. Department of Planning and Economic Development, State of Hawaii, 1980, State Energy Plan.

2. Harza Engineering Company, 1979, The Magnitude and Regional Distribution of Needs for Hydropower, The National Hydropower Study, Phase 1 - 1978 Electric Power Demand and Supply, Report prepared for the Institute for Water Resources, U.S. Army Corps of Engineers.

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4. Institute for Energy Analysis, 1977, U.S. Electricity Supply and Demand to the Year 2000, Oak Ridge National Laboratory.

5. Lane, J. A., 1977, Consensus Forecast of U.S. Electricity Supply and Demand to the Year 2000, Oak Ridge National Laboratory.

6. Pacific Analysis Corporation, 1977, An Inventory and Analysis of the Electric Energy Industry in the State of Hawaii, prepared for the U.S. Army Corps of Engineers, Pacific Ocean Division.

7. Regional Electric Reliability Council, 1979, Reply to Appendix A-2 of Order No. 383-5, Docket R-362.

8. State of Hawaii, Data Book 1977-1979.

Chapter 5
METHODOLOGY

5.1 REGIONAL PROCEDURES AND CRITERIA

Regional Screening Criteria

Potential hydropower projects in the region were screened according to physical, economic, and environmental considerations. Screening was performed in four progressive stages. Only projects that demonstrate an appropriate level of physical potential, marketability, and environmental or social acceptability were considered for future development.

Stage 1

An inventory of the existing dams, existing hydropower facilities, and undeveloped sites having the physical potential to generate hydropower was made to provide the data base for the screening process. Only sites in one of the following categories were retained for evaluation in Stage 2:

1. Existing dams exceeding 40 feet of head and 800 acre-feet of storage.

2. Existing hydropower facilities with any potential incremental capacity.

3. New undeveloped sites with developable capacity exceeding 100 kW.

Stage 2

A second screening of the sites in the inventory identified those sites which show some possibility of being marketable. Site-specific data were coded and analyzed by computer programs which evaluated site hydrology, project costs and benefits, and identified the scope of project by maximizing net benefits. Sites which did not show promising marketability were deleted from further consideration.

Stage 3

In the third stage, sites were screened on the basis of environmental, social and institutional considerations. Sites with overriding adverse environmental, social, or institutional impacts were removed from consideration.

Stage 4

For all sites passing the first three stages, economic evaluations were performed manually using cost curves published in references 7 and 9. Costs obtained from these curves may not entirely agree with manufacturer and contractor bid prices. However, since the intent of this study is to make a comparative analysis of potential projects, absolute accuracy of cost estimates is not critical. The unit energy cost for each project was estimated by comparing the project cost with the amount of energy generated. Projects costs were adjusted to the June 1980 price level based on a construction cost index. Annual costs include interest and amortization of total construction costs, based on a project economic life of 50 years and an interest rate of 7-1/8 percent, and annual maintenance and operation costs.

Data Collection Procedures

All existing dams, existing hydropower facilities, and undeveloped sites with reasonable hydropower development potential were considered to be possible sites for new or incremental hydropower development. Data on the location, ownership, available power head, and potential flow were collected for each site.

Stage 1

The data base for potential hydropower sites was established principally from two sources; the National Program of Inspection of Dams [10] and hydroelectric power resources data published by Federal Power Commission [5]. Other references [1, 2, 3, 4, 6, 8, 11, 12] were also utilized and pertinent data were adopted to complement the inventory.

Stage 2

Additional site specific data from published and unpublished reports and topographical maps as required for computer analysis, were collected during this stage. However, no site visits or field surveys were made. These data include location and identification, physical and hydrologic characteristics, and power features that were not in the Stage 1 data base.

Stage 3

Estimates of the capacity and energy generation of potential projects were determined by computer. Copies of these estimates were distributed to the concerned public for their information and comments. As a result of this public-involvement process, more data and information were obtained to modify the data base.

Stage 4

There were no data collection activities during Stage 4.

Screening Procedures and Evaluation

Stage 1

Data collected from various sources were evaluated and compared with the Stage 1 criteria. Data for sites exceeding minimum head/storage or minimum capacity were included in the preliminary inventory data base.

Stage 2

Data for sites identified during Stage 1 were added to the computerized data base for site specific evaluation. The computer performed (1) analysis of streamflow data using flow-duration techniques to develop a range of capcity and energy potentials; (2) computation of project benefits using FERC power values; (3) computation of powerhouse and switchyard costs from generalized cost curves; and (4) identification of the scope of project which would maximize net benefits. Results of the computer analysis indicated that all potential projects had a reasonable likelihood of marketability and, therefore, no sites were dropped during this stage.

Stage 3

A few sites were screened out because of environmental, social or institutional problems because (1) sites were in significant environmental pristine areas (2) sites were of questionable safety; (3) sites had incremental capacity potential of 100 kW or less; or (4) for existing hydropower plants there was no expansion potential.

Stage 4

Marketability of power that would be generated at each site was evaluated manually (the results of the computer analysis were not used), and a ranking of the projects was made according to unit energy costs. Potential energy generation from these sites falls short of meeting the projected future demand for the State and for each of the islands. To meet the regional objective of increasing Hawaii's energy self-sufficiency, all potentially feasible sites were identified as suitable for further study and no further screening was performed at this stage.

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Chapter 6
PUBLIC INVOLVEMENT

6.1 ROLE OF PUBLIC INVOLVEMENT

In this study, the purposes of public involvement were to keep the public informed about the status and findings of the National Hydroelectric Power Study (NHS); to obtain needed information on existing and potential hydropower facilities; and, to obtain public comment on potential problems.

6.2 PUBLIC CONTACTS

As mentioned in Chapter 5, information and data collected in the 1977-78 hydropower study conducted by the Corps of Engineers were used as part of the data base for this report. In that study, workshops were held at each of the four major islands in the State, namely, Oahu, Hawaii, Maui and Kauai. A public meeting was also held at Kauai. Major input and basic concerns resulting from these public contacts were:

a. Location of hydropower facilities.
b. Effect on water rights.
c. Effect on local electrical rates.
d. Environmental changes.
e. Alternative energy sources.
f. Past and current State studies.

Public information fact sheets on the National Hydroelectric Power Study were distributed to selected government agencies, industries and citizens who have an interest in hydropower development. Attached to the fact sheet were the National Hydroelectric Power Study brochure published by the Institute for Water Resources and data sheets on the preliminary inventory of existing and potential hydropower facilities in Hawaii. Many valuable comments and information were received from the public regarding additional potential sites not included in the inventory and the accuracy of some data in the inventory. The public input was incorporated in the final inventory.

U.S. Army Corps of Engineers staff members also are active participants of the Committee on Small Hydroelectric Power Systems, sponsored by the State of Hawaii, Department of Planning and Economic Development. Representatives from Waialua Sugar Company, Department of Land and Natural Resources of the State of Hawaii, Kauai Electric Division of the Citizens Utilities Company, C. Brewer & Company, AmFac Corp., U.S. Army Corps of Engineers, U.S. Department of Energy, Water Resources Research Center of the University of Hawaii, Alexander & Baldwin, Theo H. Davies & Company, Hawaiian Electric Company & Molokai Electric Company serve on the committee.

The several committee meetings held during March to August 1980 served as forums for discussing the current and future impact of hydropower in the State. A copy of the draft of this report was distributed to each of the committee members for review and comment. The draft report was discussed during the August 1980 committee meeting and additional information and input were obtained and used to revise the report.

Chapter 7
INVENTORY

7.1 STAGE 1, 2 AND 3 RESULTS

Size of Inventory

A total of 14 undeveloped sites and existing projects passed the three-stage screening process. Among these projects, seven are new sites, four are on existing reservoirs, two are active hydropower plants for which additional capacity is possible, and one is a deactivated plant which could be rehabilitated. Collection and analysis of site data were based on available and readily developed information. Detailed engineering and other technical studies were not performed specifically for this study. The results of the study, therefore, are preliminary estimates of developable hydropower within the foreseeable future.

Capacity and Energy

These 14 identified projects have a total capacity potential of 39.39 MW and could generate 119.9 GWh of energy. These estimates include the capacity of 1.5 MW and energy of 8.1 GWh for two currently active hydropower plants. The incremental capacity potential for the State is 37.89 MW and the incrmental energy generation is 111.8 GWh (excluding what is currently available at the two active hydropower plants).

Plant Factors

Plant factors for the identified projects in the inventory vary from 0.17 to 0.94. However, majority of the sites have plant factors between 0.2 and 0.3. This is attributable to the highly variable runoff in most Hawaiian streams in relation to the installed capacity.

Primary Locations

Among the 14 projects in the inventory, more than half are located on Kauai, mainly on the eastern and southwestern parts of the island the remaining projects are located on the islands of Hawaii (2), Maui (3), Oahu (1) and Molokai (1).

Potential Development

All potential projects identified in this study are small-scale in capacity (less than 25 MW). Only one project has a potential capacity of 10 MW, and capacity of all others is less than 5 MW.

Existing Projects

Development of the seven existing projects would be through expansion of existing hydropower plants, rehabilitation of abandoned hydropower sites, or construction of hydropower facilities on existing reservoirs. Total potential capacity created by this type of development is estimated to be 8.86 MW. The amount of energy which could be generated is estimated to be 27.6 GWh.

New Projects

There are seven undeveloped projects in the inventory. These sites have a total capacity of 29.03 MW and energy potential of 84.2 GWh.

7.2 STAGE 4 INVENTORY

Projects Retained During Stage 4

All 14 projects remaining in the inventory after the Stage 3 screening were retained in Stage 4 as suitable for further study. Table 7-1 tabulates some general information and estimated capacity and energy for these projects. Their locations are shown on Figure 7-1.

Physical Characteristics

Selected projects are classified into five groups:

a. Expansion of active hydropower plants.

b. Rehabilitation of abandoned hydropower sites.

c. Construction of hydropower facilities on existing reservoirs.

d. Construction of new run-of-river hydropower facilities.

e. Construction of new storage reservoir hydropower facilities.

Projects in the first two groups are privately owned existing or abandoned hydropower plants. The capacities are small, 1 MW or less. Major work for these projects would be limited to the installation or rehabilitation of turbines and generators.

Civil engineering features, in addition to electromechanical components, will be needed for the group "c" projects. The basic features include site preparation, intake, penstock, powerhouse and switchyard. Existing reservoirs included in this group are relatively small, with the largest having only a maximum storage of 9,000 acre feet. The highest dam is 105 feet high.

Construction works required for group "d" projects are essentially the same as those required for group "c" projects with the exception that diversion systems with limited pondage are included in the plans. Although built on undeveloped sites, carefully designed and constructed run-of-river projects included in group "d" may result in relatively minor changes to the natural environment.

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Table 7-1
PRELIMINARY ESTIMATES OF POTENTIAL HYDROPOWER PROJECTS, HAWAII

I.D. No.[1/]	Name of Project	Island	Owner	Incremental Capacity MW	Incremental Energy GWh	Type of Project
1	Wailoa	Hawaii	---	2.9	12.3	New site (run-of-river)
6	Union Mill	Hawaii	Kohala Corp	0.5	4.1	Rehabilitation
9	Wahiawa Res	Oahu	Waialua Sugar Co.	2.8	7.5	Existing reservoir
11	Hanalei	Kauai	---	4.5	16.5	New site (run-of-river)
12	Kokee	Kauai	---	10.0	29.2	New site (storage)
14	Waialeale 2/	Kauai	---	7.8	42.7	New site (storage)
15	Puu Lua Res.	Kauai	Kekaha Sugar Co., Ltd.	1.7	3.0	Existing reservoir
16	Kapaia Res.	Kauai	Lihue Plantation Co., Ltd.	0.12	0.2	Existing reservoir
22	Hydro Kaumakani	Kauai	Olokele Sugar Co.	0.75 4/	8.3	Existing plant
23	Waimea	Kauai	Kekaha Sugar Co.	2.9	3.9	Existing plant
31	Wailua 2/	Kauai	---	8.4	18.7	New site (run-of-river)
25	Waihee	Maui	---	0.73	2.0	New site (run-of-river)
30	Hamakua Ditch	Maui	Hawaiian Commercial & Sugar Co.	0.5	2.5	New site (run-of-river)
32	Hoopoi Chute	Maui	Hawaiian Commercial & Sugar Co.	2.0	3.0	New site (run-of-river)
26	Kualapuu Res.	Molokai	State of Hawaii	0.09 3/	0.55	Existing reservoir
	Total			37.89	111.80	

Notes:

1/ Identification numbers are referenced to locations shown on Figure 7-1.

2/ Waialeale and Wailua are alternative development schemes for the same site. Wailua is the preferred development and is the one included in summaries of potential.

3/ This site did not meet the minimum capacity criteria. It was included in the potential project list based on publication of a favorable feasibility study, Feb 1980, State of Hawaii.

4/ New 1.25 MW power plant to be installed. Existing 0.5 MW unit will be used as stand-by.

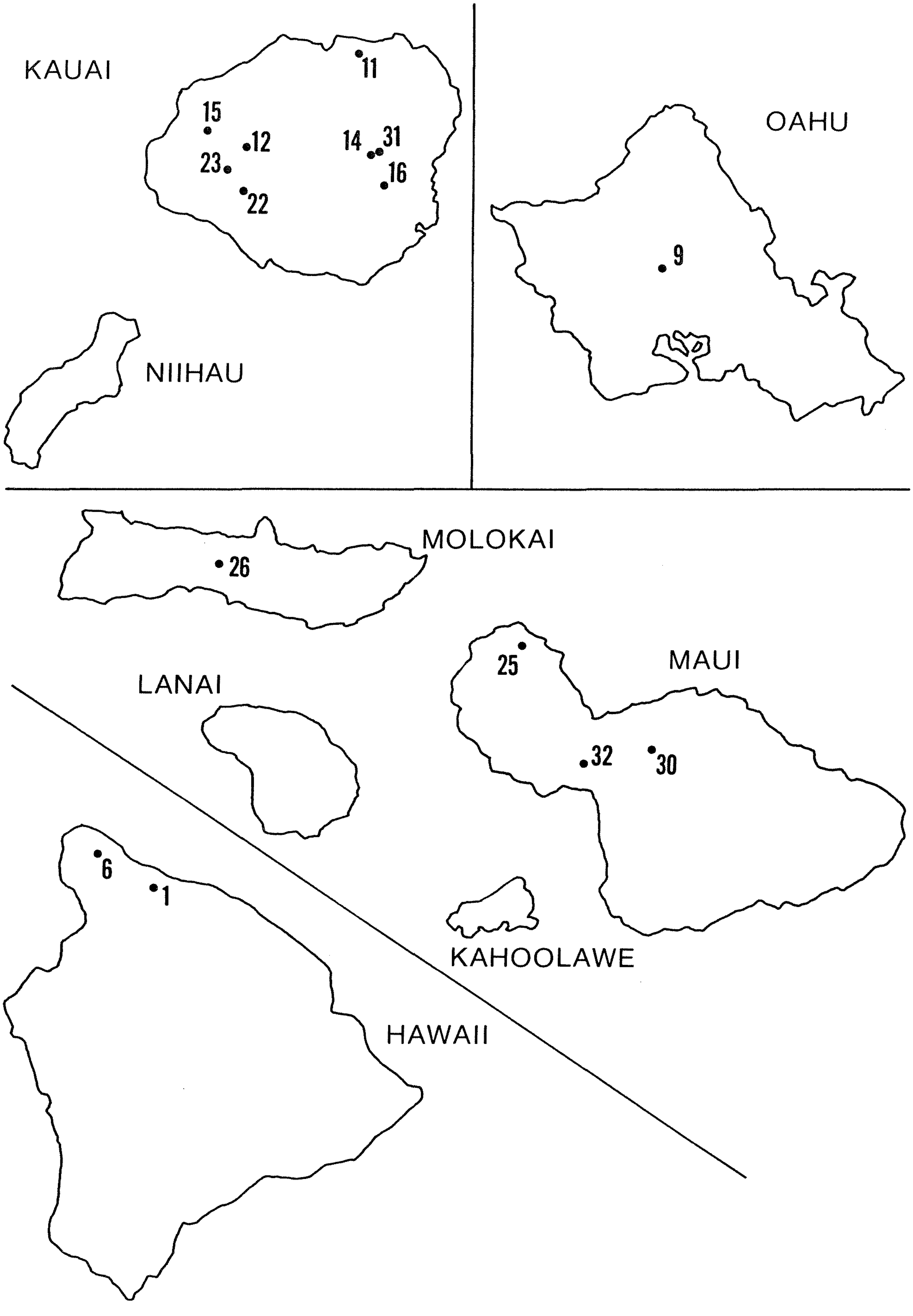

Figure 7-1
LOCATIONS OF POTENTIAL HYDROELECTRIC PROJECTS, HAWAII

Projects in group "e" include Kokee Dam, 234 feet high with maximum storage of 41,000 acre feet, and Waialeale Dam, 185 feet high with maximum storage of 47,000 acre feet. These two projects require significantly more extensive civil-works construction than other projects. Items of work are basically similar to those for group "c" projects, with the addition of reservoir construction. Construction of reservoirs would drastically alter the physical appearance and topography of the site. Regulated reservoir outflows would modify the flow regime of the existing stream.

Economic and Financial Characteristics

Estimated unit energy costs, which are the quotients of total annual project costs over the annual energy, vary from 10 to 255 mills/kWh. Total annual project costs were estimated by summing up the annual maintenance costs and the amortized first costs based on a 50-year project life and the fiscal year 1980 Federal discount rate of 7-1/8 percent. Projects of high unit energy costs include those requiring extensive construction such as large dams or long penstocks, and those with economically unfavorable energy output. However, more than 50 percent of the potential projects have a unit energy cost of 40 mills/kWh or less. This is about the price of surplus energy on the current market.

General Environmental and Social Conditions

All sites with existing hydropower facilities or civil features have no significant environmental concerns. Some of these facilities may no longer be in operation. However, all of the affected waterbodies have had a history of substantial modification to their watersheds. These modifications include clearing of natural riparian vegetation, monoculture commercial crops (and subsequent exposure to biocides), fords and road crossings, total or partial channelization, and urbanization. These waterbodies no longer harbor sustaining populations of endemic or native diadromous fishes, crustaceans or molluscs. There are no significant recreational areas, or sites of local or national historic significance located within or immediately adjacent to any of these waterbodies. Although one or more of these reservoirs and flumes may have been used for potable water supplies in the past, none are apparently being used for that purpose at present.

The Wailua and Waialeale project site on Kauai possesses one of the most disturbed aquatic fauna within the State. Continuous introductions of exotic species and modification of watershed vegetation and the streambed have resulted in the extirpation of virtually all native fauna from this extensive stream system. The lower reaches of the river along the south fork, however, drain the Wailua River State Park. Wailua Falls, the Fern Grotto, and the Wailua River boat ride are favorite tourist destination points which attracted over 4.5 million visitors to the park in 1979. The heavily vegetated banks of the estuarine reaches of the river provide habitat for three endangered Hawaiian waterbirds (Hawaiian coot, Hawaiian gallinule, and Hawaiian duck).

The Waimea river on Kauai, and its major tributary Makaweli Stream, drain the impressive Waimea Canyon. The stream itself has a high complement of indigenous aquatic fauna and is still utilized as a sport fishery. The

Waihee Stream on Maui has been dewatered by past diversions for water supply. However, subsurface discharge and spring flow create marginal habitat for a rare native fish (Lentipes concolor). Further consideration of these streams for hydropower development would require an evaluation of the potential environmental effects of development on these resources.

The Wailoa River is the principal tributary which drains historic Waipio Valley in Hamakua, Hawaii. Waipio was once the site of a large Hawaiian agricultural village; therefore, a substantial number of historic sites and archaeological resources probably exist along the stream. Wailoa/Waipio is the source of numerous ancient legends and has tremendous cultural and spiritual value to Hawaiian people today. The stream itself harbors large populations of migratory and diadromous native fauna. Lower Waipio Valley today harbors one of the State's principal centers of commercial taro agriculture. This wetland crop depends entirely upon maintenance of adequate streamflow for irrigation year-round.

Of the 14 potential projects, Hanalei and Kokee possess the most valuable and significant resources. The lower reaches of the Hanalei River flow through the Hanalei National Wildlife Refuge, which serves as prime habitat for four endangered Hawaiian waterbirds and for migratory waterfowl. Flow from the Hanalei River is needed to irrigate the island's largest commercial taro fields as well as to maintain artificial waterbird ponds. The river itself serves as the center of the seasonal fishery for native goby fishes. The estuary provides a resource for recreational boating, and is a nursery and spawning area for several marine fishes and crustaceans of commercial value. Because the watershed is almost entirely State-owned, excellent hiking trails extend toward the headwaters of the stream and are frequented by hunters, hikers and people collecting fishes and shrimp from the river. The Kokee project occurs within pristine forest reserves and also within portions of the Kokee State Park. This elevated forest is composed predominantly of native vegetation and native, endangered forest birds. Several streams within the area are annually stocked by the Hawaii Division of Fish and Game with rainbow trout to support a very small sport fishery. Much of the watershed area which may be inundated by an impoundment provides habitat for endangered species and is crisscrossed by a network of extremely popular hiking trails.

Sites Deleted Due to Noneconomic Constraints

Seven projects were deleted during Stage 3 because of enviromental, social and institutional constraints. Three of them are on Oahu, and the other four are on Kauai. The following table lists these sites and includes reasons for deletion from further consideration.

Table 7-2
SITES DELETED DURING STAGE THREE

Name of Project	Type of Project	Location	Reason(s) for Being Deleted
Kaneohe-Kailua	Existing Reservoir	Oahu	Incremental capacity is only 0.1 MW. Project purposes (flood control and recreation) not compatible with hydropower development.
Nuuanu	Existing Reservoir	Oahu	Incremental capacity is only 0.06 MW. Dam safety is questionable. Currently under investigation.
Ku-Tree	Existing Reservoir	Oahu	Incremental capacity is only 0.07 MW. Dam has been declared hazardous. Reservoir has been drained.
Lumahai	New Run of River	Kauai	Project site is in significant environmentally pristine area.
Koloko	Existing Reservoir	Kauai	Incremental capacity is only 0.07 MW.
Wainiha	Existing Plant	Kauai	There are no plans to expand the existing capacity of the plant.
Alexander	Existing Plant	Kauai	There are no plans to expand the existing capactiy of the plant.
Waialeale	New Reservoir	Kauai	Alternative to Wailua which would be more economically feasible to develop.

Chapter 8
EVALUATION

8.1 REGIONAL DEVELOPMENT PLAN

A total of 14 projects emerged from the three-stage screening process for possible inclusion in the regional plan. The total incremental capacity of these 14 sites is 37.89 MW, much less than the utility projected additional capacity requirement of 492 MW by 1990. From the preliminary analysis, it appears that some of these projects may not be feasible at the prevailing energy price level. However, the feasibility of these projects may be improved in the future as a result of oil price escalation. To meet the regional objectives of increasing Hawaii's energy self-sufficiency, all these projects were included in the regional plan for potential development.

Economically Optimum System Ranking

Unit energy cost for each selected project was determined manually using published cost curves. These projects were then ranked according to unit energy costs. This ranking is displayed following.

Project ID No.	Project Name	Estimated Energy Cost* mills/kWh	Energy Incremental Potential GWh
22	Hydro Kaumakani	10	8.3
6	Union Mill	24	4.1
9	Wahiawa Res.	29	7.5
11	Hanalei	29	16.5
1	Wailoa	33	12.3
23	Waimea	39	3.9
30	Hamakua Ditch	40	2.5
31	Wailua	46	18.7
15	Puu Lua Res.	63	3.0
32	Hoopoi Chute	64	3.0
26	Kualapuu Res.	72	0.6
25	Waihee	87	2.0
12	Kokee	119	29.2
16	Kapaia Res.	255	0.2

* June 1980 price level.

Environmentally Oriented System Ranking

Two of the 14 selected projects have unique ecological values which may be jeopardized by development of hydropower facilities. An additional four projects possess significant environmental resources within a portion of their watersheds. Future detailed studies on the feasibility of these projects should consider the preservation of certain ecological, recreational, and historical resources. The remainder of the project sites are in disturbed areas, or have little or no significant environmental concerns. The following listing of the 14 projects is in accordance with potential environmental impacts.

No Significant Concerns	Possess Important Resources	Potentially Severe Impact
Union Mill - Hawaii	Wailoa - Hawaii	Hanalei - Kauai
Wahiawa Res - Oahu	Wailua - Kauai	Kokee - Kauai
Puu Lua Res - Kauai	Waimea - Kauai	
Kapaia Res - Kauai	Waihee - Maui	
Hydro Kaumakani - Kauai		
Kualapuu Res - Maui		
Hamakua Ditch - Maui		
Hoopai Chute - Maui		

Developable System Ranking

Projects recommended for further study are listed below on the basis of combined economic and environmental considerations. Projects with high marketability (unit energy cost of up to 40 mills/kWh) and no significant environmental concerns were classified in the high-potential group. Projects with low marketability (unit energy cost in excess of 100 mills/kWh) and/or potentially severe environmental impacts were classified in the low potential groups. The remaining projects were included in the medium potential group.

High Potential	Medium Potential	Low Potential
Hydro Kaumakani	Puu Lua Res	Kapaia Res
Union Mill	Hoopoi Chute	Hanalei
Wahiawa Res	Kualapuu Res	Kokee
Hamakua Ditch	Wailoa	
	Waimea	
	Wailua	
	Waihee	

8.2 SCHEDULE FOR DEVELOPMENT

Short-Term

Short-term projects include Hydro Kaumakani, Union Mill, Wailua, Hamakua Ditch, Hoopoi Chute and Kualapuu Reservoir. They are considered to have a reasonable chance of being developed by 1990 or earlier. Among them, Hydro Kaumakani (Olokele Sugar Company) and Hamakua Ditch and Hoopoi Chute (both owned by Hawaiian Commercial and Sugar Company) are being planned for construction. A reconnaissance study of the feasibility of reactivating the Union Mill hydropower plant was completed by the U.S. Army Corps of Engineers (COE) in October 1979, under the Rural Energy Initiative Program managed by the U.S. Department of Energy. The Hawaii Electric Light Company has subsequently performed further investigations on the site. Implementation has been deferred pending resolution of water and lease agreements with the owner. A hydropower feasibility study of Kualapuu Reservoir was prepared for the State of Hawaii by W. A. Hirai and Associates, Inc. in February 1980. The design and construction of a 90-kW hydroelectric plant was recommended and is being considered by the State. COE is currently undertaking a survey study to determine the feasibility of constructing run-of-river hydropower facilities in the Wailua River Basin. The study is scheduled for completion in fiscal year 1982.

Long-Range

Long-range projects include Wahiawa Reservoir, Hanalei, Wailoa, Waimea, Puu Lua Reservoir, Waihee, Kokee, and Kapaia Reservoir. Although the Kokee project is currently under study, it is unlikely that any of these projects will be developed by 1990.

8.3 FEASIBILITY OF DEVELOPMENT PLAN

The development plan is strictly a preliminary conceptual plan for the Hawaii Region. Detailed site-specific feasibility investigations of these projects have not been performed. However, some indications of the marketability and potential environmental impacts of these projects have been generated from this study and are briefly discussed following.

Short-Term

From the results of preliminary estimates, it appears that the unit energy costs for most of the short-term projects are either below or comparable to the current market value of non-firm surplus energy. The unit energy costs of two projects exceed 40 mills/kWh: Hoopoi Chute (64 mills/kWh) and Kualapuu (72 mills/kWh). Their cost is considerably higher than the current market value but they could be marketable in the very near future. The economic, environmental and composite rankings of these short-term projects are as follows:

Economic Ranking		Environmental Ranking		Composite Ranking	
Rank	Project	Rank	Project	Rank	Project
1	Hydro Kaumakani	1	Union Mill	1	Hydro Kaumakani
2	Union Mill	1	Hydro Kaumakani	2	Union Mill
3	Hamakua Ditch	1	Kualapuu Reservoir	3	Hamakua Ditch
4	Wailua	1	Hamakua Ditch	4	Hoopoi Chute
5	Hoopoi Chute	1	Hoopoi Chute	5	Kualapuu Reservoir
6	Kualapuu Reservoir	2	Wailua	6	Wailua

Long-Range

Among the long-range sites, only four of the eight appear to yield a unit energy cost compatible with current market energy values. All the long-term projects are considered for development after 1990. It is possible that energy values will be substantially higher at that time. The marketability of the majority of the long-term projects does not seem to be encouraging at this time but may improve within the decade. The economic, environmental and composite rankings of these long-term projects are as follows:

Economic Ranking		Environmental Ranking		Composite Ranking	
Rank	Project	Rank	Project	Rank	Project
1	Wahiawa Reservoir	1	Wahiawa Reservoir	1	Wahiawa Reservoir
2	Hanalei	1	Puu Lua Reservoir	2	Puu Lua Reservoir
3	Wailoa	1	Kapaia Reservoir	3	Wailoa
4	Waimea	2	Wailoa	4	Waimea
5	Puu Lua Reservoir	2	Waimea	5	Waihee
6	Waihee	2	Waihee	6	Kapaia Reservoir
7	Kokee	3	Hanalei	7	Hanalei
8	Kapaia Reservoir	3	Kokee	8	Kokee

Comparison of Hydropower Potential with Demand

As discussed in Chapters 3 and 4, the total capacity of the State's electric system installed by utilities was 1,463 MW in 1978 (excluding MOECO), and the utility projected generating capacity is 1,955 MW in 1990 and 2,533 MW in 1998. Thus, the State needs 492 MW additional capacity by 1990 and 1070 MW by 2000 to meet the capacity requirements for the utilities alone. The additional capacity requirements by 1990 are 278 MW for HECO, 49 MW for HELCO, 145 MW for MECO and 20 MW for KED. By 1998, additional capacity of 588 MW, 90 MW, 340 MW and 52 MW will be needed for HECO, HELCO, MECO and KED, respectively. The total identified hydropower sites without overriding environmental and/or institutional problems, however, only have a total incremental capacity of 37.87 MW. Since potential power generation from all of these sites is needed, they were all included in the development plan.

8.4 SUMMARY

From the standpoint of marketability, most of the projects included in the regional plan have a unit energy cost less than or equal to the current market value of surplus energy. Energy from other projects could be marketable in the near future. From the standpoint of environmental impact, eight projects with existing hydropower facilities or civil features have no significant environmental concerns. Construction of Wailoa, Wailua, Waimea, and Waihee projects may disturb important natural resources. Hanalei and Kokee sites possess very valuable and significant resources and construction activities could cause severe environmental impacts. Key characteristics of the development plan for Hawaii are summarized in Table 8-1. The development of the hydropower sites will not satisfy the additional capacity or energy requirements of the State. The contribution of new and incremental hydropower development is expected to satisfy about 4 percent of the additional capacity demand by 1998. However, the important consideration is that development of any additional hydropower will relieve the State of the equivalent amount of petroleum. Based upon an assumed development of new hydropower plants producing 111.8 GWh of additional energy by the year 2000, the annual savings in oil used to generate electricity would total 186,000 barrels.

Table 8-1

HYDROPOWER DEVELOPMENT PLAN FOR HAWAII

Name of Project	Island	Owner	Rank			Incremental Capacity (MW)	Incremental Energy (GWh)	Type of Project
			Composite	Economic	Environmental			
				Short-Term				
Hydro Kaumakani	Kauai	Olokele Sugar Co.	1	1	1	0.75	8.3	Expansion of Existing plant by owner.
Union	Hawaii	Kohala Corp.	2	2	1	0.5	4.1	Rehabilitation of existing plant by owner and Hawaii Electric Light Co.
Hamakua Ditch	Maui	Hawaiian Commercial and Sugar Co.	3	4	1	0.5	2.5	Construction of new run-of-river plant by owner
Hoopoi Chute	Maui	Hawaiian Commercial and Sugar Co.	4	5	1	2.0	3.0	Construction of new run-of-river plant by owner
Kualapuu Reservoir	Molokai	State of Hawaii	5	6	1	0.09	0.6	Construction of new plant on existing reservoir by the State
Wailua*	Kauai	-----	6	3	2	8.4	18.7	Feasibility study of a new run-of-river plant by Corps of Engineers
				Long-Range				
Wahiawa Reservoir	Oahu	Waialua Sugar Co.	1	1	1	2.8	7.5	Existing reservoir
Puulua Reservoir	Kauai	Kekaha Sugar Co.	2	5	1	1.7	3.0	Existing reservoir
Wailoa	Hawaii	-----	3	3	2	2.9	12.3	New site (run-of-river)
Waimea	Kauai	Kekaha Sugar Co.	4	4	2	2.9	3.9	Existing plant
Waihee	Maui	-----	5	6	2	0.73	2.0	New site (run-of-river)
Kapaia Reservoir	Kauai	Lihue Plantation Co. Ltd.	6	8	1	0.12	0.2	Existing reservoir
Hanalei	Kauai	-----	7	2	3	4.5	16.5	New site (run-of-river)
Kokee	Kauai	-----	8	7	3	10.0	29.2	New site (storage) New feasibility study pending.

* The selected development in drainage area between Waialeale and Wailua projects.

APPENDIX

SUMMARY LISTING OF POTENTIAL HYDROPOWER PROJECTS

Introduction

A primary objective of the NHS was to inventory and evaluate potential hydropower projects. Projects inventoried included existing dams and other water projects and previously studied undeveloped sites. Project data were compiled from existing information sources supplemented by data from USGS topographic maps, where necessary. No site visits or other field investigations were made. Although to the extent possible, all existing and undeveloped projects were inventoried, only those projects with existing power generating facilities or projects with a reasonable potential for development for hydropower were retained in the NHS inventory. This inventory is permanently maintained in a computer data base which includes descriptive information and the results of a computer analysis of power potential and development costs for each project. In all, the inventory for Hawaii includes 28 projects.

Tabulated Data

The purpose of this appendix is to provide a summary listing of selected data on the 28 existing and potential hydropower projects which were included in the NHS inventory (computer data base) for Hawaii. In the following table, projects are listed in alphabetical order by county. A description of the data included in the table precedes the tabulated information. However, a few items warrant clarification:

(1) Up to four lines of information are presented for each project.

(2) Projects are separated by a space.

(3) As noted in the description of tabulated data. The third character of the project indentification number describes the type and status of the project. A description of each of the possible project status/types is shown in the following matrix:

STATUS OF WATERWAY STRUCTURE	TYPE OF OPERATION					
	RUN OF RIVER	DIVERSION	RESERVOIR	RES. WITH DIVERSION	IRRIGATION CANAL	STORAGE
EXISTING	A	B	C	D	E	F
EXISTING WITH POWER	G	H	I	J	K	L
EXISTING WITH RETIRED POWER PLANT	M	N	O	P	Q	R
BREACHED	S	T	U	V	W	X
BREACHED WITH RETIRED POWER PLANT	Y	Z	0	1	2	3
UNDEVELOPED	4	5	6	7	8	9

(4) Project costs shown were derived from computer application of generalized cost estimating procedures and should not be construed to be representative of actual costs. Further, it should be noted that as stated in Chapter 5 of this report, final economic screening of potential projects was based on manually computed cost estimates; not on the computer estimates shown in the summary table. The estimated energy costs used in the economic screening and ranking of projects recommended for further study are shown in Chapter 8 of this report (page 8-1).

(5) With a few exceptions, environmental and social impact assessments and codes were completed only for those projects which are recommended for further study (ACTV INV status of "2").

(6) Projects with stars appearing in seventh column (energy) are projects for which insufficient data were available to make a complete computer analysis.

Summary Listing of Existing and Potential Hydropower Projects, Hawaii
Description of Tabulated Data

COLUMN NO.	LINE NO.	FORM 2 ITEM NO.	COLUMN HEADING	DESCRIPTION
1	1	1	SITE ID NUMBER	UNIQUE 10-CHARACTER IDENTIFIER FOR EACH SITE. EXAMPLE: HICPOH0003 CHARACTERS: VALUE: 1-2 HI = **STATE** CODE (POSTAL ABBREVIATION) 3 C = **TYPE** AND STATUS CODE (REFER TO FORM 2 ITEM DESCRIPTION DOCUMENTATION FOR ITEM 84). CODES **A** THRU **R** INDICATE **EXISTING** PROJECTS. **S** THRU **3** INDICATE **BREACHED** PROJECTS AND **4** THRU **9** INDICATE **UNDEVELOPED** PROJECTS FOR VARIOUS TYPES OF OPERATION. 4-6 POH = U.S. ARMY CORPS OF ENGINEERS **DISTRICT** CODE (REFER TO FORM 2 ITEM DESCRIPTION DOCUMENTATION FOR ITEM 33) 7-10 0003 = UNIQUE SEQUENTIAL **NUMBER** WITHIN EACH DISTRICT
1	2A	65	DEP CODE	IDENTIFICATION OF UNDEVELOPED PROJECTS AS AN ALTERNATIVE TO SOME OTHER PROJECT OR AS A PART OF SOME SYSTEM. THIS ITEM ALSO INDICATES WHICH ONE OF THE POSSIBLE ALTERNATIVE PROJECTS SHOULD BE INCLUDED IN ESTIMATES OF TOTAL NATIONAL POTENTIAL. THE **DEPENDENT/INDEPENDENT** CODE IS DEFINED AS FOLLOWS: **I** = INDEPENDENT SITE. **E** = DEPENDENT, ALTERNATIVE SITE, EXCLUDED FROM SUMMARIES. **S** = DEPENDENT, PART OF A SYSTEM. THIS SITE SHOULD BE INCLUDED IN SUMMARY TABLES. **D** = DEPENDENT, ALTERNATIVE SITES WHICH ARE CHOSEN BY DISTRICT FOR INCLUSION IN SUMMARY TABLES.

Description of Tabulated Data(continued)

COLUMN NO.	LINE NO.	FORM 2 ITEM NO.	COLUMN HEADING	DESCRIPTION
1	28	3	ACTV INV	**ACTIVE IN INVENTORY** CODE FOR IDENTIFYING SITES BASED ON CAPACITY AND B/C RATIOS. (SEE FORM 2 ITEM DESCRIPTION DOCUMENTATION FOR DETAILED EXPLANATION OF CODES). SOME OF THE MORE COMMON **ACTIVE IN INVENTORY** CODES ARE AS FOLLOWS: 1 = SITES CONSIDERED INACTIVE FOR STUDY THAT HAVE A TOTAL POTENTIAL CAPACITY BETWEEN 50 KW AND 1000 KW AND A B/C RATIO GREATER THAN 1.0. 2 = SITES CONSIDERED ACTIVE FOR STUDY THAT HAVE A TOTAL POTENTIAL CAPACITY GREATER THAN OR EQUAL TO 1000 KW AND B/C RATIO GREATER THAN OR EQUAL TO 1.0 (NOTE: OTHER SITES CHOSEN BY THE DISTRICTS CAN ALSO HAVE A CODE = 2 TO INDICATE **ACTIVE** STATUS). 4 = SITES CONSIDERED INACTIVE FOR STUDY WHERE THE TOTAL POTENTIAL CAPACITY IS LESS THAN 50 KW OR THE B/C RATIO IS LESS THAN 1.0. 5 = SITE CONSIDERED INACTIVE FOR STUDY BECAUSE ADVANCED ANALYSIS SHOWED DEVELOPMENT OF THE SITE TO BE ECONOMICALLY OR ENGINEERINGLY INFEASIBLE. 6 = SITES CONSIDERED INACTIVE FOR STUDY BECAUSE THEY FAILED THE SCREENING ON ADVERSE ENVIRONMENTAL, SOCIAL, AND/OR INSTITUTIONAL IMPACTS.
1	3	53	POWER AREA	ELECTRIC RELIABILITY COUNCIL SUB-REGION (GEOGRAPHIC AREA FOR ALASKA).
2	1	2	PROJECT NAME	IDENTIFICATION **NAME** OF EXISTING DAM OR POTENTIAL WATER MANAGEMENT PROJECT (**NOTE:** ONLY THE FIRST 29 CHARACTERS OF A POSSIBLE 40 CHARACTERS ARE PRINTED).
2	2A	40	PRIMARY COUNTY	PRIMARY **COUNTY** NAME IN WHICH THE PROJECT IS LOCATED.
2	2B	31	NAME OF STREAM	NAME OF **STREAM** WHERE THE PROJECT IS LOCATED.
2	3	60	OWNER	IDENTIFICATION OF PROJECT **OWNER**. NOTE: **DAEN XXX** REPRESENTS U.S. ARMY CORPS OF ENGINEERS WHERE **XXX** INDICATES THE **DISTRICT** CODE (REFER TO FORM 2 ITEM DESCRIPTION DOCUMENTATION FOR A LIST OF DISTRICT CODES AND FEDERAL AGENCIES).
2	4	160	MAP REFERENCE	IDENTIFICATION OF USGS MAP SHOWING LOCATION OF SITES AND OTHER MAPS AS NEEDED FOR IDENTIFICATION.
3	1	36	LATITUDE	IDENTIFICATION OF PROJECT LOCATION BY **LATITUDE** (DEGREES, MINUTES AND TENTHS OF MINUTES).
3	2	37	LONGITUDE	IDENTIFICATION OF PROJECT LOCATION BY **LONGITUDE** (DEGREES, MINUTES AND TENTHS OF MINUTES).
3	3	126	DR. AREA	**DRAINAGE AREA** (IN SQUARE MILES) OF THE PROJECT.

Description of Tabulated Data(continued)

COLUMN NO.	LINE NO.	FORM 2 ITEM NO.	COLUMN HEADING	DESCRIPTION
4	1	62	PROJ. PURP.	IDENTIFICATION OF AUTHORIZED **PROJECT PURPOSES** AS FOLLOWS: **I** = IRRIGATION **H** = HYDROELECTRIC **C** = FLOOD CONTROL **N** = NAVIGATION **S** = WATER SUPPLY **R** = RECREATION **D** = DEBRIS CONTROL **P** = FARM POND **O** = OTHER
4	2	63	STATUS	INDICATION OF **PROJECT STATUS** AS FOLLOWS: **IS** = IDENTIFIED SITE **SP** = STUDY PROPOSED **SA** = AUTHORIZED FOR STUDY **FP** = FEASIBILITY STUDY IN PROGRESS **SI** = STUDY INACTIVE **PA** = PROJECT AUTHORIZED **DM** = GDM IN PROGRESS **UC** = UNDER CONSTRUCTION **OP** = PROJECT IN OPERATION
4	3	128	AVE. Q	AVERAGE ANNUAL **INFLOW** (IN CFS). NOTE: **NEGATIVE** VALUES INDICATE **MACHINE DETERMINED** VALUES BASED ON A DRAINAGE AREA RATIO OF THE PROJECT TO THE REPRESENTATIVE GAGE.
5	1	81	DAM HT	PHYSICAL **HEIGHT** (IN FEET) OF DAM ABOVE THE STREAMBED.
5	2	88	TOT. STOR	CUMULATIVE **STORAGE** (IN ACRE-FEET) AT TOP OF FLOOD CONTROL POOL. IF ITEM 88 WAS NOT SUPPLIED, THEN THE STORAGE VALUE WAS TRANSFERRED FROM ITEM 104, **MAXIMUM STORAGE** (IN ACRE-FEET).
5	3	11	PWR. HD.	WEIGHTED NET **POWER HEAD** IF DETERMINED BY PROGRAM: (**ITEM 11**) IF COMPUTED BY FLOW-DURATION PROCEDURE OR TRANSFERRED FROM NORMAL NET POWER HEAD (**ITEM 105**).
6	1	300	EXIST. CAP.	AMOUNT OF **EXISTING CAPACITY** (IN KW) FOR THE PROJECT.
6	2	310	INC. CAP.	AMOUNT OF **INCREMENTAL CAPACITY** (IN KW) THAT IS ESTIMATED FOR THE PROJECT.
6	3	290	TOT. CAP.	AMOUNT OF **TOTAL CAPACITY** (IN KW) THAT IS ESTIMATED FOR THE PROJECT (EXISTING PLUS INCREMENTAL).
7	1	301	EXIST. ENRG.	AMOUNT OF **EXISTING ENERGY** (IN MWH) FOR THE PROJECT.
7	2	311	INC. ENERGY	AMOUNT OF **INCREMENTAL** AVERAGE ANNUAL **ENERGY** (IN MWH) THAT IS ESTIMATED FOR THE PROJECT.
7	3	291	TOT. ENERGY	AMOUNT OF **TOTAL ENERGY** (IN MWH) THAT IS ESTIMATED FOR THE PROJECT (EXISTING PLUS INCREMENTAL).
8	1	318	ANUL. COST	TOTAL **ANNUAL COST** (IN 1000 $) OF PRODUCING THE INCREMENTAL POTENTIAL AVERAGE ANNUAL ENERGY THAT IS ESTIMATED FOR THE PROJECT.
8	2	318/311	ENERGY COST	**COST** (IN $/MWH) OF PRODUCING THE INCREMENTAL POTENTIAL ENERGY THAT IS ESTIMATED FOR THE PROJECT.

Description of Tabulated Data(continued)

EXPLANATION OF **ENVIRONMENTAL** AND **SOCIAL** IMPACT CODES: (COLUMNS 7 - 8)

ALPHABETICAL CODES Y, N, AND U ARE DEFINED AS FOLLOWS:

Y = YES
N = NO
U = UNKNOWN

NUMERICAL CODES 1 THROUGH 5 ARE DEFINED AS FOLLOWS:

1 = MAJOR **ADVERSE**
2 = MINOR ADVERSE
3 = INSIGNIFICANT
4 = MINOR FAVORABLE
5 = MAJOR **FAVORABLE**

COLUMN NO.	LINE NO.	FORM 2 ITEM NO.	COLUMN HEADING	DESCRIPTION
7	1	608	ENVRNMNTL IMPACT CODE	SEVEN CHARACTER **ENVIRONMENTAL IMPACT CODE** IS DEFINED AS FOLLOWS: CHARACTER POSITION — DESCRIPTION 1ST NATIONAL/STATE PARKS AND WILDERNESS 2ND WILD AND SCENIC RIVER 3RD RESIDENT FISH 4TH ANADROMOUS FISH 5TH WILDLIFE HABITAT 6TH ENDANGERED SPECIES 7TH WETLANDS
8	1	669	SOCIAL IMPACT CODE	NINE CHARACTER **SOCIAL IMPACT CODE** IS DEFINED AS FOLLOWS: CHARACTER POSITION — DESCRIPTION 1ST CULTURAL AND HISTORICAL RESOURCES 2ND COMMUNITIES RELOCATED 3RD TRANSPORTATION RELOCATED 4TH FARMLAND 5TH LOCAL GROUP COMMENT 6TH ENVIRONMENTAL GROUP COMMENT 7TH OTHER GROUP COMMENT 8TH UTILITY INTEREST 9TH STATE COMMENT

Summary Listing of Existing and Potential Hydropower Projects, Hawaii
Project Listing

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*************************************************************************************************************************************
*   SITE ID  *         PROJECT NAME        * LATITUDE *PROJ.PURP.* DAM HT  * EXIST.CAP. *EXIST.ENRG*ANUL. COST *   ENVIRONMENTAL  *
*            * PRIMARY CO. -NAME OF STREAM *LONGITUDE *  STATUS  *TOT. STOR* INC.  CAP. *INC.ENERGY*ENERGY COST*    IMPACT CODE   *
* DEP   ACTV *            OWNER            * DR.AREA  *  AVE. Q  *PWR. HD. * TOT. CAP.  *TOT.ENERGY*           *                  *
* CODE   INV *        MAP REFERENCE        * (D M.M)  *          *  (FT)   *    (KW)    *  (MWH)   * (1000 $)  *                  *
*            *                             * (D M.M)  *          * (AC FT) *    (KW)    *  (MWH)   *  ($/MWH)  *      SOCIAL      *
* POWER AREA *                             * (SQ.MI)  *   (CFS)  *  (FT)   *    (KW)    *  (MWH)   *           *    IMPACT CODE   *
*************************************************************************************************************************************
* HIHPOH0004 * HONOKAA                     * 20   5.8 *  HI      *       0 *          0 *        0 *        0  *                  *
*          5 * HAWAII         LOWER HAMAKUA* 155 28.2 *  UP      *       0 *          0 *        0 *        0  *                  *
*            * HONOKAA SUGAR CO            *          *         0*   415.0 *          0 ********** *           *                  *
*            *                             *          *          *         *            *          *           *                  *
*            *                             *          *          *         *            *          *           *                  *
* HINPOH0005 * PAPAIKOU MILL               * 19 46.9  *  H       *       0 *          0 *        0 *        0  *     NNNNNNN      *
*          5 * HAWAII         HONOLII      * 155  5.4 *  OP      *       0 *          0 *        0 *        0  *                  *
*            * HILO COAST PROCESSING CO    *          *         0*   207.0 *          0 ********** *           *    UNNNUUUNU     *
*            *                             *          *          *         *            *          *           *                  *
*            *                             *          *          *         *            *          *           *                  *
* HIHPOH0002 * PUUEO                       * 19 43.8  *  H       *       0 *          0 *        0 *        0  *                  *
*          5 * HAWAII         WAILUKU      * 155  5.5 *  OP      *       0 *          0 *        0 *        0  *                  *
*            * HAWAII ELECTRIC LIGHT CO    *          *         0*   400.0 *          0 ********** *           *                  *
*            *                             *          *          *         *            *          *           *                  *
*            *                             *          *          *         *            *          *           *                  *
* HIQPOH0006 * UNION MILL                  * 20 12.0  *  HI      *       0 *          0 *        0 *   94.687  *     NNNYNNN      *
* I        2 * HAWAII         KOHALA DITCH * 155 48.0 *          *       0 *        500 *     4100 *   23. 94  *                  *
*            * KOHALA SUGAR CO             *        2 *      41.0*   564.4 *        500 *     4100 *           *    UNNNUUUNU     *
*            *                             *          *          *         *            *          *           *                  *
*            *                             *          *          *         *            *          *           *                  *
* HIHPOH0003 * WAIAU                       * 19 43.4  *  H       *       0 *          0 *        0 *        0  *                  *
*          5 * HAWAII         WAILUKU      * 155  7.3 *  OP      *       0 *          0 *        0 *        0  *                  *
*            * HAWAII ELECTRIC LIGHT CO    *          *         0*   322.0 *          0 ********** *           *                  *
*            *                             *          *          *         *            *          *           *                  *
*            *                             *          *          *         *            *          *           *                  *
* HISPOH0001 * WAILOA                      * 20   4.8 *  H       *    10.0 *          0 *        0 *    11964  *     NNYYYNY      *
*          2 * HAWAII         WAILOA       * 155 37.3 *  IS      *       0 *       2900 *    12300 *   972.74  *                  *
*            *                             *       14 *      71.0*   252.7 *       2900 *    12300 *           *    YNNYUYUUU     *
*            * KUKUIHAELE, KAMUELA QUADS   *          *          *         *            *          *           *                  *
*            *                             *          *          *         *            *          *           *                  *
* HICPOH0009 * WAHIAWA RESERVOIR           * 21 30.0  *  IR      *    98.0 *          0 *        0 *   404.89  *     YNYNNNN      *
*          2 * HONOLULU       KAUKONAHUA ST* 158  3.0 *  OP      *       0 *       2800 *     7500 *   53.986  *                  *
*            * WAIALUA SUGAR CO            *       17 *    -212.0*    69.9 *       2800 *     7500 *           *    NNNYYYUUU     *
*            * HALEIWA QUAD                *          *          *         *            *          *           *                  *
*            *                             *          *          *         *            *          *           *                  *
* HIJPOH0018 * ALEXANDER RESERVOIR         * 21 57.6  *  IHS     *   119.0 *       1000 *     2100 *        0  *                  *
*          5 * KAUAI          WAHIAWA STREA* 159 31.5 *  OP      *       0 *          0 *        0 *        0  *                  *
*            * MCBRYDE SUGAR CO LTD        *        3 *      -6.5*   699.3 *       1000 *     2100 *           *                  *
*            * KOLOA QUAD                  *          *          *         *            *          *           *                  *
*            *                             *          *          *         *            *          *           *                  *
* HISPOH0011 * HANALEI                     * 22   7.8 *  H       *    10.0 *          0 *        0 *    12020  *     NNYYYYY      *
*          2 * KAUAI          HANALEI RIVER* 159 28.0 *  IS      *       0 *       4500 *    16500 *   728.53  *                  *
*            *                             *       10 *     104.0*   262.7 *       4500 *    16500 *           *    YNNYYYUUY     *
*            * HANALEI QUAD                *          *          *         *            *          *           *                  *
*************************************************************************************************************************************
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Project Listing(continued)

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************************************************************************************************************************************
*   SITE ID  *          PROJECT NAME       * LATITUDE *PROJ.PURP.* DAM HT   * EXIST.CAP.  *EXIST.ENRG*ANUL. COST *  ENVIRONMENTAL  *
*            * PRIMARY CO. -NAME OF STREAM *LONGITUDE *  STATUS  *TOT. STOR* INC.  CAP.  *INC.ENERGY*ENERGY COST*   IMPACT CODE   *
* DEP   ACTV *           OWNER             * OR.AREA  *  AVE. Q  *PWR. HD. * TOT. CAP.   *TOT.ENERGY*           *                 *
* CODE   INV *        MAP REFERENCE        * (D M.M)  *          *  (FT)    *    (KW)     *  (MWH)   * (1000 $)  *                 *
*            *                             * (D M.M)  *          * (AC FT)  *    (KW)     *  (MWH)   *  ($/MWH)  *     SOCIAL      *
* POWER AREA *                             * (SQ.MI)  *   (CFS)  *  (FT)    *    (KW)     *  (MWH)   *           *   IMPACT CODE   *
************************************************************************************************************************************
* HIHPOH0022 * HYDRO KAUMAKANI             * 22  0.1  *  HI      *    10.0  *         500 *     3100 *   247.61  *     NNUUNNN     *
*          2 * KAUAI          MAKAWELI     * 159 36.8 *  OP      *       0  *         750 *     8300 *   29.833  *                 *
*            * OLOKELE SUGAR CO            *        5 *     -10.1*   210.7  *        1250 *    11400 *           *    UNNNUUUNU    *
*            * WAIMEA CANYON QUAD          *          *          *          *             *          *           *                 *
*            *                             *          *          *          *             *          *           *                 *
* HICPOH0016 * KAPAIA RESERVOIR            * 22  1.1  *  I       *       0  *           0 *        0 *        0  *     NNUUNNN     *
*          2 * KAUAI          HANAMAULU STR* 159 23.9 *  OP      *       0  *           0 *        0 *        0  *                 *
*            * LIHUE PLANTATION CO LTD     *        2 *      -9.9*   -37.1  *           0 ********* *           *    UNNYUUUUU    *
*            *                             *          *          *          *             *          *           *                 *
*            *                             *          *          *          *             *          *           *                 *
* HI7POH0012 * KOKEE WATER PROJECT         * 22  7.9  *  HIRO    *   240.0  *           0 *        0 *    15508  *     YNNYYYN     *
*          2 * KAUAI          KAWAIKOI STRE* 159 37.0 *  SI      *       0  *       10000 *    29200 *   531.12  *                 *
*            * STATE                       *        1 *      -8.4*   959.0  *       10000 *    29200 *           *    UNNNYYUUY    *
*            * HAENA, KEKAHA, MAKAHA POINT,*          *          *          *             *          *           *                 *
*            *                             *          *          *          *             *          *           *                 *
* HICPOH0017 * KOLOKO RESERVOIR            * 22 10.7  *  I       *       0  *           0 *        0 *   55. 33  *                 *
*          5 * KAUAI          OFFSTREAM    * 159 22.9 *  OP      *       0  *          68 *      213 *   258.32  *                 *
*            * MARY N LUCAS ESTATE         *        1 *      -5.5*    39.9  *          68 *      213 *           *                 *
*            *                             *          *          *          *             *          *           *                 *
*            *                             *          *          *          *             *          *           *                 *
* HIKPOH0021 * LOWER LIHUE                 * 22  1.2  *  HI      *       0  *         800 *     5000 *        0  *                 *
* I        5 * KAUAI          N WAILUA-ILIC* 159 26.8 *  OP      *       0  *           0 *        0 *        0  *                 *
*            * LIHUE PLANTATION CO         *          *      48.0*   208.0  *         800 *     5000 *           *                 *
*            *                             *          *          *          *             *          *           *                 *
*            *                             *          *          *          *             *          *           *                 *
* HICPOH0015 * PUU LUA RESERVOIR           * 22  5.5  *  I       *   110.0  *           0 *        0 *   254.73  *     YNNNYYN     *
*          2 * KAUAI          TR-HAELEELE S* 159 40.8 *  OP      *       0  *        1700 *     3000 *   84.911  *                 *
*            * KEKAHA SUGAR CO LTD         *        7 *     -63.9*    81.9  *        1700 *     3000 *           *    UNNNUUUUU    *
*            * MAKAHA POINT QUAD           *          *          *          *             *          *           *                 *
*            *                             *          *          *          *             *          *           *                 *
* HIKPOH0020 * UPPER LIHUE                 * 22  1.4  *  HI      *       0  *         500 *     3100 *        0  *                 *
*          5 * KAUAI          N WAILUA-ILIC* 159 27.9 *  OP      *       0  *           0 *        0 *        0  *                 *
*            * LIHUE PLANTATION CO         *          *      22.0*   238.0  *         500 *     3100 *           *                 *
*            *                             *          *          *          *             *          *           *                 *
*            *                             *          *          *          *             *          *           *                 *
* HI7POH0014 * WAIALEALE                   * 22  1.9  *  HIR     *   185.0  *           0 *        0 *    15460  *     YNYYNYY     *
* E        2 * KAUAI          SOUTH FORK WA* 159 22.8 *  FP      *       0  *        7800 *    42700 *   362. 6  *                 *
*            * STATE                       *       18 *     -57.1*   559.4  *        7800 *    42700 *           *    YNYYYYUUY    *
*            * WAIALEALE,KAPAA QUADS       *          *          *          *             *          *           *                 *
*            *                             *          *          *          *             *          *           *                 *
* HIHPOH0024 * WAIAWA                      * 21 59.8  *  HI      *       0  *           0 *        0 *        0  *                 *
*          5 * KAUAI          KAHOANA      * 159 43.5 *  OP      *       0  *           0 *        0 *        0  *                 *
*            * KEKAHA SUGAR CO             *          *         0*   282.0  *           0 ********* *           *                 *
*            *                             *          *          *          *             *          *           *                 *
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Project Listing(continued)

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**********************************************************************************************************************************
*   SITE ID  *       PROJECT NAME          * LATITUDE *PROJ.PURP.* DAM HT  * EXIST.CAP. *EXIST.ENRG*ANUL. COST *  ENVIRONMENTAL  *
*            * PRIMARY CO. -NAME OF STREAM *LONGITUDE *  STATUS  *TOT. STOR* INC.  CAP. *INC.ENERGY*ENERGY COST*   IMPACT CODE   *
* DEP   ACTV *           OWNER             * DR.AREA  *  AVE. Q  *PWR. HD. * TOT. CAP.  *TOT.ENERGY*           *                 *
* CODE   INV *        MAP REFERENCE        * (D M.M)  *          *  (FT)   *    (KW)    *   (MWH)  * (1000 $)  *                 *
*            *                             * (D M.M)  *          * (AC FT) *    (KW)    *   (MWH)  * ($/MWH)   *      SOCIAL     *
* POWER AREA *                             * (SQ.MI)  *    (CFS) *  (FT)   *    (KW)    *   (MWH)  *           *   IMPACT CODE   *
**********************************************************************************************************************************
* HI7POH0031 * WAILUA                      * 22  2.3  *          *    10.0 *          0 *         0*    12878  *     YNNYYNY     *
* D        2 * KAUAI          SOUTH FORK WA* 159 22.8 *          *       0 *       8400 *     18700*    688.67 *                 *
*            *                             *       23 *     150.0*   309.6 *       8400 *     18700*           *    YNNYNYUNN    *
*            * WAIALEALE, KAPAA            *          *          *         *            *          *           *                 *
*            *                             *          *          *         *            *          *           *                 *
* HIHPOH0023 * WAIMEA                      * 22  2.8  *  HI      *    10.0 *       1000 *      5000*    404.78 *     UNUUUNN     *
*          2 * KAUAI          WAIMEA       * 159 38.6 *  OP      *       0 *       2900 *      3300*    122.66 *                 *
*            * KEKAHA SUGAR CO             *       32 *     -34.5*   264.7 *       3900 *      8300*           *    YNNNUYUUU    *
*            * WAIMEA CANYON QUAD          *          *          *         *            *          *           *                 *
*            *                             *          *          *         *            *          *           *                 *
* HIHPOH0019 * WAINIHA                     * 22 11.9  *  H       *    20.0 *       3600 *     24000*        0  *                 *
*          5 * KAUAI          WAINIHA      * 159 33.5 *  OP      *       0 *          0 *         0*        0  *                 *
*            * MCBRYDE SUGAR CO            *       13 *     -81.0*   564.4 *       3600 *     24000*           *                 *
*            * HAENA QUAD                  *          *          *         *            *          *           *                 *
*            *                             *          *          *         *            *          *           *                 *
* HIEPOH0030 * HAMAKUA DITCH               * 20 52.9  *  I       *       0 *          0 *         0*        0  *     NNUUNNN     *
* I        2 * MAUI           HAMAKUA DITCH* 156 20.1 *  OP      *       0 *          0 *         0*        0  *                 *
*            * HAWAIIAN COM   SUG CO       *          *         0*       0 *          0 *         0*           *    UNNNUYUNU    *
*            *                             *          *          *         *            *          *           *                 *
*            *                             *          *          *         *            *          *           *                 *
* HIEPOH0032 * HOOPUI CHUTE                *  20 53.1 *          *       0 *          0 *         0*        0  *     NNUUNNN     *
*          2 * MAUI           WAIHEI DITCH * 156 30.75*          *       0 *          0 *         0*        0  *                 *
*            * HAWAIIAN COM   SUG CO       *          *         0*       0 *          0 *         0*           *    UNNNUUUNU    *
*            *                             *          *          *         *            *          *           *                 *
*            *                             *          *          *         *            *          *           *                 *
* HIKPOH0028 * KAHEKA                      * 20 53.4  *  IH      *       0 *       5800 *     25000*        0  *                 *
*          5 * MAUI           WAILOA DITCH * 156 21.5 *  OP      *       0 *          0 *         0*        0  *                 *
*            * HAWAIIAN COM   SUG CO       *          *         0*   660.0 *       5800 *     25000*           *                 *
*            *                             *          *          *         *            *          *           *                 *
*            *                             *          *          *         *            *          *           *                 *
* HIHPOH0029 * KAUAULA                     * 20 52.6  *  HI      *       0 *          0 *         0*        0  *                 *
*          5 * MAUI           KAUAULA      * 156 38.6 *  OP      *       0 *          0 *         0*        0  *                 *
*            * PIONEER MILL CO             *        2 *      -1.5*   535.0 *          0 ***********           *                 *
*            *                             *          *          *         *            *          *           *                 *
*            *                             *          *          *         *            *          *           *                 *
* HICPOH0026 * KUALAPUU RESERVOIR          * 21  9.2  *  IS      *       0 *          0 *         0*        0  *     NNNNNNN     *
*          2 * MAUI           TR-KALUA PEEL* 157  3.0 *  OP      *       0 *          0 *         0*        0  *                 *
*            * STATE OF HAWAII DLNR        *        2 *      -7.8*   -40.9 *          0 ***********           *    YNNNUUUNN    *
*            *                             *          *          *         *            *          *           *                 *
*            *                             *          *          *         *            *          *           *                 *
* HIKPOH0027 * PAIA                        * 20 53.3  *  IH      *       0 *        800 *      2800*        0  *                 *
*          5 * MAUI           WAILOA DITCH * 156 20.4 *  OP      *       0 *          0 *         0*        0  *                 *
*            * HAWAIIAN COM   SUG CO       *          *         0*   260.0 *        800 *      2800*           *                 *
*            *                             *          *          *         *            *          *           *                 *
**********************************************************************************************************************************
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Project Listing(continued)

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**********************************************************************************************************************************
*   SITE ID  *        PROJECT NAME         * LATITUDE *PROJ.PURP.* DAM HT  * EXIST.CAP. *EXIST.ENRG*ANUL. COST *  ENVIRONMENTAL  *
*            * PRIMARY CO. -NAME OF STREAM *LONGITUDE *  STATUS  *TOT. STOR* INC.  CAP. *INC.ENERGY*ENERGY COST*   IMPACT CODE   *
* DEP   ACTV *            OWNER            * DR.AREA  *  AVE. Q  *PWR. HD. * TOT. CAP.  *TOT.ENERGY*           *                 *
* CODE   INV *        MAP REFERENCE        * (D M.M)  *          *  (FT)   *    (KW)    *  (MWH)   * (1000 $)  *                 *
*            *                             * (D M.M)  *          * (AC FT) *    (KW)    *  (MWH)   *  ($/MWH)  *     SOCIAL      *
* POWER AREA *                             * (SQ.MI)  *    (CFS) *  (FT)   *    (KW)    *  (MWH)   *           *   IMPACT CODE   *
**********************************************************************************************************************************
* HI5POH0025 * WAIHEE                      * 20 56.3  * H        *    10.0 *          0 *        0 *   11652   *     NNYYUUN     *
* I        2 * MAUI           WAIHEE RIVER * 156 32.8 *          *       0 *        730 *     2000 *   5826.0  *                 *
*            *                             *        3 *      58.0*   240.7 *        730 *     2000 *           *    YNNYUYUUU    *
*            * WAILUKU QUAD                *          *          *         *            *          *           *                 *
**********************************************************************************************************************************
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NHS MAPS

Two maps are inserted into the adjacent pocket. One is an index map and one is a site location map. The primary purpose of the index map is to show the National Electric Reliability Council (NERC) regions, the Corps of Engineers division and district boundaries, and Corps office locations. A separate regional report and accompanying site location map has been prepared for each of the NERC regions depicted on the index map.

The second map shows existing and potential hydroelectric site locations for the subject region and is intended to provide general information to the reader about the sites. The size of a project is depicted by the diameter of the circle and the type of project by color. Each site symbol on the map is labeled with a four digit number which corresponds to a ten character National Hydroelectric Power Resources Study site identification code. Each part of the 10 character ID code helps to narrow down the source of information for that site. For example, a typical site identification code is shown below:

```
                OR  A  NPP  9999
                 |  |   |     |
          State -┘  |   |     └-- Site ID Number
Type of Project ----┘   └-------- Corps Division and District
```

Consequently, for more information about a site, one needs to determine from the map a site's state and county, the Corps division and district, and the four digit number. With the site ID number, the site can then be located in the list of sites in the regional report or in Volume XII of the NHS final report. If more detailed information is desired, the appropriate Corps division and/or district office may be contacted.

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