SUMMARY REPORT
FOR
HYDROELECTRIC POWER
STATE OF HAWAII

US ARMY ENGINEER DISTRICT
HONOLULU, HAWAII

OCTOBER 1978

SYLLABUS

The purpose of this general survey investigation was to establish the feasibility and extent of Federal participation in the development of hydroelectric power in the State of Hawaii. This summary report provides reconnaissance-level information on the formulation and evaluation of hydroelectric power facilities for several sites located on the islands of Kauai, Molokai, Maui, and Hawaii. The report terminates the intermediate stage of the feasibility or survey investigation.

Drainage areas investigated included the Hanalei River on Kauai for both storage and run-of-the-river project concepts. Also investigated for the run-of-the-river concept were the Wainiha and Lumahai rivers on Kauai, Pelekunu Stream on Molokai, Waihee Stream on Maui, and Wailoa River (Waipio Valley) on Hawaii. Evaluation of the alternative sites indicated the plans are economically infeasible at this time as the benefit-to-cost ratios do not exceed 0.5 for any site. The conclusion at this stage of investigation is that the physical resources of the drainage areas in Hawaii are insufficient for cost effectiveness and significant energy production. Based upon these findings, the District Engineer recommends that the existing investigation of hydroelectric power in the State of Hawaii under the authority of Section 209 of the 1962 Flood Control Act be discontinued at this time.

SUMMARY REPORT
FOR
HYDROELECTRIC POWER
STATE OF HAWAII

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION A

THE STUDY AND REPORT

SECTION A

THE STUDY AND REPORT

PURPOSE AND AUTHORITY

1. Purpose. The purpose of this study was to determine the advisability of Federal participation for hydroelectric power development in the State of Hawaii.

2. Authority. This study was conducted under the authority of Section 209 of the River and Harbor and Flood Control Act of 1962 (Public Law 87-874). The section authorizes the Secretary of the Army to direct the Chief of Engineers to study water and related resource problems in the harbors and rivers in Hawaii and to recommend to the Congress the extent to which the Federal Government should participate in the construction of the recommended solutions. In addition, this study is in compliance with Section 167 of the Water Resources Development Act of 1976 (Public Law 94-587) which authorizes the U.S. Army Corps of Engineers to undertake feasibility studies of hydroelectric power resources.

STUDY AND REPORT SCOPE

3. Study Scope. The study was conceived as a feasibility study for the implementation of a hydroelectric power facility in Hawaii. The investigation followed the regulations of the U.S. Army Corps of Engineers for planning of water resources and hydroelectric power development. Provided the study resulted in a recommendation for potential Federal action, the findings would be submitted for possible Congressional project authorization. In the overall study there were three stages: Plan of Study (Stage I), Intermediate Plan Development (Stage II), and Detailed Plan Development (Stage III). The final document planned to be produced at the conclusion of Stage III would have been the Interim Survey Report and Environmental Statement.

4. Report Scope. This report documents the reconnaissance level investigations conducted during the initial two portions of the Intermediate Plan Development Stage. The scope included screening various sites based upon generalized technical, economic, and environmental factors. Following the first screening, the best sites were evaluated in terms of site-specific reconnaissance-level studies. The main text of the report summarizes the findings of the Stage II investigations. Appendix 1 contains technical data on each site. Appendix 2 contains pertinent correspondence.

PRIOR REPORTS

HYDROELECTRIC POWER, STATE OF HAWAII

5. In 1976 the Honolulu District, Corps of Engineers initiated the present study. This initial effort resulted in completion of the Plan of Study (POS), dated September 1977.[1/] The purpose of the Plan of Study was to develop a management plan for future investigation, to delineate public concerns and planning objectives, and to document the problem analysis and data gaps. The POS proposed a four-year effort for the initial Interim Survey Report.

KOKEE WATER PROJECT

6. Culminating in a 1964 report, the State of Hawaii's Department of Land and Natural Resources (DLNR), in cooperation with the U.S. Department of the Interior, Bureau of Reclamation, proposed the Kokee Water Project.[2/] The proposed construction called for a 32,000 acre-foot storage reservoir impounded by a 240-foot high earthfill dam on the Kawaikoi Stream, a tributary of Waimea River, island of Kauai (Figure C-4). Water would outlet through existing and improved irrigation ditches. A portion of the water would be diverted to a 13,700-foot long penstock with a drop of 1,000 feet into a 10,000 kilowatt capacity powerhouse. The project included the multipurpose features of power, irrigation, fish and wildlife enchancement and recreation. Approximately 59 percent of the project first cost of $19 million was allocated for power. The project has since been deferred principally because of lack of Federal funding.

WAIALEALE WATER STUDY

7. As an outgrowth of the growing interest in alternative energy sources for Hawaii, the State of Hawaii, Department of Land and Natural Resources has completed a draft feasibility report for a dam/reservoir hydroelectric power project in the Wailua River basin, island of Kauai, Hawaii (Figure C-4)[3/]. The selected plan, among alternatives investigated, was a 225-foot high earth embankment dam, impounding a 61,000 acre-feet reservoir. The structure was proposed to be located in the mid portion of Wailua River drainage area at the confluence of several streams leading to the South Fork Wailua River. Hydroelectric facilities included a 22,700-foot long penstock terminating in a 9,200 kilowatt powerhouse. The total project

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[1/] U.S. Army Engineer District, Honolulu, Plan of Study for Hydroelectric Power and Allied Purposes, State of Hawaii, September 1977.

[2/] State of Hawaii, Department of Land and Natural Resources, Division of Water and Land Development, Kokee Water Project, Report R22, 1964.

[3/] State of Hawaii, Department of Land and Natural Resources, Division of Water and Land Development, Multipurpose Dam Project in the Wailua River Basin, draft report, April 1978.

cost was estimated to be $72 million. The benefits were derived almost entirely from energy of the 50 million kilowatt hours produced. Although other purposes were investigated, the only other significant purpose was flood control, furnishing only about 3 percent of the benefits. The State does not plan on conducting additional engineering studies because of the low benefit-to-cost ratio of 0.3.

STUDY COORDINATION

AGENCIES

8. During the State II planning process, close coordination was maintained with the local project sponsor, the State of Hawaii, Department of Land and Natural Resources. The values of alternative sources of energy were obtained from the Department of Energy, Federal Energy Regulatory Commission (FERC). Agencies contacted during this period are shown in Table A-1.

Table A-1. STATE II KEY COORDINATION AGENCIES

Federal

Department of Energy
- Assistant Secretary for Energy Technology
  - Low-Head Hydroelectric Power Development Program
- Federal Energy Regulatory Commission (FERC)
- Western Area Power Administration

Department of the Interior
- Fish and Wildlife Service

State of Hawaii

Senate Committee on Energy/Natural Resources

Department of Budget and Finance
- Public Utilities Commission

Department of Land and Natural Resources
- Division of Water and Land Development

Department of Planning and Economic Development
- State Energy Office

County of Kauai

Office of Economic Development

Utilities and Others

Citizens Utility Company, Kauai Electric Division

Hawaii Electric Light Company

Kauai Energy Self-Sufficiency Committee

MEETINGS

9. Several informal meetings were held to present the status of the study. On 17 December 1977 the Corps participated in the Kauai Energy Fair, at the Kauai Community College. The purpose was to provide citizen participation on relevant energy programs in the State. The Corps returned to Kauai Community College on 23 May 1978 for an energy workshop sponsored by the Kauai Energy Self-Sufficiency Committee. The program consisted of status reports on hydroelectric power development by the State of Hawaii and the Corps of Engineers. The results of this survey investigation have been discussed with officials of the State Department of Land and Natural Resources, Division of Water and Land Development.

SECTION B

PLAN FORMULATION

SECTION B

PLAN FORMULATION

PLAN RESPONSIVENESS

NATIONAL OBJECTIVES

1. The development and evaluation of water resources development plans are based on planning policies established by the U.S. Water Resources Council, pursuant to Section 103 of the Water Resources Planning Act (Public Law 89-90). This set of policies, known as "Principles and Standards" (P&S) established two national objectives for water and related land planning: National Economic Development (NED) and Environmental Quality (EQ). The NED objective is to enhance national economic development by increasing the value of the Nation's output of goods and services and by improving national economic efficiency. The EQ objective is to enhance the quality of the environment by the management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural and cultural resources and ecological systems.

STATEMENT OF PROBLEM

2. Currently and in the foreseeable future, the State of Hawaii will be almost wholly dependent upon imported petroleum products for generation of power in the public utility system. The purpose of this study was to investigate the utilization of more significant hydroelectric power than presently is in existence. The development of this source of power could increase the energy self-sufficiency of the islands.

PLANNING OBJECTIVES

3. The planning objectives were established by identifying specific components of the needs and problems that are consistent with the national objectives. These planning objectives were as follows:

Objective

a. Increase the energy self-sufficiency of the State.

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

c. Enhance the stability of streamflows in consideration of affected ecosystems.

d. Provide efficient and effective use of lands in the designated project sites consistent with the socio-economic desires of residents.

ALTERNATIVE MEASURES

4. As stated in the Plan of Study, there were two basic generating systems considered, run-of-the-river and storage hydropower.

RUN-OF-THE-RIVER

5. A run-of-the-river system for hydropower development operates on instantaneous streamflow. The flows are diverted to a power plant by means of a diversion system with limited pondage. The head to be developed depends on the difference in elevation between the diversion point and the power plant location. Power generated by a run-of-the-river system depends on streamflow fluctuations and may not be significant nor dependable during low flow periods.

STORAGE

6. Storage measures consist of either a dam and reservoir or pumped storage.

a. Dam and Reservoir. A dam and reservoir system consists of a dam to store water, outlet structures to regulate flow, and power plant. The power plant may be located at the base of the dam or further downstream to obtain the necessary head. Power generated by a dam and reservoir system is generally dependable provided there is sufficient reservoir storage capacity.

b. Pumped Storage. A pumped storage system consists of upper and lower reservoirs and a power plant with both pumping and generating capacities. Power is generated by release of water during peak power demand periods from the upper reservoir. The upper reservoir is replenished by water pumped from the lower reservoir during low demand or off-peak periods. The water released by the powerhouse may be returned either to the lower reservoir or to the nearby stream. The pumping power is supplied from other generation sources, usually steam plants using coal or nuclear fuel systems.

RECONNAISSANCE SCREENING CRITERIA

GENERAL

7. As corollaries to the national and study planning objectives, criteria were established within each major study discipline. This set of criteria served to form a basis for selecting a site or sites warranted for additional study. The items of consideration included engineering, economic, environmental, and social factors. Since the basis purpose of the project was to investigate the feasibility of hydroelectric power potential, efforts were initially centered on investigating single-purpose hydropower. If this feature were demonstrated to be near-feasible, then other features (such as water supply, recreation, flood control) would be incrementally added, depending on the specific needs in the area of development.

CONSTRUCTION/INSTITUTIONAL FRAMEWORK

8. The basic premise under which all planning investigations were performed is that the implemented plan would be designed and constructed by the U.S. Army Corps of Engineers. Pertinent laws, regulations, and policies of the Corps and the Federal Government were assumed to be applicable for the selection and evaluation of potential plans.

9. Private Facilities. The proposed plan must benefit the public at large. Construction of new hydroelectric plants or modification of existing plants which primarily benefit private interests were not considered. All of the existing hydroelectric plants and over 80 percent of the existing dams and reservoirs in Hawaii are under private control. However, for initial project scoping purposes, all gaged streams and ditches were evaluated.

10. Existing Water Use. All existing water uses were assumed to be maintained. Although surface water legal rights have not been completely defined in Hawaii, the basic assumption is that the historical flow distribution will remain basically constant in the future. In addition, the existing diversions and ditch flows, particularly for private agricultural systems, were assumed to remain unchanged.

ENGINEERING CONSIDERATIONS

11. Power Determination. The development of power is directly proportional to two physical quantities: the stream discharge (or flow rate) and the effective net head (or difference in elevation). For a given power capacity, a low sustained discharge may potentially be offset by a high head. The result may be a long closed pipeline or penstock for water transmission. In contrast, for a given power capacity, a low head drop requires a high discharge. The construction implications are large structures and conduits to control of flows.

12. Hydrology. The streamflows in Hawaii originate from relatively small drainage areas generally on the order of 5 to 30 square miles. This characteristic combined with climatology and geology result in a small number of streams exhibiting significant perennial flows. Also for hydropower development, the key factor is assurance of firm or dependable power, which is directly relatable to streamflow.[1/] In hydrologic studies, the critical period of historical flow is evaluated to determine the value of dependable power. The basic criterion employed in the study was that only perennial streams/ditches would be considered.

1/ There are only eight gaged stream locations with a minimum discharge exceeding 10 cfs: Wailoa River (island of Hawaii); Hanalei River, Hanapepe River, Lumahai River, Wainiha River (all on island of Kauai); Hanawi Stream and Waihee Stream (both on island of Maui); and Pearl Harbor Springs (island of Oahu).

13. Geology. 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 occurrences of pyroclastics comprising the majority of the rock types. The decomposition of lavas and pyroclastics results in the residual, lateritic soils found blanketing most of the islands. Initial investigations included site investigations, and a review of past data including seismological, hydrological, drill boring logs, previous geological mapping and other studies applicable to the problem. The synthesis of the material resulted in a preliminary geological evaluation of sites for the siting of hydroelectric power facilities.

14. Topography. 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 and traverse through alluvial areas. The basic criteria in siting potential project features were:

a. Site the diversion/dam structure at the mid or lower portion of the drainage area to include the largest area contributing to streamflow.

b. Site the diversion/dam structure at a constricted or narrow portion of the stream topography. This consideration would minimize the extent of the structure and for potential reservoirs, may result in larger impoundment volumes.

c. Route the penstock on the most level portion of the bank area to minimize construction cost and to facilitate accessibility.

d. Site the powerhouse in a downstream area not subject to known flood inundation.

ECONOMIC CONSIDERATIONS

15. For economic feasibility, the benefits accruing from project implementation must exceed costs for implementation. In the case of hydroelectric power development, there are several economic measures which will be described subsequently in Section D. However, the basic principle is that the proposed system should be less costly than any existing power system, in this case a petroleum fueled power plant. The overall economic criterion is composed of the following elements:

a. The measurable economic value provided by the project must exceed project economic costs.

b. Each separable project function (e.g., hydropower, water supply, flood control, etc.) must contribute benefits greater than its costs.

c. The project should be scaled to maximize the net benefits.

ENVIRONMENTAL CONSIDERATIONS

16. The evaluation of potential environmental impacts of any proposed hydroelectric facility is critical to the determination of overall feasibility. Generally, the effects may be categorized in terms of (a) impact on biological species or habitat, (b) impact on special protected environmental/administrative areas or (c) impact on the physical use of water or land resources. The proposed project feature may adversely affect many of the specific values. The magnitude of adverse impacts will influence the evaluation and selection of the plan. The items in Table B-1 constitute the values required for environmental assessment.

Table B-1. ENVIRONMENTAL VALUES

Fish and Wildlife Values

- Listed or proposed endangered or threatened species and/or critical or essential habitat
- Commercial and recreational fishery resources and use
- Natural intrinsic value of stream (abundance and diversity of endemic aquatic fauna)
- National Wildlife Refuges
- National Reserve areas (State of Hawaii)
- State and National Forest Reserve
- Estuarine sanctuaries

Historic, Scenic and Recreational Values

- Historic and archeological resources
- County, State or National Parks
- Wild and Scenic Rivers
- Recreational resources and uses

Water Resources Values

- State watershed areas
- Prime recharge areas
- Agricultural use
- Proposed uses under water quality standards

SOCIAL CONSIDERATIONS

17. Social acceptability and well-being are based on the expressed views of interested or affected public, non-Corps of Engineers entities. The public includes all interested Federal and non-Federal agencies (with special emphasis on the local sponsoring agency), other public and private organizations, residents of the designated area, and individuals.

18. Items of social well-being include intangible factors of maintenance or enhancement of health, safety, and community well-being. The determination of fulfillment of social well-being considerations consists of input and evaluation emerging from the public participation program.

SCREENING PROCEDURES

PURPOSE

19. The purpose of the screening procedures was to define the most suitable areas for more detailed analysis and then define within those areas the most suitable hydropower measure. The Plan of Study defined the drainage areas for consideration. In each screening, the primary test was economic evaluation. Benefits were derived from data provided by FERC. Areas which were considered obviously unsuitable from an environmental basis were eliminated at each screening stage depending on the level of information. Social acceptability issues would be addressed following the second screening if there were clear candidate sites for future analysis.

SCREENING CHARACTERISTICS

20. The Stage II Intermediate Plan Development considered investigation of sites and measures in three screenings. The first screening was based on examination of broad based power potential, gross costs, and benefits without site analysis. The second screening considered site-specific characterisitics and approximate quantities. The third screening would have included more detailed hydrologic studies, design, and other technical data acquisition on two to three selected sites/plans. The final result of the Stage II process would have been a priority list from which one site/plan would be investigated in greater depth for feasibility determination. The final or third screening was not undertaken because of the findings of the second screening.

SECTION C

ENGINEERING EVALUATION

SECTION C

ENGINEERING EVALUATION

POWER POTENTIAL INVENTORY

PLAN OF STUDY DATA BASE

1. The data base was derived from the list of gaged streams indicated in the Plan of Study. The study was limited to the island of Kauai, Oahu, Molokai, Maui, and Hawaii since the other islands of Lanai, Niihau, and Kahoolawe have no perennial streams. Two types of development were considered for these sites: dam/reservoir storage and run-of-the-river with no storage. An estimate of power for hydropower development was made without determination of physical or economic feasibility to produce the power. This preliminary estimate was based purely on the power being a function of discharge from streams and the effective net head and an assumed turbine/generator efficiency.

STORAGE TYPE

2. For a storage type of development, the average discharge and a uniform net head for all sites were assumed for computation of the power potential. The average discharge was used as an initial estimate for the regulated flow. A net head of 150 feet was used for comparative power potential. Table C-1 is a list of stream gage locations considered to have the highest magnitude of power potential.

Table C-1. POWER POTENTIAL FOR SELECTED AREAS: STORAGE TYPE[1/]

Island	Stream	USGS Gage No.	Power Potential, KW
Kauai	Hanalei	1030	2,500
	Wainiha	1080	1,600
	Waimea	310	1,500
Oahu	Waikele	2130	430
	Kahana	2965	400
Molokai	Pulena	4020	370
	Halawa	4000	320
Maui	Wàiloa Ditch	5880	1,900
	Koolau Ditch	5410	1,300
Hawaii	Wailuku	7040	3,100
	Honolii	7170	1,400

1/ At 100 percent plant factor.

RUN-OF-THE-RIVER

3. For a run-of-the-river type of development with no storage, the minimum daily flow of record and a net head of 100 feet were used to estimate the power potential. The power plant was assumed to be located at a considerable distance downstream of a diversion structure. Shown in Table C-2 is a list of stream gage locations with the highest magnitude of power potential.

Table C-2. POWER POTENTIAL FOR SELECTED AREAS: RUN-OF-THE-RIVER TYPE1/

Island	Stream	USGS Gage No.	Power Potential, KW
Kauai	Wainiha	1080	250
	Hanalei	1030	180
	Lumahai	1060	150
Oahu	Pearl Harbor Spring	2240	80
Molokai	Pulena	4020	30
Maui	Waihee	5120	230
	Hanawi	5090	90
Hawaii	Wailoa	7322	250

1/ At 100 percent plant factor.

FIRST SCREENING

4. The purpose of the first screening was to evaluate and reduce the number of potential drainage areas. A gross relationship between benefits and costs was determined for the two hydropower concepts.

GROSS COST DATA

5. The costs were estimated based on preliminary planning curves.1/ These unit cost curves are for new construction, updated from completed projects in the United States. For storage projects less than 7,000 KW, the cost factor is $5,300 per kilowatt of developed capacity. For run-of-the-river projects less than 3,000 KW, the cost factor is $4,400 per kilowatt of developed capacity.

1/ R. M. Towill Corp., Basic Data and Conceptual Planning for Hydroelectric Development in Hawaii, 1977.

BENEFIT DATA

6. The benefits were determined from the preliminary power values furnished by FERC (Appendix 2). The power values at the current Federal interest rate of 6-5/8 percent for the July 1977 price level were the base data.

SCOPING

7. To evaluate the magnitude of the project, a range of plant factors2/ was considered. For the storage concepts, plant factors of 20 percent and 90 percent were used to cover the potential range of project scope. For the run-of-the-river concept, plant factors of 70 percent and 90 percent were used.

COMPUTATION

8. The economic indicator used was the comparability ratio (CR).3/ Although the CR value is not the only measure of economic justification, its determination is a useful indicator of feasibility. For project justification, the ratio must exceed unity.

RESULTS

9. The first screening revealed that the benefits increase with increasing plant factor. The highest benefit per kilowatt-year (both capacity and energy components) occurred at the 90 percent plant factor. The capacity of plants in Hawaii (less than 10,000 KW) does not take advantage of economies of scale. As a result, the cost per unit of installed capacity remains a constant value within the range of capacities considered. Table C-3 shows a summary of the first screening.

Table C-3. FIRST CUT ANALYSIS: AREAS AND SCOPE FOR ADDITIONAL ANALYSIS

Type Facility	Island	Plant Factor (%)
Storage	Molokai	90
Run-of-the-River	Kauai	90
	Molokai	70,90
	Maui	90
	Hawaii	90

2/ The plant factor is the ratio of average load on the generating plant for a specified period of time to the capacity rating of the plant.

3/ Comparability ratio =

Total annual costs of the most likely alternative to hydropower at Federal interest rate ÷ Total average annual separable hydropower cost of the proposed facility at Federal interst rate

All storage facilities would not merit additional studies except possibly for Molokai. For the run-of-the-river concept at 90 percent plant factor, all islands except Oahu would require additional study; at 70 percent plant factor only sites on Molokai would merit study. The approximate annual costs were determined by converting the initial cost per kilowatt to an annual basis.[4/] The annual total power value, dollars per kilowatt for each island, was derived from FERC capacity and energy values.[5/] Figure C-1 shows the relationship between the annual total power value and the annual costs. As shown in this figure, projects at plant factors above the intersection of the total power value and the first cut cost lines were subject of potential study. This relationship serves to define the range of future alternatives and locations.

PUMPED STORAGE

10. After initial screening, the pumped-storage concept was deleted from further consideration. The pumped-storage concept is dependent on operating at low plant factors and availability of inexpensive off-peak power. The inexpensive off-peak power source[6/] is not available in Hawaii. The low capacity diesel and bunker fuel oil plants of the existing utilities are not suitable. Finally, pumped-storage plants are built at large scale to take advantage of cost-scale effects. As a guide, the minimum size considered is 100 MW (100,000 KW).[7/]

SECOND SCREENING

GENERAL

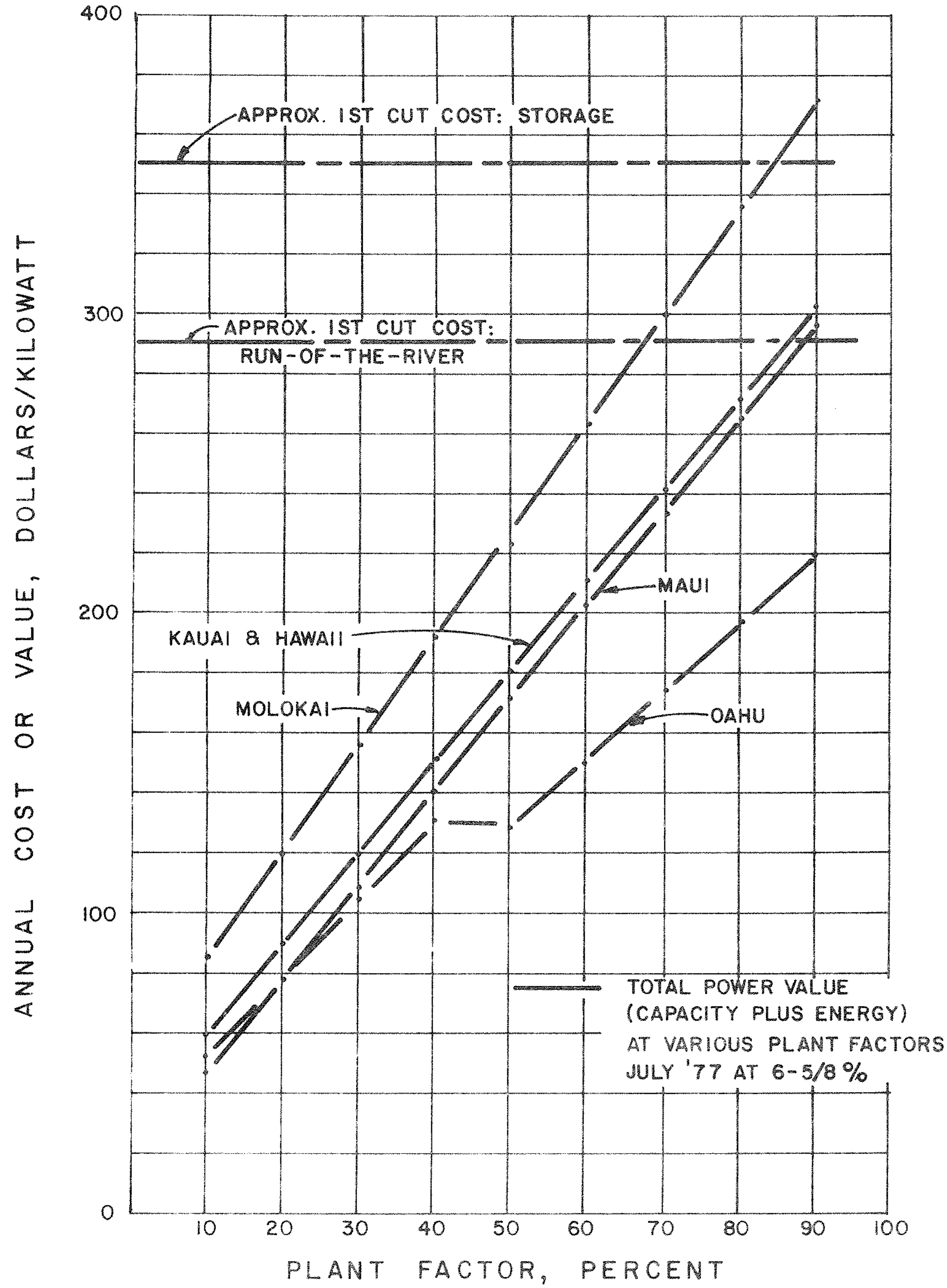
11. The second screening was a reconnaissance-level feasibility analysis based on site-specific characteristics. Following the generalized scoping in the second screening, a minimum capacity was established for site consideration. Basins with greater than 100 KW would be studied for dependable power from the run-of-the-river concept, and basins with greater than 300 KW would be studied for dependable power from the dam/storage concept. Table C-4 lists the basins and capacities that were considered. Figures C-4 through C-7 found at the end of this section, show the location of these basins.

4/ Annual cost/KW = initial cost/KW x capital recovery factor (at i = 6-5/8%, n = 100 yrs)

5/ See Section D, Economic Evaluation

6/ Characteristically, 3 units of pumping energy are required to produce 2 units of hydroelectric energy.

7/ Of the 48 pumped-storage plants in the United States either built, under construction, or planned, 42 exceed 100 MW.



SUMMARY REPORT
HYDROELECTRIC POWER

FIRST CUT ANALYSIS
TOTAL POWER VALUE
VS. PLANT FACTOR

U.S. ARMY ENGINEER DISTRICT, HONOLULU

FIGURE C-1

Table C-4. SITES FOR CONSIDERATION IN SECOND SCREENING

Type Facility	Island	Drainage Area	Gage USGS	Capacity KW[1]
Storage	Kauai	Hanalei[2]	1030	2,700
Run-of-the-River	Kauai	Wainiha	1080	280
		Hanalei	1030	190
		Lumahai	1060	170
	Molokai	Pelekunu[3]	4060	20
	Maui	Waihee	6120	260
	Hawaii	Wailoa (Waipio Valley)	7322	280

1/ All at 90 percent plant factor.

2/ Does not meet first screening criteria, but included because of higher power potential over other sites and specific recommendation by citizen groups.

3/ Does not exceed 100 KW, but is the most suitable site on Molokai.

AREAS DELETED FROM CONSIDERATION

12. Several drainage areas fulfilled the capacity requirements, but were deleted from consideration for various reasons. Pulena and Halawa Streams on the island of Molokai and Hanawi Stream on the island of Maui were deleted because of the highly sensitive environmental consideration. Pulena is an uninhabited, essentially pristine valley, and Halawa has a series of scenic waterfalls. Hanawi Stream is a spring-fed pristine stream with an abundance of aquatic fishlife and fauna and inhabited by species being considered for nomination to the National Endangered Species List. The three drainage areas contain sufficiently important aesthetic and environmental features deserving of preservation to warrant deletion from further consideration.

OTHER AREAS CONSIDERED

13. Ditch Systems. The State of Hawaii Department of Land and Natural Resources (DLNR) requested an investigation of hydropower potential be conducted for the existing ditch systems. One of the major ditch systems requested for specific consideration was the Kokee Ditch in Kauai. Among the ditch systems investigated, the Kokee Ditch in Kauai and the Honokohau Ditch in Maui best illustrate the hydropower potential of irrigation ditch systems in Hawaii.

14. Kokee Ditch. For the Kokee Ditch at USGS gage No. 140, a daily flow duration curve with 51-year record was constructed. The curve showed that 6 cfs was equalled or exceeded 90 percent of the time. This 90 percent flow of 6 cfs was used in estimating the power potential for the Kokee Ditch. The net available head was 982 feet, which was obtained essentially from utilizing the same drop in head as indicated in the 1964 State report.[8/] The power potential was estimated at 430 KW at a 90 percent plant factor. The cost and economic feasibility was determined as previously done for other potential sites in the second screening process. The comparability ratio was found to be 0.5, which is far below the point of economic justification.

15. Honokohau Ditch. In the case of the Honokohau Ditch system, head cannot be developed without adversely affecting required irrigation flow. If additional flows are diverted through a penstock to develop power, these flows (due to siting) cannot be returned for irrigation. This diverted flow is not compatible with irrigation. The problem with ditch systems for hydropower production is two-fold. First, lack of a large quantity of dependable flow as shown in the Kokee Ditch system. Secondly, when the ditches have a good supply of water, like the Honokohau Ditch in Maui, a conflict of water use exists.

SITE LAYOUT

16. The site layout for each system was based on consideration of topography, geology, accessibility, and attainment of sufficient developable head. The power plant sites were selected at sufficient elevations to avert flooding from heavy stream runoff. Geological Survey topographic maps were utilized to locate the facilities.

GEOLOGY

17. Geologic conditions were assessed by analyzing available geologic maps, references, and reports. Field work was performed for Wainiha and Hanalei Valleys in Kauai. In these locations, surface rock outcrops and landforms were identified.

8/ State of Hawaii, Department of Land and Natural Resources, Division of Water and Land Development, Kokee Water Project, Report R22, 1964.

FEATURES CONSIDERED

18. The main features considered for a run-of-the-river concept were the diversion structures, penstock, power plant, and access road. The main features considered for a storage concept were the dam, reservoir, spillway, penstock, power plant, and access road.

CRITERIA AND ASSUMPTIONS

19. Run-of-the-River Concept.

a. Flow estimates at diversion locations were prorated values based on the stream gage and the ratio of the respective drainage areas. The minimum daily flow of record constituted the base data.

b. A minimum release of 3 cfs was allowed for fish and wildlife preservation.

c. Flow velocity in penstock was specified at 5 fps for head loss computation.

d. Head loss was determined by the Darcy-Weisbach equation using steel pipe.

e. Power plants were located at the furthest practical point downstream to obtain the maximum available head.

f. Power potential was determined by the formula: $P = 0.073QH$, in which "Q" is the minimum firm flow of record (in cfs) and "H" is the net effective head (in feet). The equation assumed a turbine efficiency of 89 percent and a generator efficiency of 97 percent.

g. A plant factor of 100 percent was assumed for computation of the benefits. The 90 percent power values were applied to the energy production.

20. Storage Concept.

a. The criteria and assumptions for run-of-the-river with respect to flow estimate, flow velocity, power plant location, head loss analysis, power potential determination, and plant factor values were applied to the storage concept.

b. The sediment storage estimate was based on the same rate used in the Kaneohe-Kailua Dam project located in Kaneohe, Oahu. The rate of sediment accumulation was based on U.S. Geological Survey cooperative studies. The average sediment inflow to the reservoir was estimated at 0.64 acre-feet per square mile per year over a period of 100 years.

c. Storage yield analysis for the low flow period January-April 1934 was developed from daily flow records. Required storage was 6,900 acre-feet and sustained flow of 73 cfs.

d. The average power pool elevation was assumed at three-fourths of the power pool storage.

e. The spillway design was based on routing the probable maximum flood which was estimated to be 97,000 cfs for the 15.3 square miles Hanalei drainage area. The height of the dam was based on a spillway discharge coefficient of 3.9, a spillway crest width of 200 feet, and a freeboard of 5 feet.

f. The dam typical section was based on the Kaneohe-Kailua Dam project. Figure C-2 shows the assumed section.

OTHER FEATURES

21. The hydropower study was approached with the rationale that other multi-purpose features such as water supply, irrigation, flood control, and recreation would be considered in depth if economic feasibility were reasonably adequate to support storage development of hydropower at Hanalei Stream. The basin would be further examined for multipurpose development if the economic feasibility for hydropower was either marginal or greater than unity.

BASIS FOR COST

22. In determining economic feasibility, the cost was based on the following:

a. Power plant costs were based on preliminary planning curves developed at North Pacific Division, U.S. Army Corps of Engineers and updated to current price levels and low capacities. Figure C-3 illustrates the relationship of power plant costs to installed capacities.

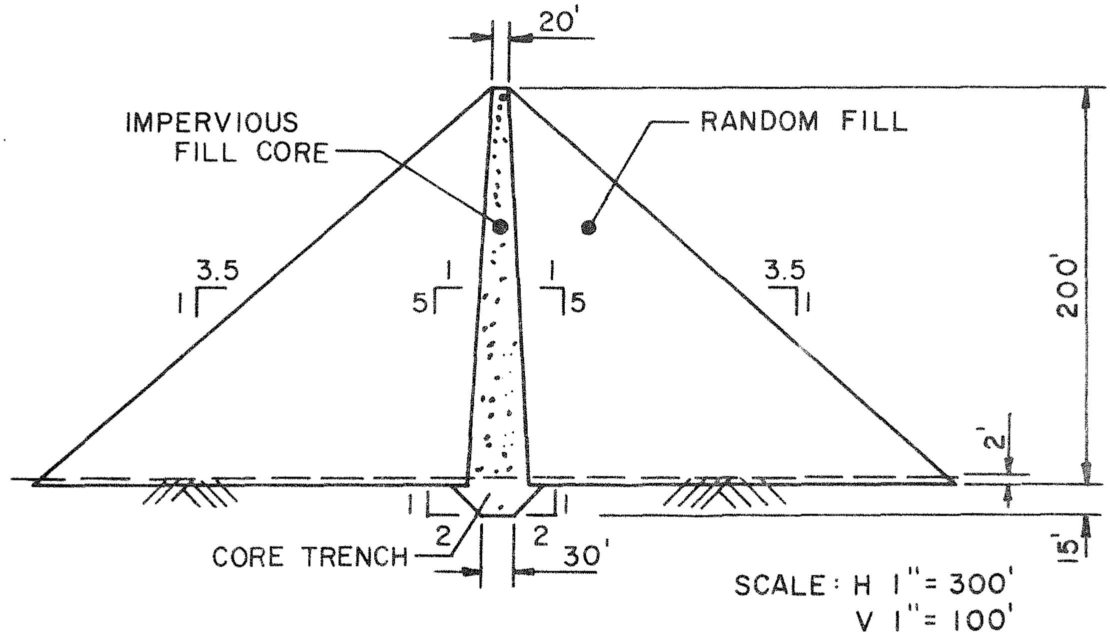
b. Penstock costs were based on the use of steel pipes.

c. Diversion structure costs were based on a typical low ogee crest structure as shown on Figure C-2.

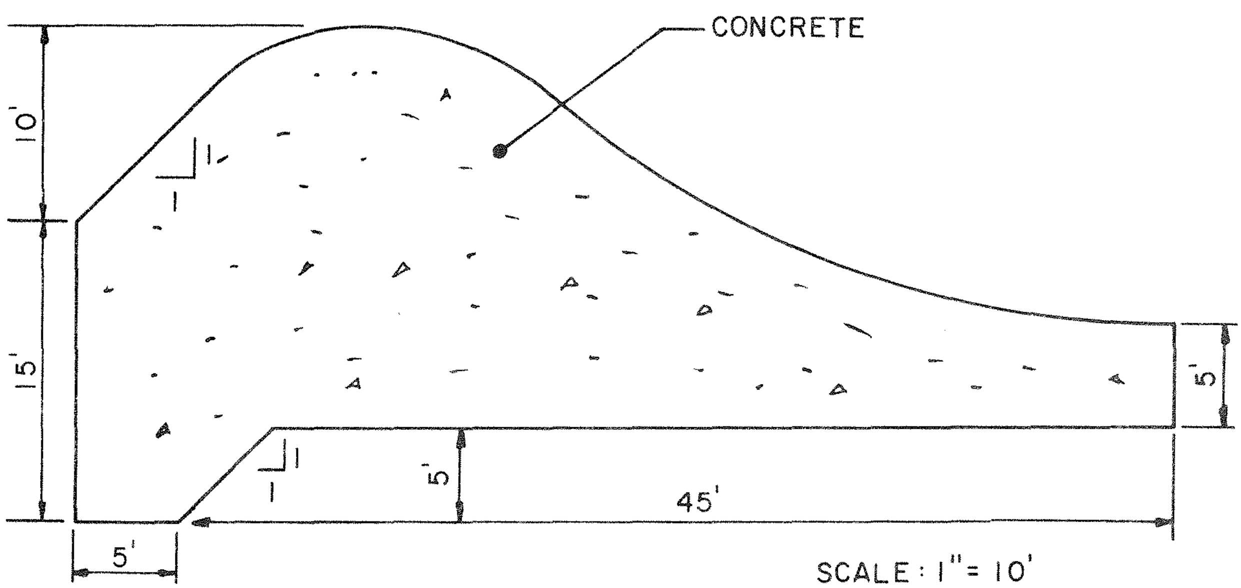
d. Access road costs were based on a 24-foot-wide road with coral surfacing.

e. The material for construction of the dam was based on availability and adequacy of material extracted locally near the reservoir and dam sites.

f. Land costs were based on a value of $20,000 per acre for conservation land and $30,000 per acre for agricultural lands. All project features were located on either conservation or agricultural lands. State government lands were assumed transferred for project purposes without cost.



TYPICAL DAM EARTHFILL SECTION



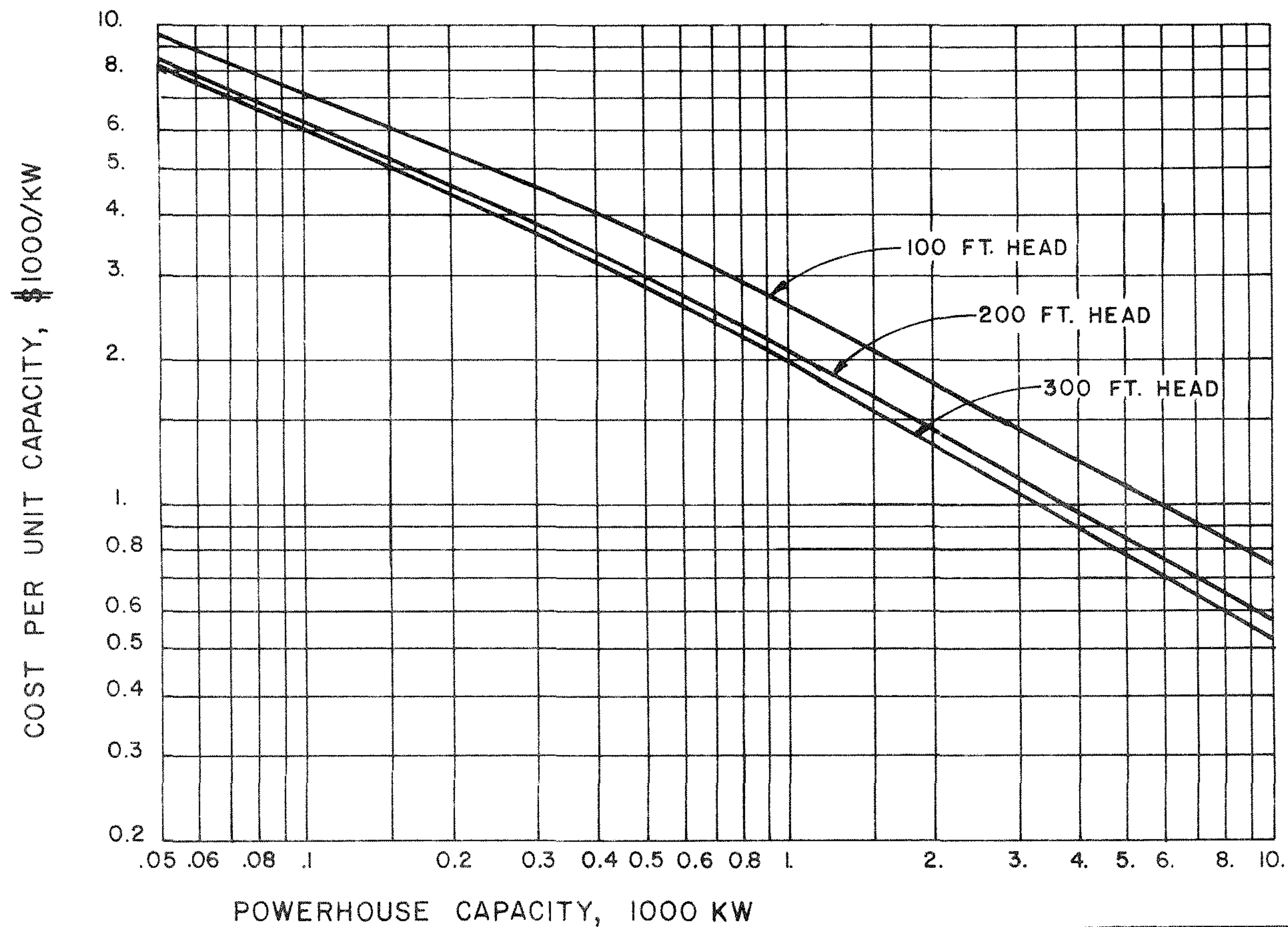
DIVERSION DAM

SUMMARY REPORT
HYDROELECTRIC POWER

TYPICAL SCHEMATIC
SECTIONS

U.S. ARMY ENGINEER DISTRICT,
HONOLULU

FIGURE C-2



NOTE:
INCLUDES TURBINES, GENERATORS, SITING, HOUSING, & SWITCHYARD.
PRICE LEVEL JULY 1977, HAWAII.
FOR RECONNAISSANCE PLANNING ONLY.

SUMMARY REPORT
HYDROELECTRIC POWER

POWERHOUSE COSTS
RECONNAISSANCE PLANNING

U.S. ARMY ENGINEER DISTRICT, HONOLULU

FIGURE C-3

FIGURE C-3

g. Operation, maintenance and replacement (OM&R) costs were based on Corps of Engineers guidelines. OM&R was estimated at 0.5 percent of first cost (excluding engineering and design) for run-of-the-river systems and 0.2 percent for storage systems.

h. A contingency of 25 percent over the construction cost was included in the project first cost determination.

i. A twelve percent factor was applied to the total construction value (including contingencies) for engineering/design and supervision/administrative costs.

j. Effective date of cost price level was July 1977.

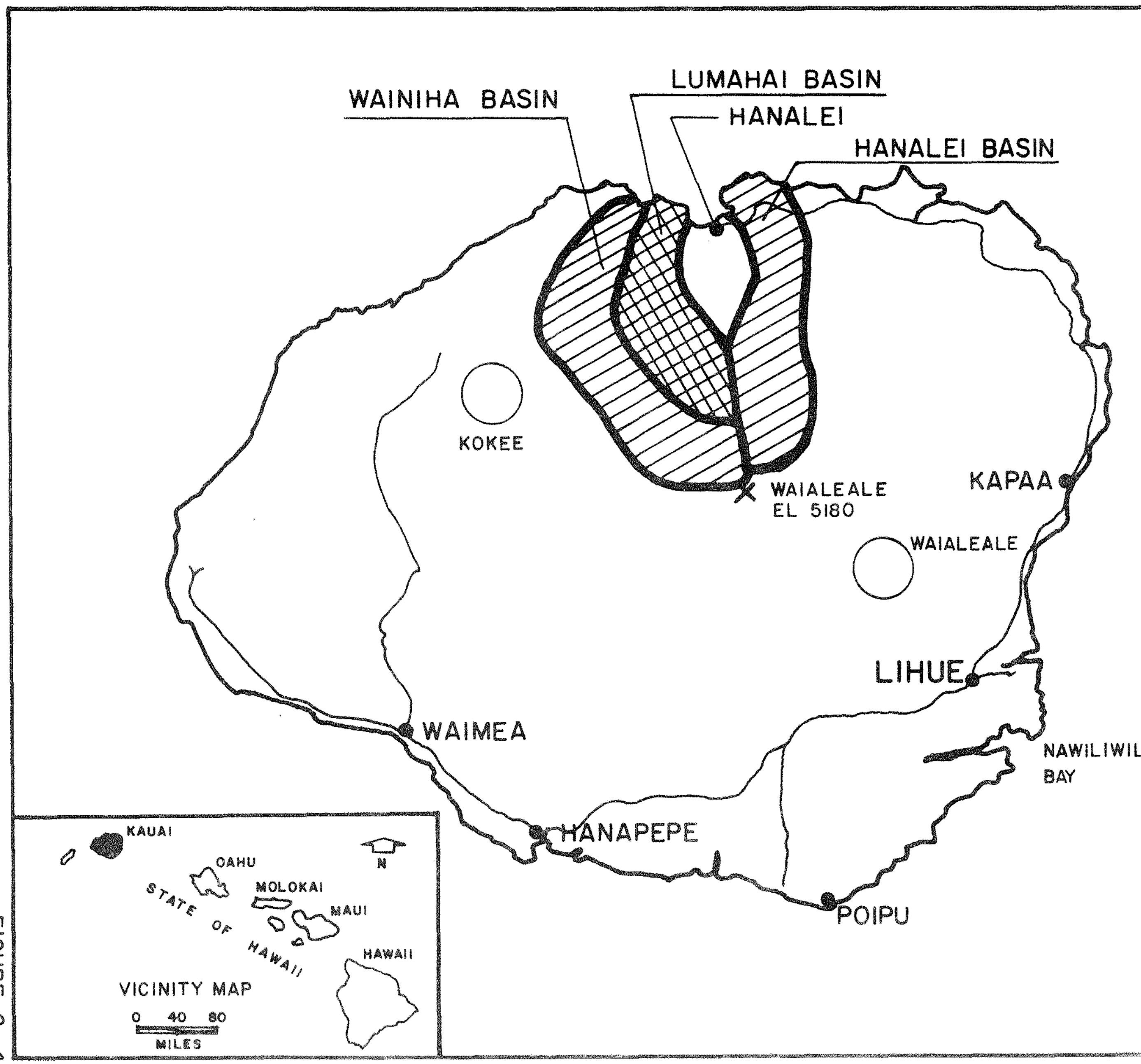
RESULTS

23. Storage. The Hanalei storage scheme would result in 1,400 KW capacity. The 193-foot-high earthfill dam would impound 11,800 acre-feet of storage. Approximately 6,900 acre-feet would be utilized for power, the remaining volume reserved for sediment and flood surcharge. Structural works would include an 8,000-foot-long penstock. The first cost was estimated to be $35 million. A summary of the site characteristics is shown in Table C-5.

24. Run-of-the-River. The run-of-the-river capacities ranged from a low of 30 KW at Pelekunu to a high of 590 KW at Lumahai. Effective heads varied from 189 feet to 312 feet and firm flows from 2 cfs to 31 cfs. The sites are roughly similar topographically except for the Wailoa River location. There does not appear to be a site characterized by a sharp drop and plentiful dependable flows. As a result, long penstocks are required from the diversion location. The first cost varied between $1.8 to $7.6 million.

Table C-5. ENGINERING RESULTS OF SECOND SCREENING

Type Facility and Island	Stream	Net Head (feet)	Flow (cfs)	Power (KW)	First Cost ($)
Storage					
Kauai	Hanalei	261	73	1,400	$35,000,000
Run-of-the-River					
Kauai	Wainiha	189	31	430	6,000,000
	Hanalei	263	9	170	5,600,000
	Lumahai	312	26	590	7,200,000
Molokai	Pelekunu	194	2	30	1,800,000
Maui	Waihee	241	20	350	4,000,000
Hawaii	Wailoa (Waipio Valley)	253	30	550	7,600,000



SUMMARY REPORT
HYDROELECTRIC POWER

LOCATION MAP
ISLAND OF KAUAI

U.S. ARMY ENGINEER DISTRICT,
HONOLULU

FIGURE C-

FIGURE C-4

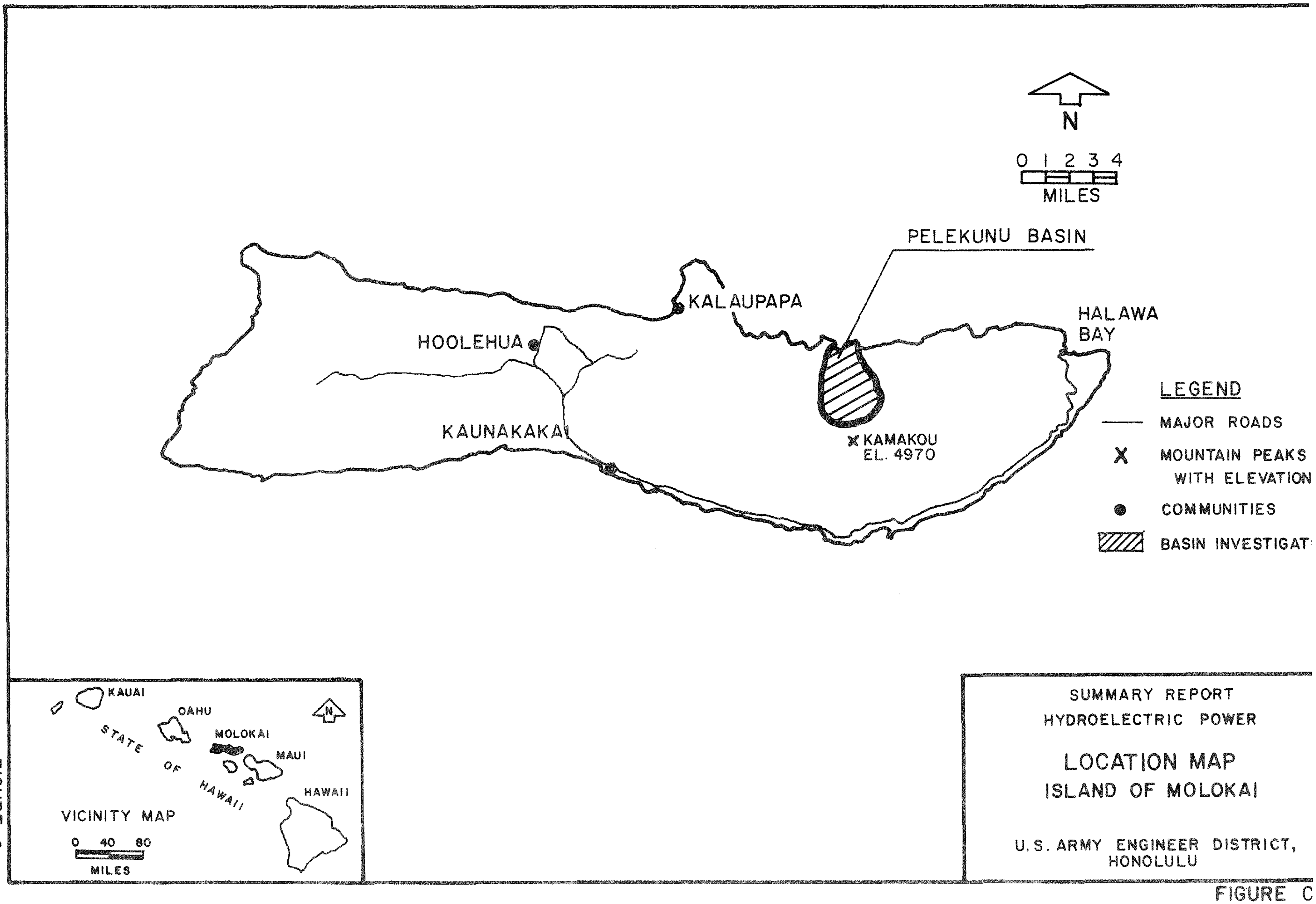
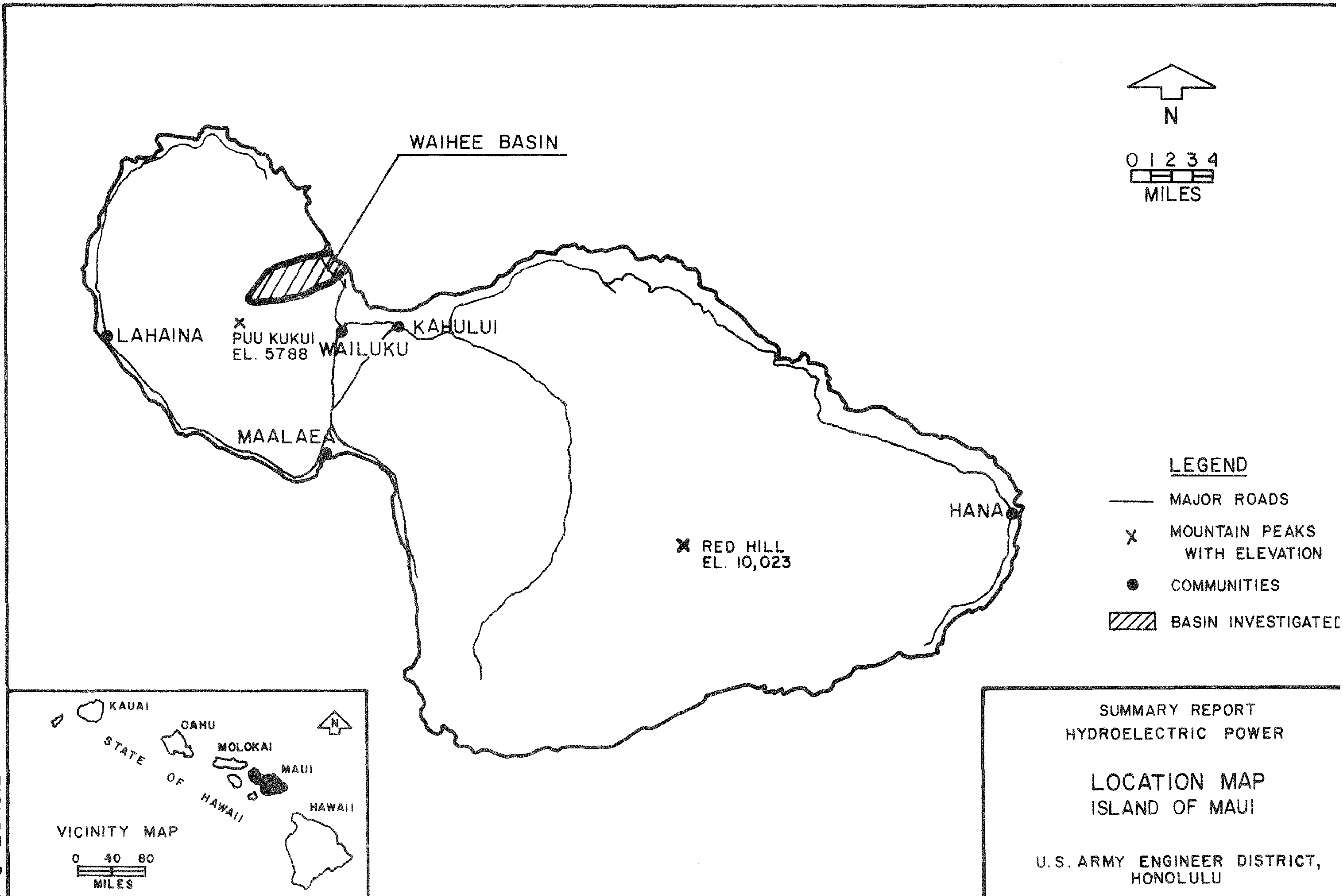

N
0 1 2 3 4
MILES
PELEKUNU BASIN
KALAUPAPA
HALAWA BAY
HOOLEHUA
KAUNAKAKAI
KAMAKOU
EL. 4970
LEGEND
MAJOR ROADS
MOUNTAIN PEAKS WITH ELEVATION
COMMUNITIES
BASIN INVESTIGAT
KAUAI
OAHU
MOLOKAI
MAUI
HAWAII
STATE OF HAWAII
VICINITY MAP
0 40 80
MILES
SUMMARY REPORT
HYDROELECTRIC POWER
LOCATION MAP
ISLAND OF MOLOKAI
U.S. ARMY ENGINEER DISTRICT, HONOLULU
FIGURE C

FIGURE C-5

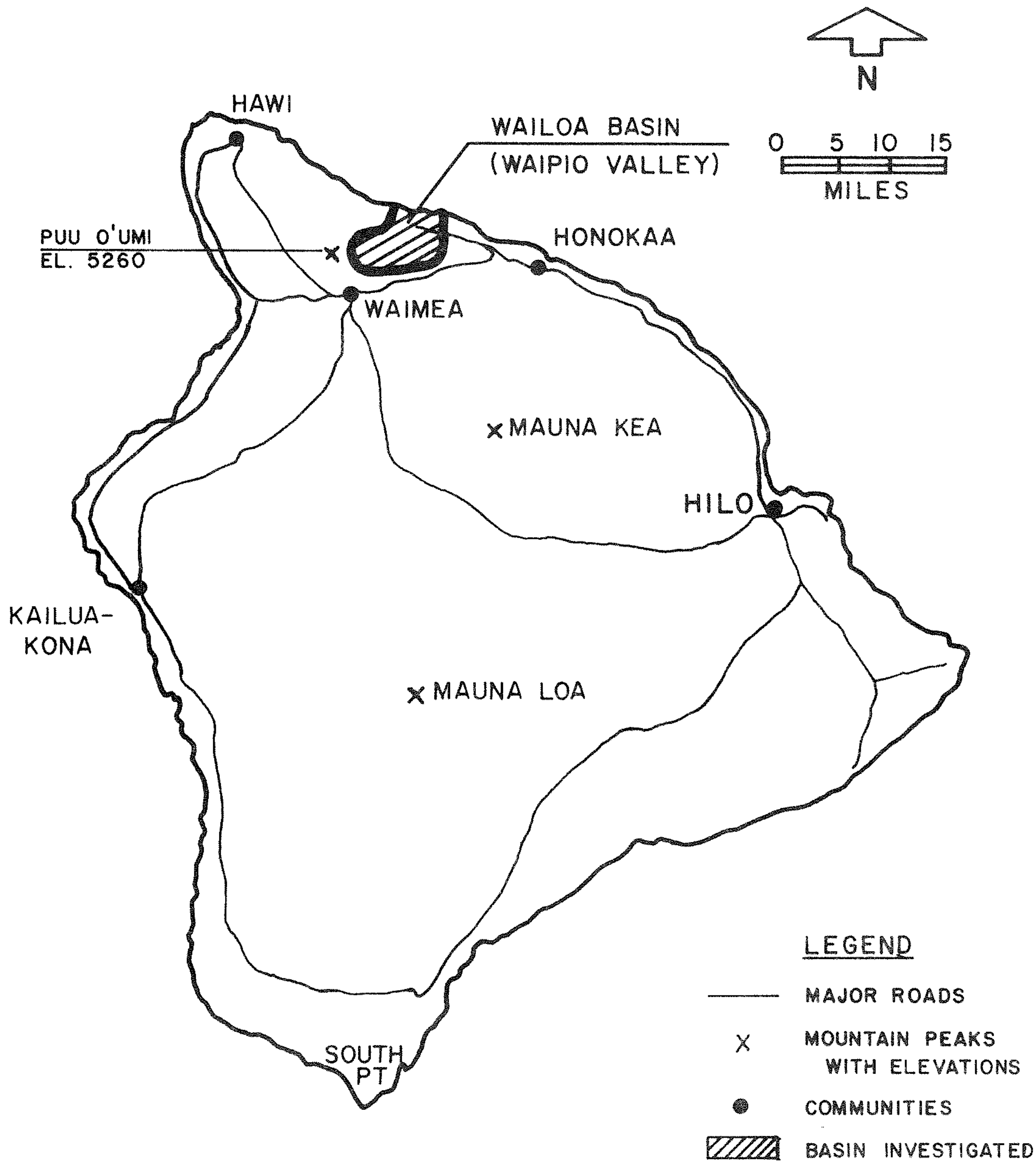


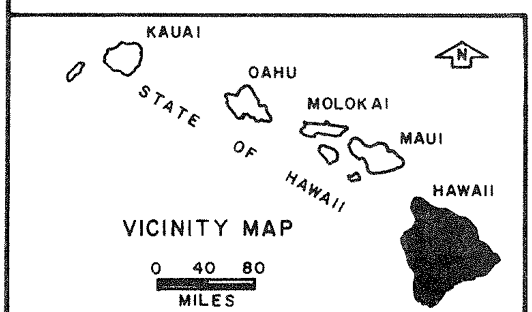
SUMMARY REPORT
HYDROELECTRIC POWER

LOCATION MAP
ISLAND OF MAUI

U.S. ARMY ENGINEER DISTRICT, HONOLULU

FIGURE C-6





SUMMARY REPORT
HYDROELECTRIC POWER

LOCATION MAP
ISLAND OF HAWAII

U.S. ARMY ENGINEER DISTRICT,
HONOLULU

FIGURE C-7

SECTION D

ECONOMIC EVALUATION

SECTION D

ECONOMIC EVALUATION

ECONOMIC TESTS

GENERAL

1. A hydroelectric power project must satisfy three economic tests for potential authorization and construction by the U.S. Army Corps of Engineers. These economic tests apply for projects whose primary purpose is hydropower development and those that encompass multiple purposes and for which hydropower is a minor function. In these matters, the Corps is responsible for the determination of benefits but by law and policy is required to obtain collaborating data and assistance from the Department of Energy's Federal Energy Regulatory Commission (formerly Federal Power Commission) and regional marketing agencies (formerly under the Department of the Interior). The three tests are the economic test, the comparability test, and the marketing test.

ECONOMIC TEST

2. The economic test consists of determining the relationships between hydropower benefits and project costs. These relationships are the difference between annual benefits and costs (termed net benefits) and the ratio of annual benefits to annual costs (benefit-to-cost ratio).

3. Benefits. The economic value or benefit is estimated as being equal to the cost of the most likely alternative sources of power in the absence of the hydropower project. Because the measuring criterion is the most likely alternative, the model for the alternative is usually the existing regional power system and provided the predominant source of power is from private sources, prevailing market discount rate for private financing is utilized.

4. Costs. Project costs include the initial capital investment and interest over the project life and the annual operation and maintenance expense. The cost used in the analysis are annual values at the Federal interest rate (since the Federal government will implement the project) over a life of 100 years (major water resource projects).

COMPARABILITY TEST

5. The comparability test is similar to the economic test in terms of the computational techniques. The important difference is that the analysis must demonstrate the effect of the least costly alternative source of power in the absence of the hydropower project.

6. Benefits. The comparability test benefits are derived from the same data base as compared to the economic test. The assumption is that for the near future, the least costly alternative source of power will continue to be the existing power system. The difference is that the Federal discount rate is utilized, based on the criterion that power should be supplied at the least possible cost to the consumer and that the Federal government invests in economically efficient projects.

7. Costs. The project costs are the same as the costs for the economic test.

SUMMARY OF ECONOMIC AND COMPARABILITY TESTS

8. For the conduct of this study the hydropower benefits were assumed to equal the preliminary power values furnished by FERC. The discussion of power values is shown in the succeeding section. As previously described, a key relationship is the ratio between the benefits and the costs. For economic justification, the ratio must exceed unity. The two tests are summarized using the following notation:

$$BCR = \frac{B_P}{C} > 1.0 \quad \text{(economic test : benefit-to-cost ratio)}$$

$$CR = \frac{B_F}{C} > 1.0 \quad \text{(comparability test : comparability ratio)}$$

in which:

B_P = equivalent annual cost of the most likely alternative power source based on non-Federal financing at 10 percent.

B_F = same as B_p except financing is from Federal sources. Discount rate is 6-5/8 percent established for FY 1978 by the U.S. Water Resources Council.

C = equivalent annual separable hydropower project costs, including initial investment, operation and maintenance, and any other costs, computed at the Federal interest rate, 6-5/8 percent.

B_P, B_F, and C are based on the same period of analysis, in this case 100 years.

9. Controlling measure. Since the only difference between the two tests is the discount rate in computing the benefits, the controlling test between the two tests is the comparability ratio. The numerator or value of benefits in the comparability ratio will in all cases be less than the corresponding value in the benefit-to-cost ratio.

MARKETABILITY TEST

10. The marketability test, or test of financial feasibility, requires that project costs allocated to hydroelectric power be repaid to the Federal treasury under an administratively established 50-year period. For Corps of Engineers projects, revenue requirements and repayment are administered by an agency of the Department of Energy (DOE). Initial coordination for this study was conducted with the DOE's Western Area Power Administration. Definitive analysis of market conditions were not conducted in this study. This test of marketability would normally be determined if economic feasibility were established and engineering plans completed to a degree sufficient for discussion with utility power companies.

POWER VALUES

GENERAL

11. Power values consist of two components: capacity value and energy value. The capacity value includes annual fixed charges on the capital investment and other non-variable costs such as fixed operation and maintenance, administration, fixed fuel inventory and fixed transmission capacity costs. The energy value includes all costs which vary directly with energy generation such as variable fuel costs, variable operation and maintenance, and transmission energy losses. The power values as derived by FERC are shown in Appendix 2. Both the capacity and energy values vary depending on the island energy system and the discount rate considered.

CAPACITY VALUE

12. The capacity value is expressed as one annual value, in dollars per kilowatt-year. The values for each island and discount rate are constant for the full range of potential hydropower plant factors. The capacity value is based on the single most likely lifetime average plant factor for the thermal alternative.

ENERGY VALUE

13. The energy value is expressed as an annual value, in mills per kilowatt-hour. Characteristically, this value increases with increasing hydropower plant factors. Hydroelectric installations at high plant factors (baseload) will reduce overall system generating costs to a larger extent than at low plant factors (peak load). In general, although hydropower facilities are suitable over the full range of varying system loads, there is no basis for the contention that a peaking power project is inherently more highly valued than base load power project. Depending on the characteristics of the most likely alternative power source, hydropower plants can economically supplant thermal systems for base load conditions.

TOTAL POWER VALUE

14. The total power value may be determined, based on the capability and plant factor of the hydropower plant under consideration. This "total value," expressed in terms of annual cost per unit capacity, is an increasing function of the plant factor. The typical relationship is illustrated in Figure C-1. The reason is the greater generation quantity (KWH) associated with the high plant factor. The "total value," expressed as cost per unit energy, decreases slightly with increasing plant factor, due to higher fixed system unit costs at low plant factors. The 90 percent plant factor values were applied to all sites analyzed. The total annual power value can be summarized by the following equation.

$$B = (KW) \left[(CV) + (PF) \times (8760) \times EV) \right]$$

in which:

B = annual benefit value, dollars using the appropriate interest rate.

KW = dependable capacity of the potential hydropower plant in kilowatts.

CV = capacity value, in $/KW-yr.

PF = plant factor of the potential hydropower plant (decimal). (8760 = number of hours per year)

EV = energy values, in $/kwh.

LAND

LAND USE

15. Land use for each of the seven alternative sites for the major components of penstock, power plant, and dam structure are summarized in Table D-1. Most of the property involved is presently conservation use land, with only a small amount of the land being used for agriculture. The area currently being used for agriculture is the Wailoa River area, located in Waipio Valley on the island of Hawaii.

Table D-1. LAND USE AND OWNERSHIP FOR ALTERNATIVE PROJECT SITES 1/

Island	Project Site 2/	Penstock Ownership	Penstock Land Use	Power Plant Ownership	Power Plant Land Use	Dam Ownership	Dam Land Use
Kauai	Wainiha	P	C	P	C	P	C
	Lumahai	P	C	P	C	P	C
	Hanalei	G	C	G	C	G	C
	Hanalei 3/	G	C	G	C	G	C
Molokai	Pelekunu	G - 1/3	C	P	C	G	C
		P - 2/3	C				
Maui	Waihee	P	C	P	C	P	C
Hawaii	Wailoa	G - 1/3	C	P	A	G	C
		P - 2/3	A				

1/ Predominant ownership and land use codes:

G - government; C - conservation; P - private; A - agriculture

Ownership data from Real Estate Atlas of Hawaii, 1977
Land Use information from State of Hawaii Land Use Districts and Regulations Review, 1971.

2/ Run of river project unless otherwise indicated.

3/ Storage project.

OWNERSHIP

16. All project sites were at least partially within private ownership except the Hanalei area. Generally ownership is consolidated in large ownership parcels except for the Wailoa and Pelekunu areas. All areas indicated as "government" in Table D-1 are owned by the State of Hawaii.

LAND COSTS

17. Detailed analysis of land value were beyond the scope of the reconnaissance studies. Acquisition costs were approximated at $20,000 per acre for conservation lands and $30,000 per acre for agriculture lands. State lands were assumed to be acquired without charge to the project. Costs varied from 0 to 10 percent of the total project first cost.

POTENTIAL ECONOMIC FEASIBILITY

HYDROPOWER DEVELOPMENT

18. As discussed in Section C, Engineering Evaluation, seven sites in Hawaii emerged from the screening process for further analysis. A summary of the basic data for these seven sites, along with results of the economic tests are displayed in Table D-2. As the data clearly show, none of the sites are economically feasible. The lack of feasible hydropower sites in Hawaii is due to a combination of small stream drainage basins with little potential for energy generation, and relatively high fixed costs. Economies of scale for hydropower project construction costs are not evident for the streams investigated.

MULTIPURPOSE DEVELOPMENT

19. Flood Control. An approximation of other separable benefits for the Hanalei River storage site was determined. A concurrent investigation of flood control improvements for Hanalei under the Continuing Authorities Program authorized under Section 205 of the 1948 Flood Control Act, as amended, indicated average annual flood damage reduction benefits of $175,000. These separable benefits could support an equivalent first cost of $2.6 million.

20. Water Supply. Domestic water supply for Hanalei is currently provided by the local system. According to the Kauai County Department of Water Supply, future needs will also be met by the existing water supply sources.

21. Recreation. An approximate first cut analysis of water based recreation for a reservoir was made under the following assumptions: the recreational demand is a function of the resident population and the characteristics of the demand for Kauai is similar to Oahu. Assuming 10 percent of the separable annual recreation benefits of the Kaneohe-Kailua, Oahu project[1/] can be achieved for Hanalei (the population of Kauai is

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1/ U.S. Army Engineer District, Kaneohe-Kailua Area Design Memorandum No. 2, January 1975

Table D-2. SUMMARY OF ECONOMIC ANALYSIS

Item/Type Facility	Storage	Run-of-the-River					
Drainage Area	Hanalei	Wainiha	Lumahai	Hanalei	Pelekunu	Waihee	Wailo
Power/Energy							
Plant Capacity, kw	1,400	430	590	170	30	350	550
Annual Generation1/ mil kwH	12.3	3.77	5.17	1.49	0.263	3.07	4.8
Cost2/							
Total First Cost, mil $	35.0	6.0	7.2	5.6	1.8	4.0	7.6
Annual Interest & Amort3/, $	2,322,000	398,000	478,000	372,000	119,000	265,000	505,0
Annual Oper & Main, $	58,000	22,000	32,000	23,000	11,000	25,000	35,0
Avg Annual Cost, $	2,380,000	420,000	510,000	395,000	130,000	290,000	540,0
Average Annual Benefit2/							
Private Financing4/, $	532,000	163,000	225,000	65,000	14,000	128,000	208,0
Federal Financing3/, $	464,000	142,000	195,000	56,000	12,000	114,000	182,0
Economic Tests							
Benefit-to-Cost Ratio	0.2	0.4	0.4	0.2	0.1	0.4	0.4
Comparability Ratio	0.2	0.3	0.4	0.1	0.1	0.4	0.3

1/ Plant factor 100 percent

2/ Benefits and costs based on 100-yr life

3/ Based on 6-5/8 percent discount rate

4/ Based on 10 percent discount rate

less than 5 percent of Oahu), the benefits would total approximately $90,000. This annual amount is equivalent to an approximate $1.4 million in first cost.

22. Based upon the reconnaissance level studies, the sum total of the separable flood control, water supply, and recreation benefits would not exceed $0.3 million. The addition of multi-purpose feature will not change the feasibility results for the Hanalei storage site.

POTENTIAL FINANCIAL FEASIBILITY

GENERAL

23. Although any hydropower project must pass the basic economic and comparability tests, perhaps the most significant criterion for potential feasibility of a project is the marketability test. The electrical generation produced by the project must be sold at a price to sufficiently recover project costs, at an appropriate interest rate and a given project life. Two key factors play a role in determining this marketability. First, the generation must be compatible with the appropriate market area demand both in location and time. Second, and perhaps more important, the cost of project power must be sufficiently competitive with power produced from alternative sources.

COMPATIBILITY WITH EXISTING SYSTEMS

24. The project magnitude was sufficiently low to consider that any hydroelectric energy produced would be readily absorbed by the existing utility system.

POTENTIAL PRICE RANGE

25. The project power must pass the basic benefit criterion of willingness-to-pay. For an initial determination of financial feasibility, a comparision may be made between the willingness to pay and the costs for electricity produced by hydropower projects in Hawaii. Table D-3 shows the range of electrical generation purchase price range of values potentially acceptable to utilities in Hawaii. These values have been applied in the analysis of a federal hydropower project. It is not likely that project energy rates significantly in excess of the range of 12 to 54 mills/kwh would be marketable.

Table D-3. POTENTIALLY ACCEPTABLE PRICE RANGE FOR THE SALE OF FEDERAL HYDROPOWER IN HAWAII

	mills/kwH [1]	
Source	High	Low
FERC [2]	54	36
Recent Financial Data for Utilities[3]	25	12

[1] $1 = 1,000 mills

[2] Computed from "Power Values for the State of Hawaii," for Oahu, Maui, Hawaii, Molokai, and Kauai, for plant factor = 90%. Furnished by FERC (See FERC letter dated 29 November 1977, pertinent correspondence)

[3] Computed from data contained in Pacific Analysis Corp, An Inventory and Analysis of the Electric Industry in the State of Hawaii, March 1977 and other data.

MINIMUM REPAYMENT

26. The repayment required at any project first cost may be determined, given a fixed period and interest rate. The required repayment in terms of dollars per unit energy is determined using the following equation:

$$C_K = \frac{C_I \text{ (CRF)}}{8760 \text{ (KW)(PF)}}$$

in which:

C_k = repayment cost per unit energy, \$/kwH

C_I = project cost, present value, \$

CRF = capital recovery factor at interest rate 6-5/8 percent and period of 50 years

PF = plant factor of designated hydroelectric plant (decimal)

KW = dependable capacity of hydroelectric plant, kilowatts

27. Based upon an assumed 100 percent plant factor (for maximum electrical generation), and various total project costs, minimum energy charges may be computed for a range of dependable capacities. Table D-4 shows representative values of minimum charge per energy to recover hydroelectric power project costs. The accompanying Table D-5 shows the estimated cost per kilowatt-hour for each of the seven sites.

Table D-4. HYDROPOWER COST PER UNIT ENERGY[3]

Million $		Cost Per Unit Energy mill/kwh at Various Dependable Capacities 1000 kw[1]			
Total Cost	Annual[2] Repayment Cost	.5	1.0	4.0	10.0
3.00	0.207	47.	24.	5.9	2.4
15.0	1.04	240.	120.	30.	12.
40.0	2.76	630.	320.	79.	32.

1/ Cost Per Unit Energy = $\frac{\text{Annual repayment cost}}{\text{kwh generated (100\% plant factor)}}$

1000 mills = $1.00

2/ 6-5/8%, 50 year life

3/ The concept is illustrated on Figure D-1

Table D-5. PROJECT COST PER KWH FOR FINANCIAL FEASIBILITY

Site	Annual Cost[1]	Energy[2] Generation KWH	Cost Per Unit Energy mills/kwh
Storage			
Hanalei, Kauai	$2,470,000	12,300,000	201
Run-of-the-River			
Wainiha, Kauai	436,000	3,770,000	116
Lumahai, Kauai	529,000	5,170,000	102
Hanalei, Kauai	410,000	1,490,000	275
Pelekunu, Molokai	135,000	263,000	513
Waihee, Maui	301,000	3,070,000	98
Wailoa, Hawaii	564,000	4,820,000	117

1/ From construction and O&M estimates, Table D-2.

50 year life and 6-5/8% interest rate

2/ From Table D-2.

24. The data displayed in Tables D-3 through D-5 is summarized in a single graphical display, Figure D-1. The shaded area represents the range of potential financial feasibility. Clearly all the sites investigated in this study fall outside the range of financial feasibility.

SENSITIVITY TO FUEL COSTS

GENERAL

29. The purpose of this analysis is to determine what escalation rate of fuel costs are required for economic justification of the projects investigated.

30. Inflation, or the general increase in prices, is typically not taken into account in Corps of Engineers benefit-cost studies. The implicit assumption is that the relative impacts of inflation and escalation on benefits and costs and on the discount rate are mutually offsetting. Furthermore, it is impossible to confidently forecast the long term inflation for any single cost item. However, fuel prices have risen significantly in recent years relative to the general economy.

RELATIONSHIP TO ENERGY VALUE

31. Fuel costs typically account for about 90% of the energy value component of the FERC power values. Table D-6 shows the percent of total unit power values accounted for by fuel costs, based on this assumption.

Table D-6. FUEL COST AS A PERCENT OF BENEFIT VALUE

	Fuel Cost as a % of Hydropower Benefit 1/	
Island	90% Plant Factor	10% Plant Factor
Kauai	64%	6%
Molokai	64%	10%
Maui	68%	4%
Hawaii	63%	6%

1/ Based on power values using non-Federal financing. Assumes fuel cost = 90% of energy value component of power value.

32. Sustained rates of inflation in fuel prices for long periods would have some effect on the findings of feasibility for hydropower projects in Hawaii. By using the values shown in Table D-6, the excess rate of inflation required to change a finding of infeasibility to feasibility can be computed for each of the seven sites shown in Table D-2. This excess rate of inflation can be expressed as follows:

$$R_E = \frac{1 + R_F}{1 + R} - 1$$

in which:

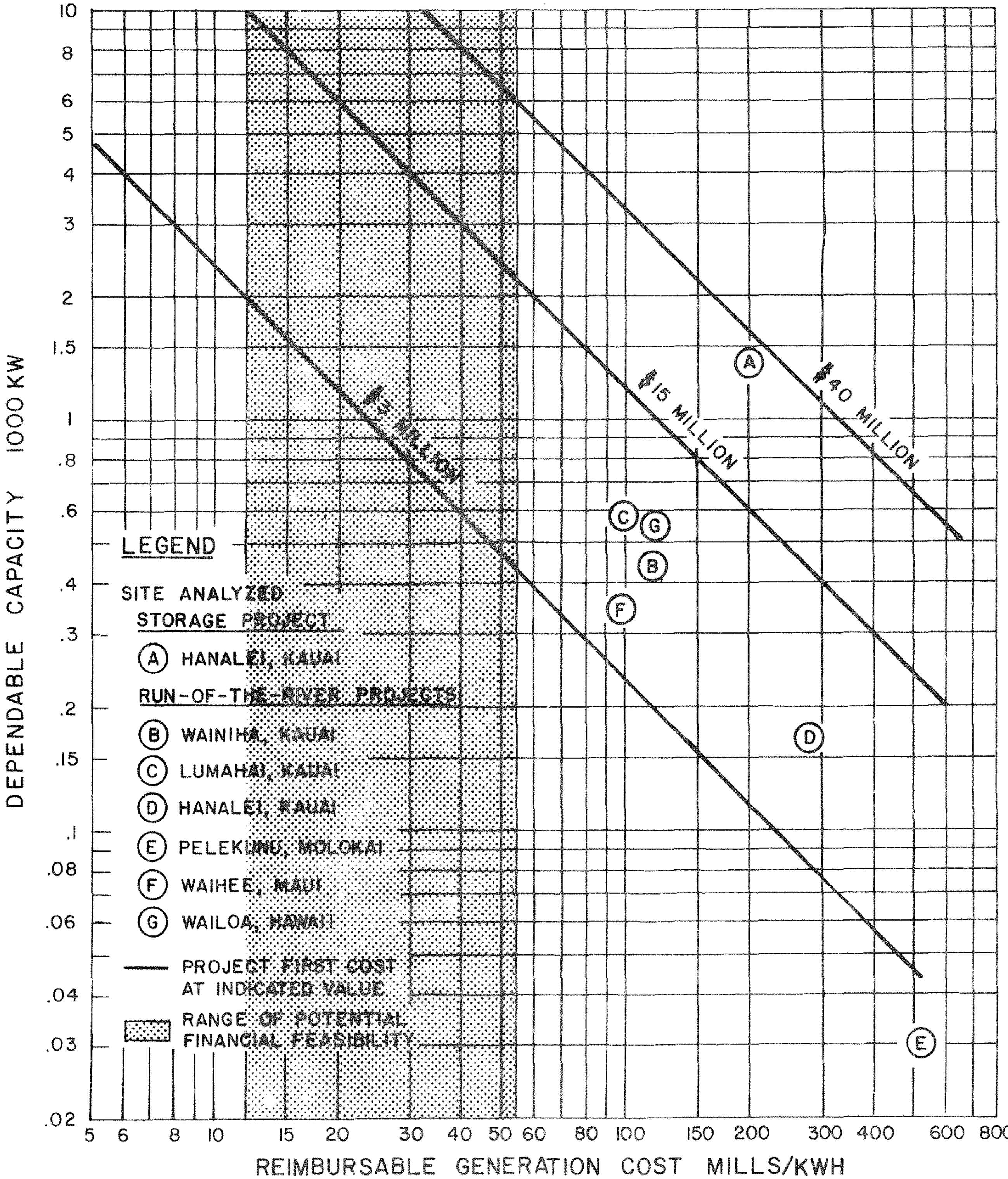
R_E = excess inflation rate

R_F = annual rate of fuel cost increases

R = annual rate of general inflation

LONG TERM FUEL EFFECT

33. The comparability ratio (CR) was used in the analysis because it is lower than the benefit-to-cost ratio. By setting the CR equal to unity, the annual rate of excess inflation of (R_E) can be determined. For each of the seven project concepts, the excess inflation rate varied from 4.9 to 8.4 percent. For CR equal to unity, the annual fuel cost increase must exceed the given inflation rate by approximately seven percent for an entire project life of 100 years. At this rate, fuel cost on the 100th year would be about 870 times the present real cost. These results point to two observations: (a) it is unlikely that a high excess inflation rate can be sustained over a long period of time and (b) other technological advances may become competitive long before the attainment of such high fuel price levels. In summary, it appears that fuel cost escalation will not significantly affect the feasibility of this study within the limits of the investigation and existing Federal evaluation policies.



SUMMARY REPORT
HYDROELECTRIC POWER

POTENTIAL FINANCIAL FEASIBILITY FOR SITES ANALYZED

U.S. ARMY ENGINEER DISTRICT, HONOLULU

FIGURE D-1

SECTION E

ENVIRONMENTAL EVALUATION

SECTION E

ENVIRONMENTAL EVALUATION

ENVIRONMENTAL SETTING

GENERAL CONDITIONS

1. Most of the potential hydropower sites in Hawaii are located in relatively inaccessible areas that have been subject to relatively little past disturbance from human activity. These include the remote upper reaches of valleys with associated wet and dry forest vegetation zones and relatively pristine stream systems with endemic (native) aquatic biota. Wetlands also occur in the lower reaches of most of these valleys but have been modified to a greater extent by man's activities. In any case, all of these areas are potentially environmentally sensitive and provide essential and possibly critical habitat for a variety of Hawaii's endangered species. Hawaii's unique flora and fauna, distinguished by its high incidence of endemism as a result of an extended period of evolutionary isolation, has, as a consequence of man's activities and introductions of exotic species, suffered numerous extinctions. Hawaii has become noted for its exceptional number of endangered or threatened species which include 31 taxa of native birds, two endemic mammal species, one endemic freshwater fish, and nearly 900 species of endemic plants officially listed or proposed as endangered or threatened by the Department of the Interior, U.S. Fish and Wildlife Service.

2. Importance of Assessment. Due to the migratory and endemic nature of Hawaiian stream fauna and the large number of endangered native forest plants and birds, much effort must be taken to mitigate, to the greatest extent possible, potential adverse affects associated with the development of a hydropower facility. Since little is known about the environmental base conditions in the remote upper valleys and in some cases the streams themselves, a careful assessment of these areas is extremely important.

BIRDLIFE

3. Upland. Twenty-one of the 30 endangered Hawaiian birds are forest or upland species, many of which are in the endemic family *Drepanididae* (Honeycreepers). All available evidence suggests that these birds have very narrow habitat requirements and are largely dependent upon the native forest ecosystems in which they evolved. Most honeycreepers inhabit the upper canopy of wet ohia forests. Destruction of their habitat would result in the eventual demise of these rare endemic birds.

4. Lowland. The Hawaiian duck, coot, gallinule, and stilt comprise the group of endangered waterbirds whose distribution is now largely restricted to several wetland areas designated as State or Federal wildlife refuges and to the few remaining nonprotected ponds and marshes in the coastal lowlands of the main islands. Several of these protected and essential habitat areas are located downstream of potential hydropower sites.

PLANTLIFE

5. A majority of Hawaii's rare or endangered endemic plants occur in the upper dry forest and wet forest vegetation zones. One dominant tree in the wet forest is the ohia lehua. The ohia forests probably contain the richest assemblage of genera and species of native plants, compared to other habitats in the Hawaiian Islands. Many of these native plants have very limited mechanisms for seed dispersal and are thus restricted to small isolated areas. Any major pertubations within these vegetation zones could be extremely detrimental to resident endangered plants.

AQUATIC LIFE

6. Hawaiian stream fauna, in general, exhibit low species diversity. Most of the native stream species have a diadromous life cycle. After the eggs hatch in freshwater, stream currents carry the larvae to the ocean where they undergo early development as marine plankton. Upon metamorphosis, they settle to the bottom at steam mouths and migrate upstream to continue their growth to maturity. Therefore, the physical integrity of the lower stream course and continuous flow to the sea must be maintained year-round to assure the survival of diadromous species.

DISTRIBUTION OF FAUNA

7. Stream. There is a clear zonal distribution of Hawaiian stream fauna. Insects and lower invertebrates exist throughout stream courses, but predominate in the upper reaches and headwaters. Species characterizing the middle reaches include the mountain opae and the rare goby, o'pu alamo'o. The endangered species committee of the American Fisheries Society has listed this goby as rare and endangered and another goby (o'opu nopili) as threatened. Lentipes concolor, which is now extinct on Oahu, is being officially considered for nomination to the Endangered Species List by the U.S. Fish and Wildlife Service. Lower reaches of streams have the greatest diversity. Representative species are the gobies; o'opu nakea, o'pu nopili, 'o'opu akupa, and a limpet-like gastropod, hihiwai or wi. Species common to the terminal reaches include the 'o'opu akupa, and 'o'opu naniha, an endemic prawn, opae 'oeha'a, and the limpets, hihiwai and hapawai.

ENVIRONMENTAL RECONNAISSANCE CONDUCTED

GENERAL

8. Baseline environmental investigations of aquatic fauna, terrestrial flora and fauna, and historic and archeological resources were conducted for Waihee Valley, Maui and Lumahai Valley, Kauai. Of the six candidate hydroelectric power drainage areas evaluated in this study, these were considered the most promising on the basis of preliminary hydrologic, economic and topographic/site adequacy criteria. In addition, surveys of aquatic fauna were conducted for Wainiha and Hanalei Rivers on Kauai and Wailoa Stream in Waipio Valley, Hawaii. No surveys of any nature were conducted for Pelekunu Stream, Molokai.

AQUATIC SURVEY

9. A survey of aquatic macrofauna of four streams was conducted under a contract administered by the Corps of Engineers.[1/] Of the streams surveyed, three were included among those considered for hydropower development: Wainiha and Hanalei on Kauai, and Wailoa on Hawaii. The U.S. Fish and Wildlife Service conducted an aquatic survey of Lumahai and the Waihee rivers in July 1978 to supplement the information and analysis of the earlier survey (Appendix 2). Both surveys were a one-time, one-season assessment of the stream macrofauna of these waterways. Although they do not present a complete picture of the biological potential of these streams, they do provide sufficient information to make a preliminary evaluation of their intrinsic biological value. The streams were ranked according to their relative ecological quality on the basis of three parameters: faunal inventory, species distribution and abundance, and species composition and diversity. The faunal inventory included the total number of species present, the number of native species present and the presence of depleted or rare species. Distribution and abundance ratings were based on the abundance of the native mountain shrimp, opae kala'ole, bacause this species occurred in all streams sampled. Species composition values included the percent number of native species and percent biomass of native species. Diversity indices were calculated for species number and species biomass. Wainiha River ranked first in overall quality followed by Lumahai, Hanalei, Waihee, and Wailoa rivers. All five rivers possessed relatively large populations of the native gobies, o'opu nakea (depleted) and o'opu nopili (rare). Waihee River also contained concentrations of juvenile o'opu alamo'o, a species recommended for federal endangered species status.

1/ Timbol, Amadeo; and Environment Impact Study Corp., A Report on the Aquatic Survey of Stream Macrofauna for the Hydroelectric Power Study for Hawaii, September 1977.

TERRESTRIAL BIOLOGICAL STUDY

10. General. A survey of terrestrial flora and fauna of Lumahai Valley, Kauai and Waihee Valley, Maui, was conducted under a contract administered by the Corps of Engineers.[2/] The study area comprised a corridor along the valley floor from the beginning of the proposed access road to the proposed stream diversion site upstream for each valley. Transmission line rights-of-way were assumed to parallel the access road route. The objectives of the study were to provide an assessment of botanical and wildlife resources in the study area; to compile an inventory of plants, birds and mammals occurring in these areas; to identify and map listed and proposed endangered and threatened species or unique elements and their habitats; and to discuss potential environmental problems or concerns related to the terrestrial flora and fauna of the study sites.

11. Lumahai Valley. The botanical survey identified four vegetation types within the study area at Lumahai. The valley floor has been disturbed by past cultivation practices and by grazing. Vegetation consists largely of introduced species and extensive hau thickets. No threatened or endangered species were found during the survey. The faunal survey identified four major wildlife zones in the study area. These are: lower river and estuary, pastureland, forest and upper riverbed. The lower estuary, providing habitat for four native waterbird species, is the most significant zone. The blackcrowned night heron (auku'u) and the endangered Hawaiian duck, Hawaiian stilt and Hawaiian coot were sighted here during the survey. The Hawaiian coot was the most abundant species with 51 individuals sighted. In the forest zone, the only native forest bird sighted was the Hawaiian owl (pueo). However, this zone is considered suitable habitat for the endangered honeycreepers ('amakihi and 'apapane) and the endemic 'elepaio. Non-avian vertebrates sighted in the zone were marine toads and feral pigs. The upper riverbed provides habitat for the Hawaiian ducks and Black-crowned Night Herons.

12. Potential Impacts. Several potential environmental problems may occur as a consequence of hydropower development in the valley. Grading and construction of roadbeds, cuts and fills would hasten invasion by weedy plant species and could result in increased erosion and sedimentation of the stream. The stream diversion would decrease the quality of waterbird habitat in the directed segment of the stream. The extent of this impact could not be fully evaluated since the streamflow remaining after project implementation is not known. Since the diverted water would be returned to the stream course below the power plant, substantial changes

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2/ Environmental Impact Study Corp., A Report on the Terrestrial Biological Survey of Potential Hydroelectric Power Sites in Hawaii, September 1978.

in hydrological patterns in the lower stream and estuary that could affect the waterbird habitat would not be expected. However, this area is recognized as prime habitat in the Hawaii Waterbird Recovery Plan (1977) and has been considered for future refuge status in the National Wildlife Refuge System. For these reasons, possible changes resulting from the proposed plan should be thoroughly evaluated prior to any future hydropower investigation.

13. Waihee Valley. The botanical survey determined that the vegetation along the valley floor has been disturbed by past cultivation practices. Guava is the dominant vegetation type. Large patches of uluhe, hau, and bamboo are also present. A forest of 'ohia forms the dominant canopy on the upper slopes and ridges outside the study area. One proposed endangered plant species, halapepe, was found in the study area in both the closed guava and the kukui vegetation types.

14. The faunal survey of Waihee Valley identified only one wildlife zone, based on the distribution or abundance of vertebrates in the study area. Ten bird species were sighted in the course of the survey including two indigenous species, the white-tailed tropic bird and wandering tattler. Of the species observed, the wandering tattler is most likely to be adversely affected by alteration of stream flow and volume patterns caused by a potential hydropower development. However, this migratory species is widely distributed throughout the Pacific during fall and winter months. Non-avian vertebrates occupying the study area include rats, mice, dogs, mongoose, cats, and feral pigs. Although amphibians were not recorded, it is likely that both the marine toad and Japanese wrinkle-backed frog are present.

15. Potential Impacts. Environmental problems related to implementation of the plan could occur as a result of extensive clearing and grading. Increased runoff, erosion and invasion by weedy plant species are likely to result. A decrease in the quality of forest bird habitat would be anticipated. However, since forest bird habitat in the proposed project area is limited, significant impact on any given species would not be expected. The native bird most likely to be affected is the 'ulili or wandering tattler. It is unclear how the streamflow pattern would be affected by the project and what effect this modified streamflow would have on food species for the 'ulilu. Thus, it is not possible at this time to determine whether or not the stream course between the proposed diversion and powerplant would still provide suitable habitat for this bird.

HISTORICAL-ARCHEOLOGICAL SURVEY

16. General. Historical/archeological reconnaissance surveys of Waihee and Lumahai Valleys were performed under a contract administered by the Corps of Engineers.[3/] The study area for each valley consisted of a corridor along the valley floor from the beginning of the proposed access road to the proposed stream diversion site. The objectives of the study were to identify and assess the general nature and significance of historical and archeological resources present and discuss potential impacts of construction activities on these resources.

17. Both valleys were surveyed in the area of potential hydropower facilities, focusing on stream flats and gradual slopes. Steep areas above cliffs were generally not surveyed since cultural sites were not expected in these areas. Where sites were encountered, site area numbers were assigned to the location. Brief descriptions and photographs including dimensions, were recorded to clarify the nature of the cultural resources.

18. Waihee Valley. Thirteen archeological site areas were located in Waihee Valley. Most of the site areas are located in the upper valley on flats near Waihee Stream. The dominant types of structures are stone terraces and stone and earthen canals. Some site areas include one or two terraces while the largest includes at least fifty. Every site area with terracing includes at least one canal. Structures were grouped into two general categories: agricultural and housing. In addition to the archeological sites identified within the study area, a historical tunnel and ditch system exists in Waihee Valley. This system was constructed in stages, beginning in 1882 with the Spreckels Ditch, to provide large-scale irrigation for sugar cultivation. The ditch-dam-tunnel complex belongs to the modern historic period while the other structures appear to belong to the prehistoric and/or early historic era, based on architectural form.

19. Evaluation. An evaluation of the significance of these sites was made on the basis of two criteria: information and preservation. Information significance was considered in terms of the potential to yield information vital to understanding prehistory. Preservation significance was assessed according to the value of each site for the purpose of exhibition or long-term scientific research. All sites in Waihee Valley were considered to have information significance, one of these being potentially very significant. High exhibition significance was attributed to two site areas.

20. Potential Impact. Impacts of construction related to hydropower development are considered to be potentially highly detrimental to archeological sites. Culturally significant sites occur on both sides of the stream, all of which require additional scientific evaluation. Two site areas may merit preservation.

[3/] Bishop Museum, Department of Anthropology, Cultural Reconnaissance of Hydroelectric Power Plant Sites, September 1978.

21. Lumahai Valley. The survey of Lumahai was not considered a complete survey of the transect corridor since it was confined to the eastern half of the valley. In the upper valley, only about one-third of each stream flat area on the east side could be reached due to cliffs and dense hau thicket. This prevented representative sampling of potential site areas in this part of the study area.

22. Three archeological sites were found in Lumahai during the survey, one in the upper valley and two in the lower valley. All of these are classified as agricultural and could be prehistoric or early historic in date, based on architectural form. One of these site areas is considered to have information significance. None have exhibition or long-term research significance. Extensive ranch clearing in the lower valley has eliminated most archeological sites in the study area.

23. Potential Impacts. Provided the two archeological sites located in the lower valley portion of the study area will be affected by a hydropower project, additional mapping and test excavation of these areas would be required. Restricted survey conditions in the upper valley due to terrain conditions precluded a comprehensive determination of project impact in this area.

24. Summary. A summary of fish and wildlife; historic, scenic and recreational; and water resources values for each of the six drainage areas is shown in Table E-1.

Table E-1. SUMMARY OF ENVIRONMENTAL DATA

ENVIRONMENTAL SCREENING CRITERIA	Wainiha Kauai	Hanalei Kauai	Lumahai Kauai	Pelekunu Molokai	Waihee Maui	Wailoa Hawaii
	DRAINAGE AREA/ISLAND					
Fish and Wildlife Values						
(a) Listed or proposed endangered or threatened species and/or essential habitat	P,M	P,H	P,H	*	P,L	P,L
(b) Commercial and recreational fishery resources and use	P,M	P,H	P,L	P,L	P,L	P,H
(c) Natural intrinsic value of stream (abundance and diversity of endemic aquatic fauna)	H	H	H	H	M	M
(d) National Wildlife Refuges	A	P	C	A	A	A
(e) Natural Reserve Areas (State of Hawaii)	A	A	C	A	A	A
(f) State and/or National Forest Reserve	P	P	P	P	P	P
(g) Estuarine Sanctuaries	A	A	A	A	A	A
Historic, Scenic and Recreational Values						
(a) Historic and Archeological Resources	P,H	P,H	P,L	*	P,H	P,H
(b) County, State or National Parks	A	A	A	A	A	A
(c) Wild and Scenic Rivers	A	A	A	A	A	A
(d) Recreational Resources and Used (Fishing & Public Access)	M	H	L	L	L	H
Water Resources Values						
(a) State Watershed Areas	P	P	P	P	P	P
(b) Prime recharge areas	P,L	P,L	P,L	P,L	P,M	P,H
(c) Agricultural use	P,H	P,H	A	A	P,H	P,H
(d) Water Quality Standards, proposed usages	II	II	II	II	II	II

Explanation of Symbols

Occurrence or Presence within the drainage area
- P-Present
- A-Absent
- C-Candidate/Proposed
- L-Limited/Marginal
- *-Information not available

Relative value of resources or magnitdue of use
- H-High
- M-Moderate
- L-Low

Status-use categories, Department of Health Proposed Water Quality Standards (1977)
- I-Pristine-Preservation
- II-Limited-Consumption
- III-Exploitive - Consumptive
- IV-Construct - Alter

SECTION F

CONCLUSION AND RECOMMENDATION

SECTION F

CONCLUSION AND RECOMMENDATION

CONCLUSION

FEASIBILITY PROBLEM

1. Preliminary cost and benefit estimates indicate a very unfavorable economic situation for hydroelectric power development. The cost estimates were performed on reconnaissance-level studies. Uniform unit costs were used and site specific material, construction, and estimating analysis were not performed. Benefits were derived from preliminary power values determined by FERC. The level of detail provided in these estimating techniques was appropriate for justification of findings and recommendation on any future study.

TYPE AND LOCATION OF FACILITY

2. Single purpose storage and run-of-the-river hydropower plants on selected perennial streams were evaluated. Provided hydroelectric power developed appeared near favorable, additional project purposes would have been added and subsequently evaluated.

3. The Hanalei River was the drainage area selected for the storage concept. Run-of-the-river facilities were formulated for the Wainiha, Lumahai, and Hanalei rivers on the island of Kauai, Pelekunu Stream on the island of Molokai, Waihee Stream on the island of Maui, and Wailoa River (Waipio Valley) on the island of Hawaii.

BENEFIT AND COST ANALYSIS

4. The greatest power benefits per unit cost for hydroelectric plants in the state of Hawaii are for base load plants. Characteristically, the annual total benefits per unit capacity increase with increase in plant factor because of greater generation (kilowatt-hours) associated with the high plant factor.

5. For implementation of machinery and physical facilities for projects less than 10 MW (10,000 kw) economies of scale are not apparent. The cost function for potential projects in this study is relatively high, in the range of $10,000 to $15,000 per installed kilowatt. Based on the relationship between benefits and costs, it is clear that base load plants achieve maximization of net benefits.

PHYSICAL RESOURCES

6. The key problem for areas investigated in Hawaii is that there are insufficient physical resources. An adequate combination of dependable flow and high head is imperative for hydropower development. Among the sites investigated, firm flows do not exceed 40 cubic feet per second (cfs). To obtain over 5,000 kw of power at 40 cfs, a net effective head of over 1,700 feet is required. Run-of-the-river sites which exhibit these physical characteristics are non-existent. Storage facilities combined with long penstocks can potentially achieve a suitable combination of discharge and head. However, the sheer size requirement of such structural works makes these measures prohibitively costly.

ENERGY RESOURCE MANAGEMENT

7. An analysis was conducted to determine the effect of fuel costs of the existing energy system on potential feasibility of hydroelectric power development. At high plant factors, fuel constitutes approximately 60 to 70 percent of the total power value. For economic feasibility, fuel prices would have to rise approximately 5 to 8 percent over and above the general inflation rate. This excess inflation is too large to be sustained over a long project life. Hence, fuel cost escalation will not have a significant bearing on the feasibility results.

RECOMMENDATION

The District Engineer concludes that the investigation, within the scope of study, has provided sufficient information for the determination of continued study. The investigation has shown that there does not exist suitable physical conditions for economic implementation of a hydroelectric power facility in the State of Hawaii at this time. He therefore recommends that the existing investigation of implementation of hydroelectric power under the authority of Section 209 of the 1962 River and Harbor and Flood Control Act be discontinued.

PETER D. STEARNS
Colonel, Corps of Engineers
District Engineer

APPENDIX 1

TECHNICAL INFORMATION

SUMMARY REPORT
HYDROELECTRIC POWER - STATE OF HAWAII
APPENDIX 1 - TECHNICAL INFORMATION

TABLE OF CONTENTS

SECTION 1A

HANALEI RIVER, KAUAI
STORAGE PLAN

TECHNICAL DATA

FACILITY FEATURES		PHYSICAL FACTORS	
Plant Capacity, KW:	1,400	Drainage Area, Sq. Mi.:	15.3
Plant Factor, %:	100	Stream Length, Mi.:	7.6
Net Head, Ft:	261	Average Gradient, Ft/Ft: (Crest to Plant)	0.11
Penstock Length, Ft:	8,000	Accessibility:	Poor
Storage, AF: (to Top of Power Pool)	7,880	Proximity to Load Center:	3.0 miles

HYDROLOGY

Average Annual Rainfall Variation:	160" to 450"
Streamflow Gage of Record: USGS#	1010 and 1030
Diversion/Impoundment Location:	7.7 miles upstream of mouth
Average Discharge, Cfs:	163
Dependable Discharge, Cfs:	23

GEOLOGY

Location and Local Geology. Hanalei Valley, which is drained by the Hanalei River, is located on the north shore of Kauai. The 9-mile-long valley is structurally controlled by a previous ancestral valley and the Koloa Volcanic Series that was deposited earlier. The Koloa Series is composed primarily of lava, cinder, ash, and tuff. Intermixed with the basalt lavas of the Koloa Series are the sedimentary conglomerates of the Palikea Formation.

Dam Site Location. The most favorable site for dam construction is a location in the valley directly east of Waiopa and above the reach where the river channel begins to meander. The west abutment, which lies in lavas of the Koloa Volcanic Series, is fractured and jointed, which would require abutment and foundation preparation. Located in Zone 0, Kauai is considered aseismic. Embankment materials could be excavated from river terraces on the western valley slopes or from river banks on either side of the river.

ECONOMIC DATA

PROJECT FIRST COST

Item	Unit	Unit Cost $	Qty	Cost $
Penstock	Ft	440	8,000	3,520,000
Power House	Kw	1,700	1,400	2,380,000
Access Road	Ft	22	8,000	176,000
Structure	L.S.	-		19,100,000
Land	Ac	0	46	0
Subtotal				25,176,000
Contingency 25%±				6,148,000
Engr & Admin 12%±				3,676,000
TOTAL FIRST COST				35,000,000

ECONOMIC TEST

Annual Cost (Discount Rate = 6-5/8%, Period = 100 Yrs)		
Interest & Amortization :		2,322,000
Operation, Maintenance & Replacement:		58,000
TOTAL AVERAGE ANNUAL COST		2,380,000
Annual Benefit (Discount Rate = 10 Percent)		
Hydropower		532,000
Net Benefits :	(-)	1,848,000
Benefit/Cost Ratio :		0.2

COMPARABILITY TEST

Annual Cost, Total :		2,380,000
Annual Benefit (Discount Rate = 6-5/8%, Period = 100 Yrs)		
Hydropower :		464,000
Net Benefits	(-)	1,916,000
Comparability Ratio		0.2

SOCIAL DATA

	Facility		
	Dam	Penstock	Power Plant
Existing Land Use	Conservation	Conservation	Conservation
Ownership	Government	Government	Government

ENVIRONMENTAL DATA

(1)	Fish and Wildlife Values	
	(a) Listed or proposed endangered or threatened species and/or essential habitat	P,H
	(b) Commercial and recreational fishery resources and use	P,H
	(c) Natural intrinsic value of stream (abundance and diversity of endemic aquatic fauna)	H
	(d) National Wildlife Refuges	P
	(e) Natural Reserve Areas (State of Hawaii)	A
	(f) State and/or National Forest Reserve	P
	(g) Estuarine Sanctuaries	A
(2)	Historic, Scenic and Recreational Values	
	(a) Historic and Archeological Resources	P,H
	(b) County, State or National Parks	A
	(c) Wild and Scenic Rivers	A
	(d) Recreational Resources and Used (Fishing & Public Access)	H
(3)	Water Resources Values	
	(a) State Watershed Areas	P
	(b) Prime recharge areas	P,L
	(c) Agricultural use	P,H
	(d) Water Quality Standards, proposed usages	II

Explanation of Symbols

Occurrence or Presence within the drainage area

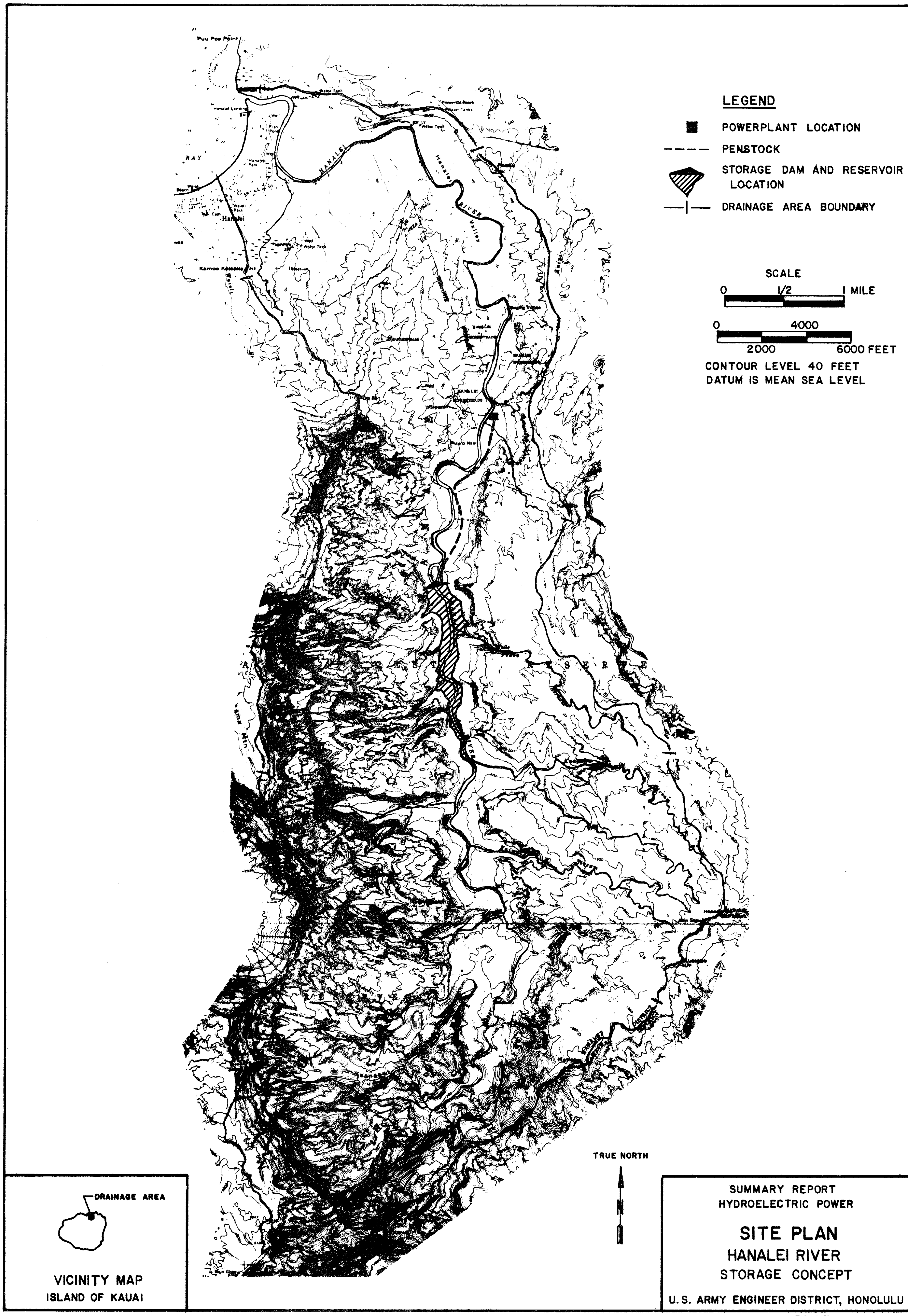
- P-Present
- A-Absent
- C-Candidate/Proposed
- L-Limited/Marginal
- *-Information not available

Relative value of resource or magnitude of use

- H-High
- M-Moderate
- L-Low

Status-use categories, Department of Health
Proposed water quality Standards (1977)

- I-Pristine-Preservation
- II-Limited-Consumptive
- III-Exploitive - Consumptive
- IV-Construct - Alter



SUMMARY REPORT
HYDROELECTRIC POWER

SITE PLAN
HANALEI RIVER
STORAGE CONCEPT

U. S. ARMY ENGINEER DISTRICT, HONOLULU

PLATE IA

SECTION 1B

WAINIHA RIVER, KAUAI
RUN-OF-THE-RIVER PLAN

TECHNICAL DATA

FACILITY FEATURES		PHYSICAL FACTORS	
Plant Capacity, KW:	430	Drainage Area, Sq. Mi.:	10.2
Plant Factor, %:	100	Stream Length, Mi.:	7.1
Net Head, Ft:	189	Average Gradient, Ft/Ft: (Crest to Plant)	0.11
Penstock Length, Ft:	6,800	Accessibility:	poor
Storage, AF: (to Top of Power Pool)	0	Proximity to Load Center:	6 miles

HYDROLOGY

Average Annual Rainfall Variation:	200" to 450"
Streamflow Gage of Record: USGS#	1080
Diversion Location:	7.3 miles upstream of mouth
Average Discharge, Cfs:	143
Dependable Discharge, Cfs:	31

GEOLOGY

Location and Local Geology. The ten mile long Wainiha Valley is located on the north shore of Kauai. The Alakai swamp is the source of the Wainiha River that flows through the valley. The upper portion of the river rests on basalts of the Olokele Formation while the lower reaches flow over lava deposits of the Napali Formation.

Diversion Dam Site. The most suitable location for a dam is in the Olokele Formation which is more massive and contain less permeable material than does the Napali Formation. In addition, the dam would be above most of the dikes found in the valley and the fault scarp and buried talus located between the Olokele and Napali Formations. Furthermore, the valley walls are steep and close together thus requiring less embankment material, abutment preparation and grouting.

ECONOMIC DATA

PROJECT FIRST COST

Item	Unit	Unit Cost $	Qty	Cost $
Penstock	Ft	199	6,800	1,353,000
Power House	Kw	3,300	430	1,419,000
Access Road	Ft	22	6,800	150,000
Structure	Cy	170	7,960	1,353,000
Land	Ac	20,000	12	240,000
Subtotal				4,275,000
Contingency 25%±				1,084,000
Engr & Admin 12%±				641,000
TOTAL FIRST COST				$6,000,000

ECONOMIC TEST

Annual Cost (Discount Rate = 6-5/8%, Period = 100 Yrs)	
Interest & Amortization :	398,000
Operation, Maintenance & Replacement:	22,000
TOTAL AVERAGE ANNUAL COST	420,000
Annual Benefit (Discount Rate = 10 Percent)	
Hydropower	163,000
Net Benefits :	(-) 257,000
Benefit/Cost Ratio :	0.4

COMPARABILITY TEST

Annual Cost, Total :	420,000
Annual Benefit (Discount Rate = 6-5/8%, Period = 100 Yrs)	
Hydropower :	142,000
Net Benefits	(-) 378,000
Comparability Ratio	0.3

SOCIAL DATA

	Facility		
	Dam	Penstock	Power Plant
Existing Land Use	Conservation	Conservation	Conservation
Ownership	Private	Private	Private

ENVIRONMENTAL DATA

(1)	Fish and Wildlife Values		
	(a)	Listed or proposed endangered or threatened species and/or essential habitat	P,M
	(b)	Commercial and recreational fishery resources and use	P,M
	(c)	Natural intrinsic value of stream (abundance and diversity of endemic aquatic fauna)	H
	(d)	National Wildlife Refuges	A
	(e)	Natural Reserve Areas (State of Hawaii)	A
	(f)	State and/or National Forest Reserve	P
	(g)	Estuarine Sanctuaries	A
(2)	Historic, Scenic and Recreational Values		
	(a)	Historic and Archeological Resources	P,H
	(b)	County, State or National Parks	A
	(c)	Wild and Scenic Rivers	A
	(d)	Recreational Resources and Used (Fishing & Public Access)	M
(3)	Water Resources Values		
	(a)	State Watershed Areas	P
	(b)	Prime recharge areas	P,L
	(c)	Agricultural use	P,H
	(d)	Water Quality Standards, proposed usages	II

Explanation of Symbols

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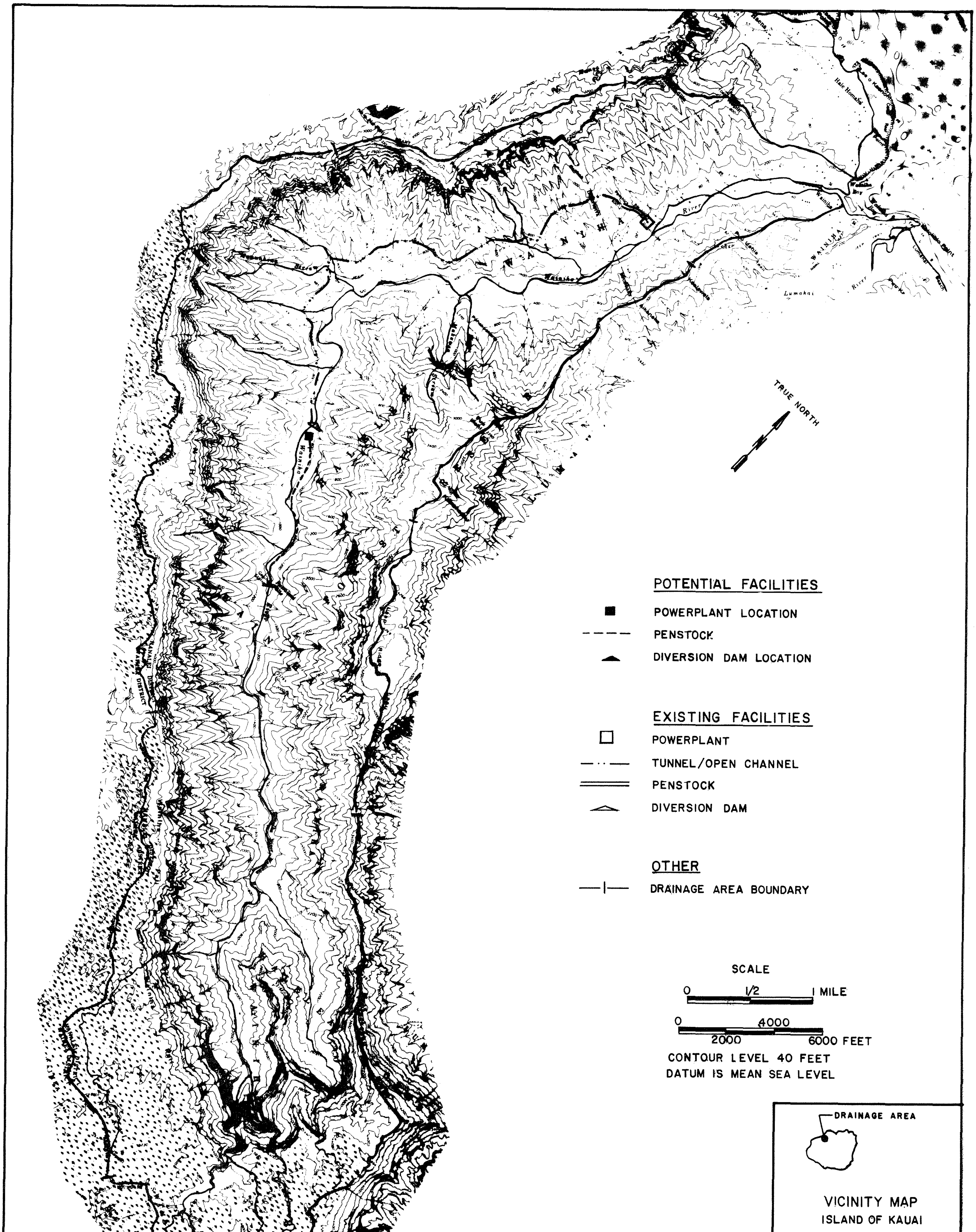


SUMMARY REPORT
HYDROELECTRIC POWER

SITE PLAN
WAINIHA RIVER
RUN-OF-THE-RIVER

U. S. ARMY ENGINEER DISTRICT, HONOLULU

PLATE IB

SECTION 1C

LUMAHAI RIVER, KAUAI
RUN-OF-THE-RIVER PLAN

TECHNICAL DATA

FACILITY FEATURES		PHYSICAL FACTORS	
Plant Capacity, KW:	590	Drainage Area, Sq. Mi.:	10.4
Plant Factor, %:	100	Stream Length, Mi.:	5.2
Net Head, Ft:	312	Average Gradient, Ft/Ft: (Crest to Plant)	0.10
Penstock Length, Ft:	11,400	Accessibility:	Poor
Storage, AF: (to Top of Power Pool)	0	Proximity to Load Center:	2.5 miles

HYDROLOGY

Average Annual Rainfall Variation:	170" to 350"
Streamflow Gage of Record: USGS#	1060
Diversion Location:	4 miles upstream of mouth
Average Discharge, Cfs:	162
Dependable Discharge, Cfs:	29

GEOLOGY

Location and Local Geology. Lumahai Valley is an arc-shaped, river eroded valley on the north shore of Kauai. The Lumahai River drains the valley from Mt. Waialeale in the southeast to the Pacific Ocean in the north. The upper reaches of the Lumahai River flow over the dense basalts of the Olokele Formation and old alluvium consisting of rock indurated by clay and silt. The lower reaches of the river cross lava deposits of the Napali Formation.

Diversion Dam Site Location. The area best suited for dam construction is just above the Olokele and Napali Formation contacts, where the crest width is minimal, and the foundation least permeable. In addition, this location would allow most of the tributary streams to contribute water for power generation. Located in Zone 0, Kauai is considered aseismic. The alluvial material would be usable in addition to materials taken from the channel bottom. The suitability and quantity would require additional investigation. All foundation work would require careful cleaning and in some cases, grouting.

ECONOMIC DATA

PROJECT FIRST COST

Item	Unit	Unit Cost $	Qty	Cost $
Penstock	Ft	200	11,400	2,280,000
Power House	Kw	2,600	590	1,534,000
Access Road	Ft	22	11,400	251,000
Structure	Cy	170	4,520	768,000
Land	Ac	20,000	16	320,000
Subtotal				5,153,000
Contingency 25%±				1,274,000
Engr & Admin 12%±				773,000
TOTAL FIRST COST				7,200,000

ECONOMIC TEST

Annual Cost (Discount Rate = 6-5/8%, Period = 100 Yrs)	
Interest & Amortization :	478,000
Operation, Maintenance & Replacement:	32,000
TOTAL AVERAGE ANNUAL COST	510,000
Annual Benefit (Discount Rate = 10 Percent)	
Hydropower	225,000
Net Benefits :	(-) 285,000
Benefit/Cost Ratio :	0.4

COMPARABILITY TEST

Annual Cost, Total :	510,000
Annual Benefit (Discount Rate = 6-5/8%, Period = 100 Yrs)	
Hydropower :	195,000
Net Benefits	(-) 315,000
Comparability Ratio	0.4

SOCIAL DATA

	Facility		
	Dam	Penstock	Power Plant
Existing Land Use	Conservation	Conservation	Conservation
Ownership	Private	Private	Private

ENVIRONMENTAL DATA

(1) Fish and Wildlife Values

(a)	Listed or proposed endangered or threatened species and/or essential habitat	P,H
(b)	Commercial and recreational fishery resources and use	P,L
(c)	Natural intrinsic value of stream (abundance and diversity of endemic aquatic fauna)	H
(d)	National Wildlife Refuges	C
(e)	Natural Reserve Areas (State of Hawaii)	C
(f)	State and/or National Forest Reserve	P
(g)	Estuarine Sanctuaries	A

(2) Historic, Scenic and Recreational Values

(a)	Historic and Archeological Resources	P,L
(b)	County, State or National Parks	A
(c)	Wild and Scenic Rivers	A
(d)	Recreational Resources and Used (Fishing & Public Access)	L

(3) Water Resources Values

(a)	State Watershed Areas	P
(b)	Prime recharge areas	P,L
(c)	Agricultural use	A
(d)	Water Quality Standards, proposed usages	II

Explanation of Symbols

Occurrence or Presence within the drainage area

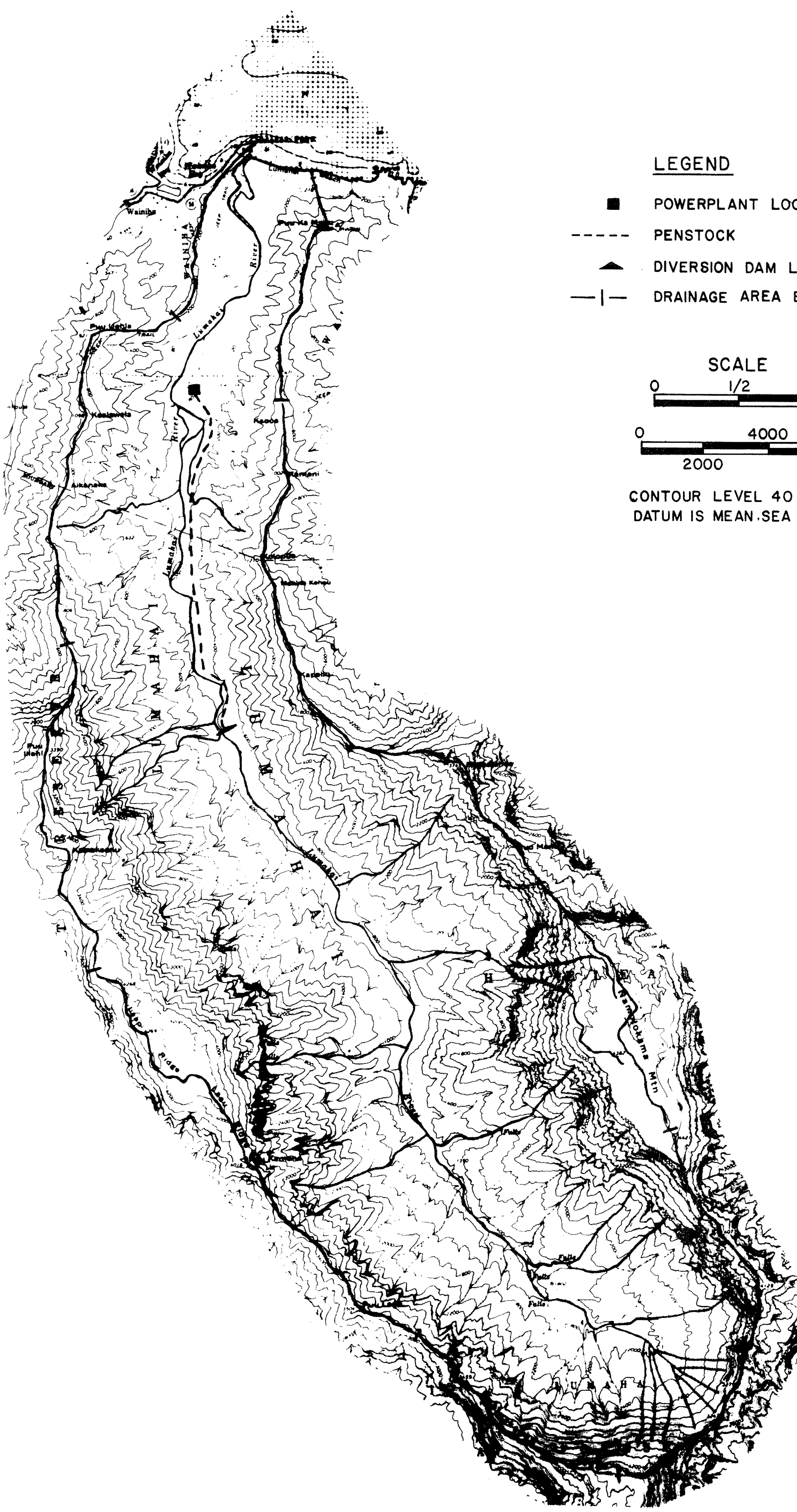
P-Present
A-Absent
C-Candidate/Proposed
L-Limited/Marginal
*-Information not available

Relative value of resource or magnitude of use

H-High
M-Moderate
L-Low

Status-use categories, Department of Health
Proposed water quality Standards (1977)

I-Pristine-Preservation
II-Limited-Consumptive
III-Exploitive - Consumptive
IV-Construct - Alter



LEGEND

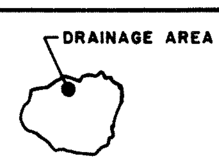
- POWERPLANT LOCATION
- PENSTOCK
- DIVERSION DAM LOCATION
- DRAINAGE AREA BOUNDARY

SCALE

0 1/2 1 MILE

0 2000 4000 6000 FEET

CONTOUR LEVEL 40 FEET
DATUM IS MEAN SEA LEVEL



VICINITY MAP
ISLAND OF KAUAI

SUMMARY REPORT
HYDROELECTRIC POWER

SITE PLAN

LUMAHAI RIVER
RUN-OF-THE-RIVER

U. S. ARMY ENGINEER DISTRICT, HONOLULU

PLATE IC

SECTION 1D

HANALEI RIVER, KAUAI
RUN-OF-THE-RIVER PLAN

TECHNICAL DATA

FACILITY FEATURES		PHYSICAL FACTORS	
Plant Capacity, KW:	170	Drainage Area, Sq. Mi.:	9.8
Plant Factor, %:	100	Stream Length, MI.:	5.8
Net Head, Ft:	263	Average Gradient, Ft/Ft: (Crest to Plant)	0.14
Penstock Length, Ft:	18,000	Accessibility:	poor
Storage, AF: (to Top of Power Pool)	0	Proximity to Load Center:	3 miles

HYDROLOGY

Average Annual Rainfall Variation:	170" to 450"
Streamflow Gage of Record: USGS#	1010 and 1030
Diversion Location:	9.5 miles upstream of mouth
Average Discharge, Cfs:	104
Dependable Discharge, Cfs:	12

GEOLOGY

Location and Local Geology. Hanalei Valley, which is drained by the Hanalei River, is located on the north shore of Kauai. The 9-mile-long valley is structurally controlled by a previous ancestral valley and the Koloa Volcanic Series that was deposited earlier. The Koloa Series is composed primarily of lava, cinder, ash, and tuff. Intermixed with the basalt lavas of the Koloa Series are the sedimentary conglomerates of the Palikea Formation.

Diversion Dam Site Location. The most favorable site for dam construction is a location in the valley directly east of Waiopa and above the reach where the river channel begins to meander. The west abutment, which lies in lavas of the Koloa Volcanic Series, is fractured and jointed, which would require abutment and foundation preparation. Located in Zone 0, Kauai is considered aseismic. Embankment materials could be excavated from river terraces on the western valley slopes or from river banks on either side of the river.

ECONOMIC DATA

PROJECT FIRST COST

Item	Unit	Unit Cost $	Qty	Cost $
Penstock	Ft	80	18,000	1,440,000
Power House	Kw	4,800	170	816,000
Access Road	Ft	22	18,000	396,000
Structure	Cy	170	7,960	1,354,000
Land	Ac	0	22	0
Subtotal				4,006,000
Contingency 25%±				1,003,000
Engr & Admin 12%±				601,000
TOTAL FIRST COST				5,610,000

ECONOMIC TEST

Annual Cost (Discount Rate = 6-5/8%, Period = 100 Yrs)		
Interest & Amortization :		372,000
Operation, Maintenance & Replacement:		23,000
TOTAL AVERAGE ANNUAL COST		395,000
Annual Benefit (Discount Rate = 10 Percent)		
Hydropower		65,000
Net Benefits :	(-)	330,000
Benefit/Cost Ratio :		0.2

COMPARABILITY TEST

Annual Cost, Total :		395,000
Annual Benefit (Discount Rate = 6-5/8%, Period = 100 Yrs)		
Hydropower :		56,000
Net Benefits	(-)	339,000
Comparability Ratio		0.1

SOCIAL DATA

	Facility		
	Diversion Dam	Penstock	Power Plant
Existing Land Use	Conservation	Conservation	Conservation
Ownership	Government	Government	Government

ENVIRONMENTAL DATA

(1)	<u>Fish and Wildlife Values</u>	
	(a) Listed or proposed endangered or threatened species and/or essential habitat	P,H
	(b) Commercial and recreational fishery resources and use	P,H
	(c) Natural intrinsic value of stream (abundance and diversity of endemic aquatic fauna)	H
	(d) National Wildlife Refuges	P
	(e) Natural Reserve Areas (State of Hawaii)	A
	(f) State and/or National Forest Reserve	P
	(g) Estuarine Sanctuaries	A
(2)	<u>Historic, Scenic and Recreational Values</u>	
	(a) Historic and Archeological Resources	P,H
	(b) County, State or National Parks	A
	(c) Wild and Scenic Rivers	A
	(d) Recreational Resources and Used (Fishing & Public Access)	H
(3)	<u>Water Resources Values</u>	
	(a) State Watershed Areas	P
	(b) Prime recharge areas	P,L
	(c) Agricultural use	P,H
	(d) Water Quality Standards, proposed usages	II

<u>Explanation of Symbols</u>

Occurrence or Presence within the drainage area.

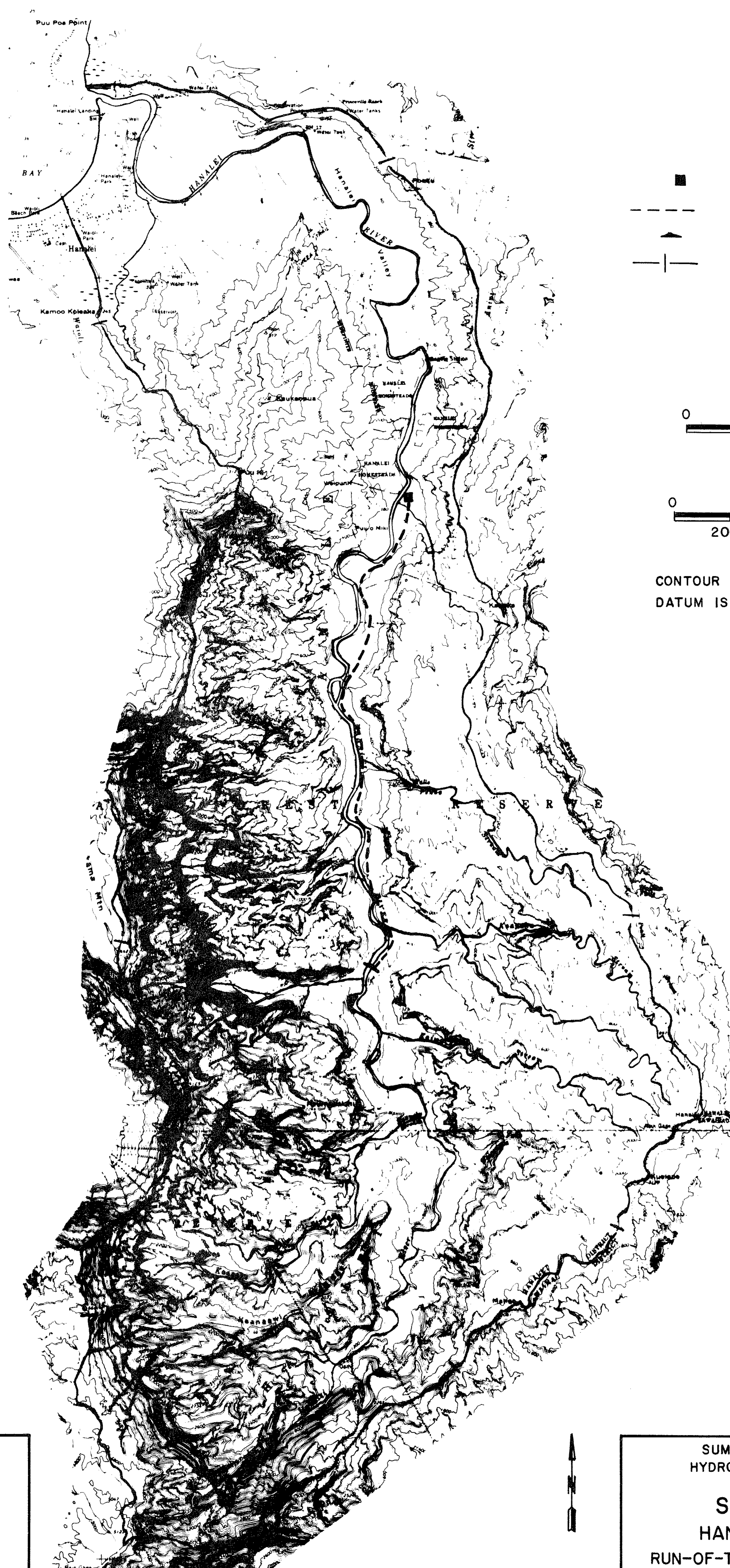
P-Present
A-Absent
C-Candidate/Proposed
L-Limited/Marginal
*-Information not available

Relative value of resource or magnitude of use

H-High
M-Moderate
L-Low

Status-use categories, Department of Health
Proposed water quality Standards (1977)

I-Pristine-Preservation
II-Limited-Consumptive
III-Exploitive - Consumptive
IV-Construct - Alter



LEGEND

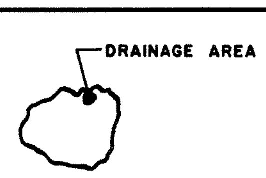
- ■ POWERPLANT LOCATION
- – – – – PENSTOCK
- ▲ DIVERSION DAM LOCATION
- —|— DRAINAGE AREA BOUNDARY

SCALE

0 1/2 1 MILE

0 2000 4000 6000 FEET

CONTOUR LEVEL 40 FEET
DATUM IS MEAN SEA LEVEL



VICINITY MAP
ISLAND OF KAUAI

SUMMARY REPORT
HYDROELECTRIC POWER

SITE PLAN
HANALEI RIVER
RUN-OF-THE-RIVER CONCEPT

U.S. ARMY ENGINEER DISTRICT, HONOLULU

PLATE ID

SECTION 1E

PELEKUNU STREAM, MOLOKAI
RUN-OF-THE-RIVER PLAN

TECHNICAL DATA

FACILITY FEATURES		PHYSICAL FACTORS	
Plant Capacity, KW:	30	Drainage Area, Sq. Mi.:	5.4
Plant Factor, %:	100	Stream Length, Mi.:	2.7
Net Head, Ft:	194	Average Gradient, Ft/Ft: (Crest to Plant)	0.33
Penstock Length, Ft:	6,200	Accessibility:	Very poor
Storage, AF: (to Top of Power Pool)	0	Proximity to Load Center:	7.5 miles

HYDROLOGY

Average Annual Rainfall Variation:	80" to 200"
Streamflow Gage of Record: USGS#	4040
Diversion Location:	1.5 miles upstream of mouth
Average Discharge, Cfs:	35
Dependable Discharge, Cfs:	5

GEOLOGY

Location and Local Geology. The Pelekunu Stream drains the central portion of the east Molokai mountains. East Molokai mountain was built 1.5 million years ago over northwest and east trending rifts as an elongated basaltic shield-shaped dome. The geology is predominantly volcanic with lava basalt comprising the lower member while the upper member consists chiefly of andesite and trachyte. Alluvium covers the valley floor and walls to the 600-foot elevation level. Two large systems of several hundred dikes strike west and north 60° west across the valley.

Diversion Dam Site Location. The proposed diversion dam is located on alluvium that has been graded and terraced by ancient stands of the sea and consist of gravels and conglomerate in the stream channel. Due to the proximity of the Molokai fault zone, the proposed dam site would require analysis and review for seismic stability.

ECONOMIC DATA

PROJECT FIRST COST

Item	Unit	Unit Cost $	Qty	Cost $
Penstock	Ft	28	6,200	174,000
Power House	Kw	9,000	30	270,000
Access Road	Ft	22	6,200	136,000
Structure	Cy	170	3,900	662,000
Land	Ac	20,000	9	180,000
Subtotal				1,302,000
Contingency 25%±				303,000
Engr & Admin 12%±				195,000
TOTAL FIRST COST				1,800,000

ECONOMIC TEST

Annual Cost (Discount Rate = 6-5/8%, Period = 100 Yrs)	
Interest & Amortization :	119,000
Operation, Maintenance & Replacement:	11,000
TOTAL AVERAGE ANNUAL COST	130,000
Annual Benefit (Discount Rate = 10 Percent)	
Hydropower	14,000
Net Benefits :	(-) 116,000
Benefit/Cost Ratio :	0.1

COMPARABILITY TEST

Annual Cost, Total :	130,000
Annual Benefit (Discount Rate = 6-5/8%, Period = 100 Yrs)	
Hydropower :	12,000
Net Benefits	(-) 118,000
Comparability Ratio	0.1

SOCIAL DATA

	Facility		
	Dam	Penstock	Power Plant
Existing Land Use	Conservation	Conservation	Conservation
Ownership	Government	Government (1/3) Private (2/3)	Private

ENVIRONMENTAL DATA

(1)	Fish and Wildlife Values	
(a)	Listed or proposed endangered or threatened species and/or essential habitat	*
(b)	Commercial and recreational fishery resources and use	P,L
(c)	Natural intrinsic value of stream (abundance and diversity of endemic aquatic fauna)	H
(d)	National Wildlife Refuges	A
(e)	Natural Reserve Areas (State of Hawaii)	A
(f)	State and/or National Forest Reserve	P
(g)	Estuarine Sanctuaries	A
(2)	Historic, Scenic and Recreational Values	
(a)	Historic and Archeological Resources	*
(b)	County, State or National Parks	A
(c)	Wild and Scenic Rivers	A
(d)	Recreational Resources and Used (Fishing & Public Access)	L
(3)	Water Resources Values	
(a)	State Watershed Areas	P
(b)	Prime recharge areas	P,L
(c)	Agricultural use	A
(d)	Water Quality Standards, proposed usages	II

Explanation of Symbols

Occurrence or Presence within the drainage area
- P-Present
- A-Absent
- C-Candidate/Proposed
- L-Limited/Marginal
- *-Information not available

Relative value of resource or magnitude of use
- H-High
- M-Moderate
- L-Low

Status-use categories, Department of Health Proposed water quality Standards (1977)
- I-Pristine-Preservation
- II-Limited-Consumptive
- III-Exploitive - Consumptive
- IV-Construct - Alter

TRUE NORTH

LEGEND

POWERPLANT LOCATION

PENSTOCK

DIVERSION DAM LOCATION

DRAINAGE AREA BOUNDARY

SCALE

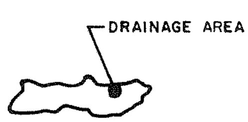
0 1/2 1 MILE

0 4000

2000 6000 FEET

CONTOUR LEVEL 40 FEET

DATUM IS MEAN SEA LEVEL



VICINITY MAP

ISLAND OF MOLOKAI

SUMMARY REPORT

HYDROELECTRIC POWER

SITE PLAN

PELEKUNU STREAM

RUN-OF-THE-RIVER

U.S. ARMY ENGINEER DISTRICT, HONOLULU

PLATE 1E

SECTION 1F

WAIHEE STREAM, MAUI
RUN-OF-THE-RIVER PLAN

TECHNICAL DATA

FACILITY FEATURES

Plant Capacity, KW:	350
Plant Factor, %:	100
Net Head, Ft:	241
Penstock Length, Ft:	4,400
Storage, AF: (to Top of Power Pool)	0

PHYSICAL FACTORS

Drainage Area, Sq. Mi.:	2.8
Stream Length, Mi.:	3
Average Gradient, Ft/Ft: (Crest to Plant)	0.25
Accessibility:	Poor
Proximity to Load Center:	2.5 miles

HYDROLOGY

Average Annual Rainfall Variation:	190" to 300"
Streamflow Gage of Record: USGS#	6120
Diversion Location:	3.9 miles upstream of mouth
Average Discharge, Cfs:	58
Dependable Discharge, Cfs:	23

GEOLOGY

Location and Local Geology. The Waihee River rises in a deep amphitheater headed canyon on the north central flank of the West Maui mountains. The mountains are mainly olivine basalt lavas from flows each about 15 feet thick, which are grouped together in the Wailuku Volcanic Series. Overlying the Wailuku Series are andesites and stiff trachytes that have been expelled from fissures and local vents. Fluvial sediments are found in and near the river.

Diversion Dam Site Location. The proposed low diversion dam would lie between elevations 1100 and 1200 feet where the canyon has widened to 300 feet. The general area of construction will be on alluvium that has been graded and terraced by ancient stands of the sea and consist of gravels and conglomerate in the stream channel. Several springs near the proposed dam sites would require hydrogeologic analysis.

ECONOMIC DATA

PROJECT FIRST COST

Item	Unit	Unit Cost $	Qty	Cost $
Penstock	Ft	147	4,400	647,000
Power House	Kw	3,500	350	1,225,000
Access Road	Ft	22	4,400	97,000
Structure	Cy	170	3,900	662,000
Land	Ac	20,000	9	180,000
Subtotal				2,811,000
Contingency 25%±				767,000
Engr & Admin 12%±				442,000
TOTAL FIRST COST				4,000,000

ECONOMIC TEST

Annual Cost (Discount Rate = 6-5/8%, Period = 100 Yrs)	
Interest & Amortization :	265,000
Operation, Maintenance & Replacement:	25,000
TOTAL AVERAGE ANNUAL COST	290,000
Annual Benefit (Discount Rate = 10 Percent)	
Hydropower	128,000
Net Benefits :	(-) 162,000
Benefit/Cost Ratio :	0.4

COMPARABILITY TEST

Annual Cost, Total :	290,000
Annual Benefit (Discount Rate = 6-5/8%, Period = 100 Yrs)	
Hydropower :	114,000
Net Benefits	(-) 176,000
Comparability Ratio	0.4

SOCIAL DATA

	Facility		
	Dam	Penstock	Power Plant
Existing Land Use	Conservation	Conservation	Conservation
Ownership	Private	Private	Private

ENVIRONMENTAL DATA

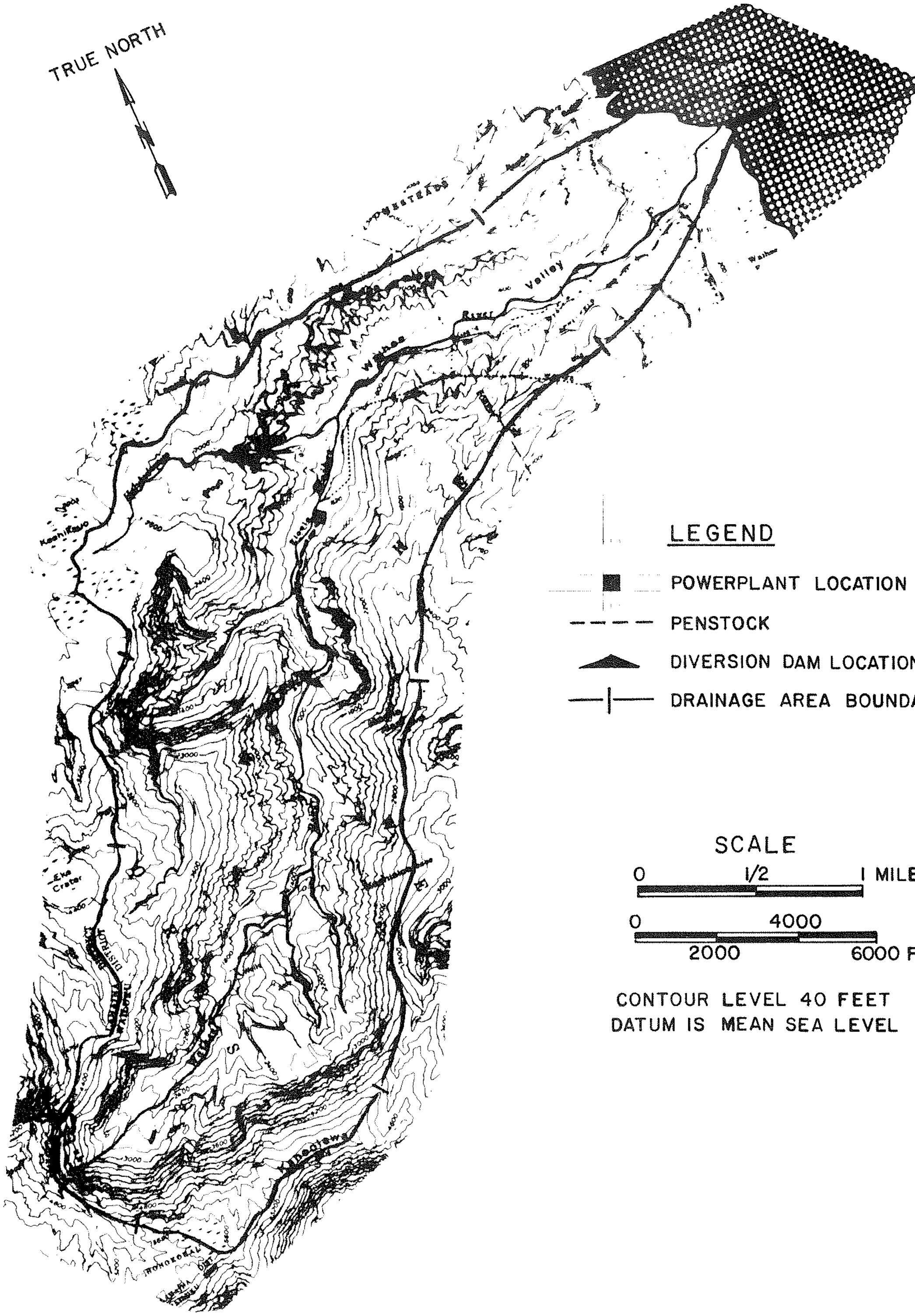
(1)	<u>Fish and Wildlife Values</u>	
	(a) Listed or proposed endangered or threatened species and/or essential habitat	P,L
	(b) Commercial and recreational fishery resources and use	P,L
	(c) Natural intrinsic value of stream (abundance and diversity of endemic aquatic fauna)	M
	(d) National Wildlife Refuges	A
	(e) Natural Reserve Areas (State of Hawaii)	A
	(f) State and/or National Forest Reserve	P
	(g) Estuarine Sanctuaries	A
(2)	<u>Historic, Scenic and Recreational Values</u>	
	(a) Historic and Archeological Resources	P,H
	(b) County, State or National Parks	A
	(c) Wild and Scenic Rivers	A
	(d) Recreational Resources and Used (Fishing & Public Access)	L
(3)	<u>Water Resources Values</u>	
	(a) State Watershed Areas	P
	(b) Prime recharge areas	P,M
	(c) Agricultural use	P,H
	(d) Water Quality Standards, proposed usages	II

<u>Explanation of Symbols</u>

Occurrence or Presence within the drainage area
- P-Present
- A-Absent
- C-Candidate/Proposed
- L-Limited/Marginal
- *-Information not available

Relative value of resource or magnitude of use
- H-High
- M-Moderate
- L-Low

Status-use categories, Department of Health
Proposed water quality Standards (1977)
- I-Pristine-Preservation
- II-Limited-Consumptive
- III-Exploitive - Consumptive
- IV-Construct - Alter



LEGEND

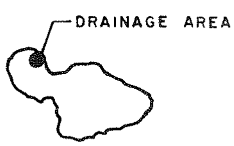
- ■ POWERPLANT LOCATION
- ---- PENSTOCK
- ▲ DIVERSION DAM LOCATION
- —|— DRAINAGE AREA BOUNDARY

SCALE

0 1/2 1 MILE

0 2000 4000 6000 FEET

CONTOUR LEVEL 40 FEET
DATUM IS MEAN SEA LEVEL



VICINITY MAP
ISLAND OF MAUI

SUMMARY REPORT
HYDROELECTRIC POWER

SITE PLAN
WAIHEE RIVER
RUN-OF-THE-RIVER

U.S. ARMY ENGINEER DISTRICT, HONOLULU

PLATE 1F

SECTION 1G

WAILOA RIVER (WAIPIO VALLEY), HAWAII
RUN-OF-THE-RIVER PLAN

TECHNICAL DATA

FACILITY FEATURES		PHYSICAL FACTORS	
Plant Capacity, KW:	550	Drainage Area, Sq. Mi.:	13.8
Plant Factor, %:	100	Stream Length, Mi.:	7.2
Net Head, Ft:	253	Average Gradient, Ft/Ft: (Crest to Plant)	0.11
Penstock Length, Ft:	11,000	Accessibility:	Good
Storage, AF: (to Top of Power Pool)	0	Proximity to Load Center:	18 miles

HYDROLOGY

Average Annual Rainfall Variation:	100" to 200"
Streamflow Gage of Record: USGS#	7322
Diversion Location:	3.9 miles upstream of mouth
Average Discharge, Cfs:	71
Dependable Discharge, Cfs:	33

GEOLOGY

Location and Local Geology. Waipio Valley is a steep sided canyon that has cut into the upper limb of the Kohala Volcano on the northern end of the Hamakua coast on the Island of Hawaii. The Kohala Volcano, which has built the northern part of the island is composed largely of rocks of the Pololu Volcanic Series which are dominantly olivine basalt with a few thin intercalated beds of vitric ash. Extensive dike swarms trending west northwest are located in the middle reaches of the stream system. Overlying the Pololu Series, and exposing an erosional unconformity, are the Hawi Volcanic Series.

Diversion Dam Site Location. The lower reaches of Waipio Valley represent suitable areas for low embankment dam construction. However, the abutments and dam foundation would rest on rocks of the Pololu Volcanic Series thus requiring a grout curtain and drainage filter system. In addition, any dam would require design provisions considering moderate seismic activity.

ECONOMIC DATA

PROJECT FIRST COST

Item	Unit	Unit Cost $	Qty	Cost $
Penstock	Ft	199	11,000	2,189,000
Power House	Kw	2,800	550	1,540,000
Access Road	Ft	22	11,000	242,000
Structure	Cy	170	6,550	1,114,000
Land	Ac	30,000	11	330,000
Subtotal				5,415,000
Contingency 25%±				1,373,000
Engr & Admin 12%±				812,000
TOTAL FIRST COST				7,600,000

ECONOMIC TEST

Annual Cost (Discount Rate = 6-5/8%, Period = 100 Yrs)		
Interest & Amortization	:	505,000
Operation, Maintenance & Replacement	:	35,000
TOTAL AVERAGE ANNUAL COST		540,000
Annual Benefit (Discount Rate = 10 Percent)		
Hydropower		208,000
Net Benefits	:	(-) 332,000
Benefit/Cost Ratio	:	0.4

COMPARABILITY TEST

Annual Cost, Total	:	540,000
Annual Benefit (Discount Rate = 6-5/8%, Period = 100 Yrs)		
Hydropower	:	182,000
Net Benefits		(-) 358,000
Comparability Ratio		0.3

SOCIAL DATA

	Facility		
	Dam	Penstock	Power Plant
Existing Land Use	Conservation	Conservation	Agriculture
Ownership	Government	Government (1/3) Private (2/3)	Private

ENVIRONMENTAL DATA

(1)	Fish and Wildlife Values	
(a)	Listed or proposed endangered or threatened species and/or essential habitat	P,L
(b)	Commercial and recreational fishery resources and use	P,H
(c)	Natural intrinsic value of stream (abundance and diversity of endemic aquatic fauna)	M
(d)	National Wildlife Refuges	A
(e)	Natural Reserve Areas (State of Hawaii)	A
(f)	State and/or National Forest Reserve	P
(g)	Estuarine Sanctuaries	A
(2)	Historic, Scenic and Recreational Values	
(a)	Historic and Archeological Resources	P,H
(b)	County, State or National Parks	A
(c)	Wild and Scenic Rivers	A
(d)	Recreational Resources and Used (Fishing & Public Access)	H
(3)	Water Resources Values	
(a)	State Watershed Areas	P
(b)	Prime recharge areas	P,H
(c)	Agricultural use	P,H
(d)	Water Quality Standards, proposed usages	II

Explanation of Symbols

Occurrence or Presence within the drainage area

- P-Present
- A-Absent
- C-Candidate/Proposed
- L-Limited/Marginal
- *-Information not available

Relative value of resource or magnitude of use

- H-High
- M-Moderate
- L-Low

Status-use categories, Department of Health
Proposed water quality Standards (1977)

- I-Pristine-Preservation
- II-Limited-Consumptive
- III-Exploitive - Consumptive
- IV-Construct - Alter

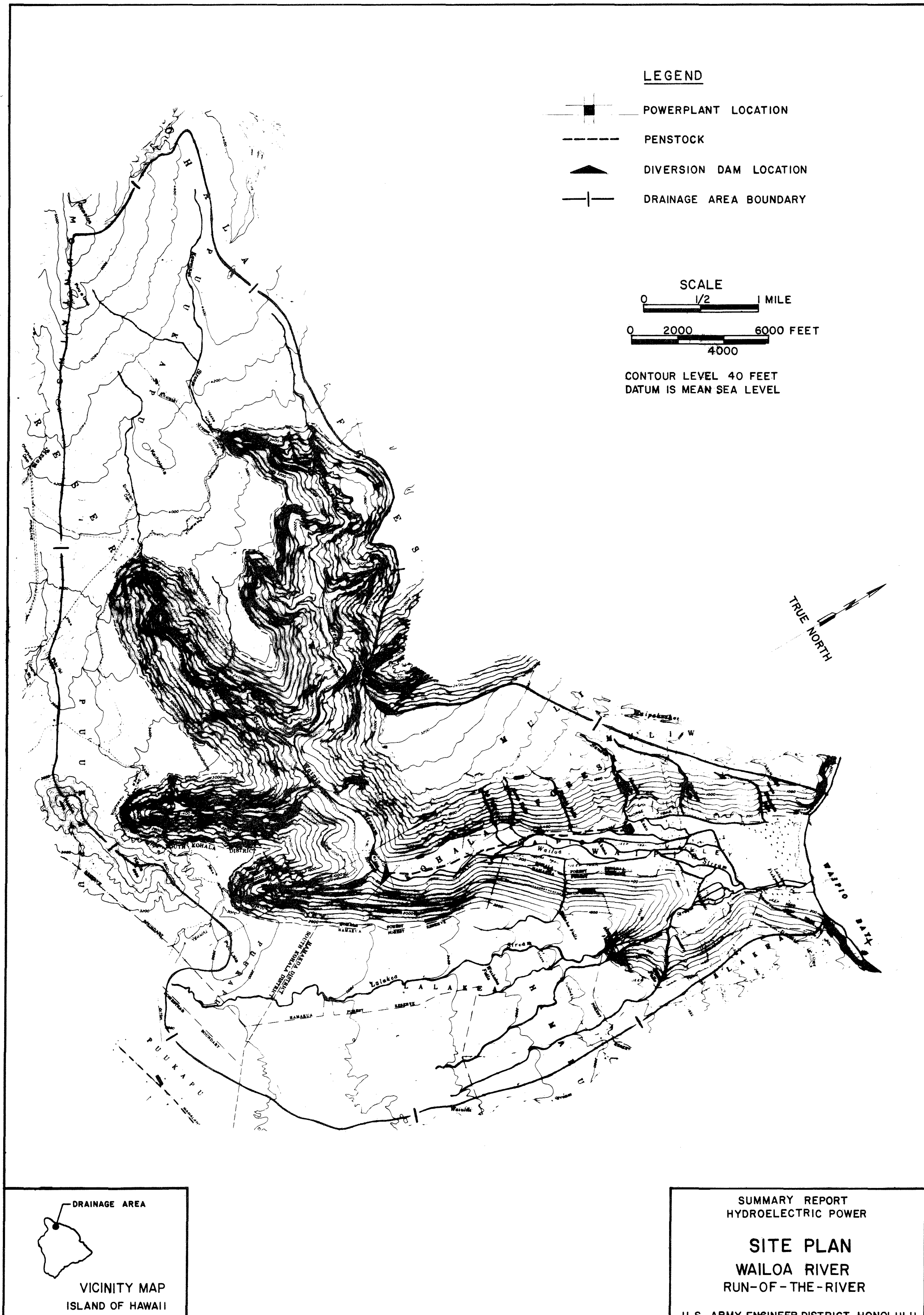

LEGEND
POWERPLANT LOCATION
PENSTOCK
DIVERSION DAM LOCATION
DRAINAGE AREA BOUNDARY
SCALE
0 1/2 1 MILE
0 2000 4000 6000 FEET
CONTOUR LEVEL 40 FEET
DATUM IS MEAN SEA LEVEL
TRUE NORTH
WAIPIO BAY
DRAINAGE AREA
VICINITY MAP
ISLAND OF HAWAII
SUMMARY REPORT
HYDROELECTRIC POWER
SITE PLAN
WAILOA RIVER
RUN-OF-THE-RIVER
U.S. ARMY ENGINEER DISTRICT, HONOLULU

PLATE 1G

APPENDIX 2

PERTINENT CORRESPONDENCE

SUMMARY REPORT
HYDROELECTRIC POWER - STATE OF HAWAII
APPENDIX 2 - PERTINENT CORRESPONDENCE

TABLE OF CONTENTS

HAWAIIAN ISLANDS

Hydroelectric Plant Power Values at Market
(Based on July 1, 1977 price levels)

Private Financing at 10% Interest

Hydro Plant Annual Capacity Factor %	Molokai 1/		Maui 1/		Hawaii 1/	
	Dependable Capacity $/kW-yr.	Usable Energy mills/kWh	Dependable Capacity $/kW-yr.	Usable Energy mills/kWh	Dependable Capacity $/kW-yr.	Usable Energy mills/kWh
10	122.96	19.29	81.50	4.43	100.95	8.35
20	"	30.12	"	20.11	"	21.51
30	"	33.72	"	25.33	"	25.89
40	"	35.53	"	27.95	"	28.09
50	"	36.61	"	29.51	"	29.40
60	"	37.33	"	30.56	"	30.28
70	"	37.85	"	31.31	"	30.91
80	"	38.23	"	31.87	"	31.38
90	"	38.54	"	32.30	"	31.74

1/ *Based on the cost of internal combustion alternative.*

HAWAIIAN ISLANDS

Hydroelectric Plant Power Values At Market
(Based on July 1, 1977 price levels)

Private Financing at 10% Interest

Hydro Plant Annual Capacity Factor %	Kauai 1/		Oahu 2/	
	Dependable Capacity $/kW-yr.	Usable Energy mills/kWh	Dependable Capacity $/kW-yr.	Usable Energy mills/kWh
10	100.95	7.62	44.83	35.38
20	"	21.25	"	32.78
30	"	25.79	"	31.92
40	"	28.06	"	31.48
50	"	29.42	"	31.22
60	"	30.33	"	31.05
70	"	30.98	"	30.93
80	"	31.47	"	30.83
90	"	31.85	"	30.76

1/ *Based on the cost of internal combustion alternative.*
2/ *Based on the cost of combustion turbine alternative.*

U S ARMY ENGINEER DISTRICT, HONOLULU
BUILDING 230
FT SHAFTER HAWAII 96858

PODED-PJ 1 June 1977

Mr. George R. Bell
Acting Regional Engineer
Federal Power Commission, Region IX
US Customhouse
San Francisco, California 94111

Dear Mr. Bell:

In Fiscal Year 1978, the Pacific Ocean Division of the Corps of Engineers is continuing a Survey Study for Hydroelectric Development in the State of Hawaii, under authority of Section 209 of the 1962 Flood Control Act. To evaluate power for project development purposes, it will be necessary to determine power values for various locations in the State of Hawaii. In view of your regulatory function and existing information on hydroelectric power, we request that your agency develop power values for the State of Hawaii. The following is a description of the requirements. The value of power should be determined with the following conditions:

a. Full range of capacity factors for 10 to 90 percent in 10 percent increments.

b. A Federal financing interest rate of 6-3/8 percent based on the price level of 1 January 1977.

c. Information on primary power in terms of ($/kw-yr) capacity and (mills/kwh) usable energy.

d. For secondary power, as in item c.

e. Comparable values for each of the principal islands of Kauai, Oahu, Molokai, Maui, and Hawaii.

f. The values should also be computed for "at site" and "at market" conditions for each island system.

g. The estimates for "at market" condition should indicate the basis for alternative costs.

The need to receive information on secondary power is of critical importance for this study. Although certain locations in Hawaii receive substantial rainfall annually, the relative small drainage areas and short durations of rainfall contribute to the intermittency of the streamflows. As a result, very low flows are experienced even among the largest streams and rivers. During periods of increased streamflows, the worth of secondary power becomes evident.

In the current plan of study stage, we have developed "An Inventory and Analysis of the Electric Energy Industry in the State of Hawaii" prepared by a local consultant. Inclosed is a copy for your use.

We would appreciate an estimated date when this information can be expected.

Sincerely yours,

1 Incl
As stated

F. M. PENDER
Colonel, Corps of Engineers
District Engineer

Cy Furn:
HQDA (DAEN-CWP-W) wo incl

DEPARTMENT OF ENERGY
FEDERAL ENERGY REGULATORY COMMISSION
~~FEDERAL POWER COMMISSION~~
REGIONAL OFFICE
U. S. CUSTOM HOUSE
SAN FRANCISCO, CA. 94111

November 29, 1977

Colonel F. M. Pender, District Engineer
Honolulu District, Corps of Engineers
Bldg. 230, Ft. Shafter
APO San Francisco 96558

Subject: Power Values for the State of Hawaii
(Your PODED-PJ)

Dear Colonel Pender:

In response to your letter of June 1, 1977, we are furnishing the attached power values. We understand that these values are to be used in your Survey Study for Hydroelectric Development in the State of Hawaii. Therefore, these values have been developed for preliminary studies of projects conforming to the list of "typical" installations received from Mr. Paul Mizue of your staff for the Islands of Oahu, Hawaii, Kauai, Maui, and Molokai.

The at-market power values are based on a July 1, 1977 price level and federal and private financing at 6-5/8% and 10% interest rates respectively. The estimated cost of the assumed alternative power source should be based upon the type of financing that would be expected to apply to the alternative plant that would be constructed in the absence of the proposed hydroelectric project. Thus, for the five islands, alternative power source estimates are based on private financing. Values for federal financing at 6-5/8% are also supplied at your request.

The at-market power values for the islands are based on the estimated costs of the thermal-electric alternatives as described below:

Molokai

(1) Internal combustion (diesel) plant with 1750 kW installed capacity operating at 45% average annual capacity factor; heat rate, 10,200 Btu/kWh; capital cost, $540 per kilowatt; service life, 35 years; and fuel oil cost of $2.90 per million Btu.

Maui

(1) Internal combustion plant with 40 MW total capacity consisting of two 20 MW units operating at 45% average annual capacity factor; heat rate, 9100 Btu/kWh; capital cost, $365 per kilowatt; service life, 35 years; and fuel oil cost of $2.90 per million Btu.

(2) Oil-fired steam-electric plant with 46 MW total capacity consisting of two 23 MW units operating at 55% average annual capacity factor; heat rate, 12,500 Btu/kWh; capital cost, $675 per kilowatt; service life, 30 years; and fuel oil cost of $2.25 per million Btu.

Hawaii and Kauai

(1) Internal combustion plant with 24 MW total capacity consisting of two 12 MW units operating at 45% average annual capacity factor; heat rate, 9100 Btu/kWh; capital cost, $440 per kilowatt; service life, 35 years; and fuel oil cost of $2.90 per million Btu.

(2) Oil-fired steam-electric plant with 23 MW capacity (one unit) operating at 55% average annual capacity factor; heat rate, 12,500 Btu/kWh; capital cost, $675 per kilowatt; service life, 30 years; and fuel oil cost of $2.25 per million Btu.

Oahu

(1) Oil-fired steam-electric plant with 260 MW total capacity consisting of two 130 MW units operating at 55% average annual capacity factor; heat rate, 9900 Btu/kWh; capital cost, $480 per kilowatt; service life, 30 years; and fuel oil cost of $2.25 per million Btu.

(2) Combined cycle generating plant with 200 MW total capacity consisting of two 100 MW units operating at 25% average annual capacity factor; heat rate, 8500 Btu/kWh; capital cost, $300 per kilowatt; service life, 30 years; and fuel oil cost of $2.90 per million Btu.

(3) Combustion turbine generating plant with 210 MW total capacity consisting of three 70 MW units operating at 7½% average annual capacity factor; heat rate, 12,000 Btu/kWh; capital cost, $205 per kilowatt; service life, 30 years; and fuel oil cost of $2.90 per million Btu.

Project power values are given in terms of $/kW-yr. per unit of dependable capacity and mills/kWh for usable average annual energy output. The values of usable energy are the same for both "primary" and "secondary" energy production. Hydro-thermal capacity and energy value adjustments are reflected in the estimates. "At market," as used in this study, refers to a point on the high-voltage side of the alternative step-up substation. As previously noted, these at-market values have been developed for preliminary studies. Upon request, these values can be modified to be directly applicable to any specific hydro project. A hydro project's installed capacity, operating capacity factor, and location are among the elements which affect the power value computation. Given the proposed size and location of a project, "at-site" power values can be calculated to include transmission costs from the site to the power market. Also, specific size and capacity factor information will result in a more accurate energy value. If a particular proposed hydro project has no dependable capacity you may need a value of thermal displacement which this office can provide.

These power values are subject to Washington Office approval. Please do not hesitate to contact us if there are any questions concerning these estimated values.

Very truly yours,

Eugene Neblett
Acting Regional Engineer

Attachments (2)

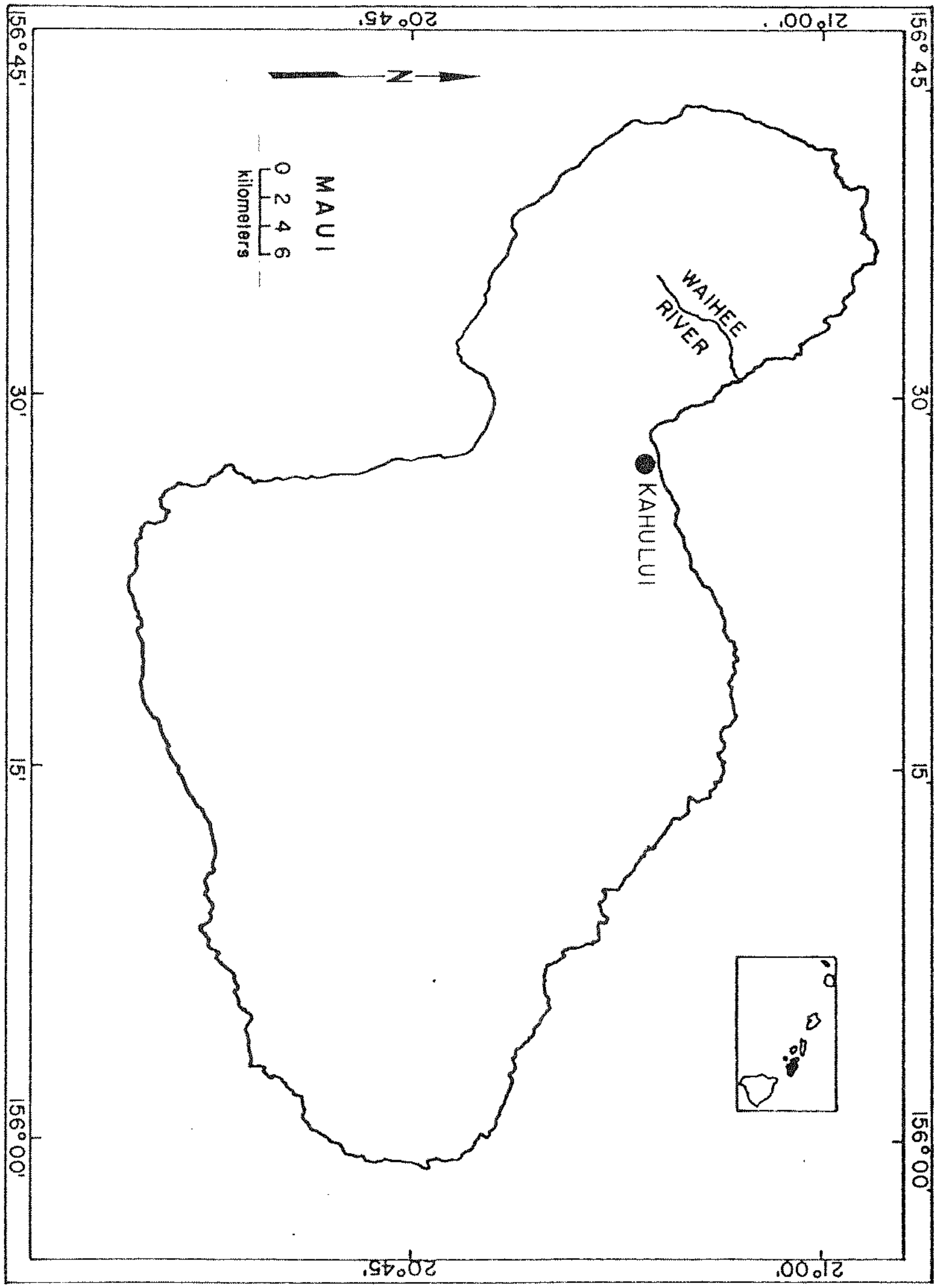


Figure 4. Location of Waihee River on the Island of Maui.

At present, the Waihee River is diverted at two sites. At the time of this study, the total river flow was being diverted at the Waihee Tunnel. Flows gradually accumulated below this point from groundwater seepage, springs and tributary inflow. This flow was completely diverted into the Spreckels Ditch. Some flow was returned to the riverbed from the drainage of taro fields beginning at approximately 2 km. from the river's confluence with the Pacific Ocean.

Materials and Methods

Sampling Stations

The number of sampling sites varied for the two streams surveyed. Six sites were sampled on the main stem of the Lumahai River. Additional sampling was done on a small tributary less than 0.7 m. wide to obtain species composition and abundance data only. Eight sites were sampled on the Waihee. These sites were selected to provide stream faunal information for both the main stem and tributary sections. For the Waihee River, approximately one-third of tne sites were at high elevations, one-third at mid elevations, and one-third at low elevations, with respect to the potential diversion site. High flows and lack of safe access prevented upper elevation sampling on the Lumahai River within the study's time frame. However, the two stations sampled immediately below the diversion site should provide a good estimate of the composition and abundance of macrofauna both within and above this point. Location of the sampling stations and the proposed dam site and power plant for the Lumahai and Waihee River are shown in Appendices A and B respectively.

Biological

For comparative purposes, sampling methods and data presentation follows the format used by Timbol (1977). Collecting was done along a 20 x 1 meter transect starting at the lower limit of the transect line. Stream macrofauna was collected with a battery-energized backpack electrofishing unit. While this is generally the best method of collecting mobile Hawaiian stream life, high flows on Lumahai River prevented effective biomass sampling. The unit was too cumbersome to transport to the more remote

HAWAIIAN ISLANDS

Hydroelectric Plant Power Values At Market
(Based on July 1, 1977 price levels)

Federal Financing at 6-5/8% Interest

Hydro Plant Annual Capacity Factor %	Molokai 1/		Maui 1/		Hawaii 1/	
	Dependable Capacity $/kW-yr.	Usable Energy mills/kWh	Dependable Capacity $/kW-yr.	Usable Energy mills/kWh	Dependable Capacity $/kW-yr.	Usable Energy mills/kWh
10	67.69	19.29	42.44	4.43	52.20	8.35
20	"	30.12	"	20.11	"	21.51
30	"	33.72	"	25.33	"	25.89
40	"	35.53	"	27.95	"	28.09
50	"	36.61	"	29.51	"	29.40
60	"	37.33	"	30.56	"	30.28
70	"	37.85	"	31.31	"	30.91
80	"	38.23	"	31.87	"	31.38
90	"	38.54	"	32.30	"	31.74

1/ *Based on the cost of internal combustion alternative.*

HAWAIIAN ISLANDS

Hydroelectric Plant Power Values At Market
(Based on July 1, 1977 price levels)

Federal Financing at 6-5/8% Interest

Hydro Plant Annual Capacity Factor %	Kauai 1/		Oahu 2/	
	Dependable Capacity $/kW-yr.	Usable Energy mills/kWh	Dependable Capacity $/kW-yr.	Usable Energy mills/kWh
10	52.20	7.62	40.97	12.02
20	"	21.25	"	21.10
30	"	25.79	"	24.12
40	"	28.06	"	25.63
50	"	29.42	68.95	20.14
60	"	30.33	"	21.11
70	"	30.98	"	21.80
80	"	31.47	"	22.32
90	"	31.85	"	22.73

1/ *Based on the cost of internal combustion alternative.*
2/ *Based on combined cycle alternative for 10 to 40% hydro capacity factor and on oil-fired steam-electric plant alternative for 50% hydro capacity factor and above.*

United States Department of the Interior

FISH AND WILDLIFE SERVICE
300 ALA MOANA BOULEVARD
P. O. BOX 50167
HONOLULU, HAWAII 96850

IN REPLY REFER TO:
ES

Division of Ecological Services
Room 6307

September 8, 1979

Colonel Peter D. Stearns
U.S. Army Engineer District Honolulu
Building 230
Fort Shafter, Hawaii 96858

Re: Hydroelectric Power Study, Hawaii

Dear Sir:

This report presents the results of the U.S. Fish and Wildlife Service's aquatic macrofauna survey of the Lumahai River, Island of Kauai, and the Waihee River, Island of Maui, Hawaii.

This survey was performed to provide biological data for the preliminary evaluation of the impacts of hydroelectric power development on these two rivers as part of an initial feasibility study undertaken by the U.S. Army Corps of Engineers. Based on the results of this feasibility study, hydroelectric power development proposals may be transmitted by the U.S. Army Corps of Engineers to the Department of Energy for further review.

The information presented in this report supplements the findings and analyses of an earlier aquatic survey of four river systems, three on the Island of Kauai (the Hanalei, Wainiha and the North Fork Wailua River) and the Wailoa River on the Island of Hawaii, conducted by consultants for the U.S. Army Corps of Engineers (Timbol 1977).

Both of these surveys were a one-time, one-season assessment of the stream macrofauna of these waterways. They by no means present a complete picture of their biological potential.

This report has been prepared under the authority of and in accordance with the provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended, 16 U.S.C. 661 et seq.) and other authorities mandating Department of Interior concern for environmental values. It does not include a full assessment of the biological impacts of the proposed hydroelectric power development. Therefore, this report does not fulfill Section 2(b) of the Fish and Wildlife Coordination Act. Should this project be undertaken by the Department of Energy, additional analyses will have to be completed by the Fish and Wildlife Service to fulfill the requirements of this Act. The U.S. Fish and Wildlife Service will request additional funding from the Department of Energy at that time.

The Proposed Project and Study Area

Proposed Project

The U.S. Army Corps of Engineers identified two potential hydroelectric power plant and diversion sites, one each on the Lumahai River, Island of Kauai, and Waihee River, Island of Maui.

On the Lumahai River, the potential hydroelectric power plant was sited at about 1.8 miles (2.9 km.) from its confluence with the Pacific Ocean, just above the existing power line. The diversion site was located at about 4.2 miles (6.8 km.) from the river's mouth. An access road was proposed for the east bank of the river following roughly an existing pig hunter trail.

On the Waihee River, the hydroelectric power plant was sited preliminarily at the existing Waihee Tunnel diversion. A diversion site was located approximately 3.4 miles (5.5 km.) from the river's confluence with the Pacific Ocean. A potential access road to the diversion site was located on the east bank of the river.

Because of the preliminary nature of this feasibility study, no diversion pool contour limits, release schedules or additional data required to fully evaluate the impact of hydroelectric power development on the biota of and surrounding these streams was transmitted at the time this report was submitted.

Drainage Basin Characteristics

Lumahai River

The Lumahai River drains the Lumahai Valley on Kauai (Figure 1). The extent of its drainage area is delineated in Appendix A. Its headwaters originate approximately at the 930 meter elevation and flow a distance of about 15.7 km. A channel profile is shown in Figure 2. Due to the unavailability of current flow data, the mean annual discharge of 107.34 cfs (3.04 m^3/s) is a five-year average of river discharge rates taken during the period spanning July 1925 to June 1930 (USGS 1926, 1927, 1928, 1929, 1930). There are no diversions to the river's main channels. Its flow regime is moderate but erratic as compared with the Wailoa, Wainiha, Hanalei, and Waihee Rivers (Timbol, 1977). Peak discharges occur during the months of April, June, November and December (Fig. 3). An estuary extends about 1 km. upstream. The lower river valley approximately 3 km. from the mouth of the river, is well drained and used for cattle grazing. The interior portion is forested and is commonly inhabited by feral pigs.

Waihee River

Waihee River drains Waihee Valley on Maui (Fig. 4). Appendix B delineates the drainage basin. Its headwaters originate at the 1280 m. elevation. The main channel is about 19 km. in length. The main channel's profile is shown in Figure 2. Current river flow data for the mainstem is unavailable, therefore a five-year average of river discharge rates obtained from a gage located above the Waihee Tunnel diversion was calculated to show a mean annual discharge of 146.5 cfs (4.15 m^3/s) (USGS, 1913, 1914, 1915, 1916, 1917).

As compared with the Lumahai, Wailoa, Wainiha, and Hanalei Rivers, its flow regime is relatively low and irregular (Timbol 1977). May, June and September are months of high discharge (Fig. 3).

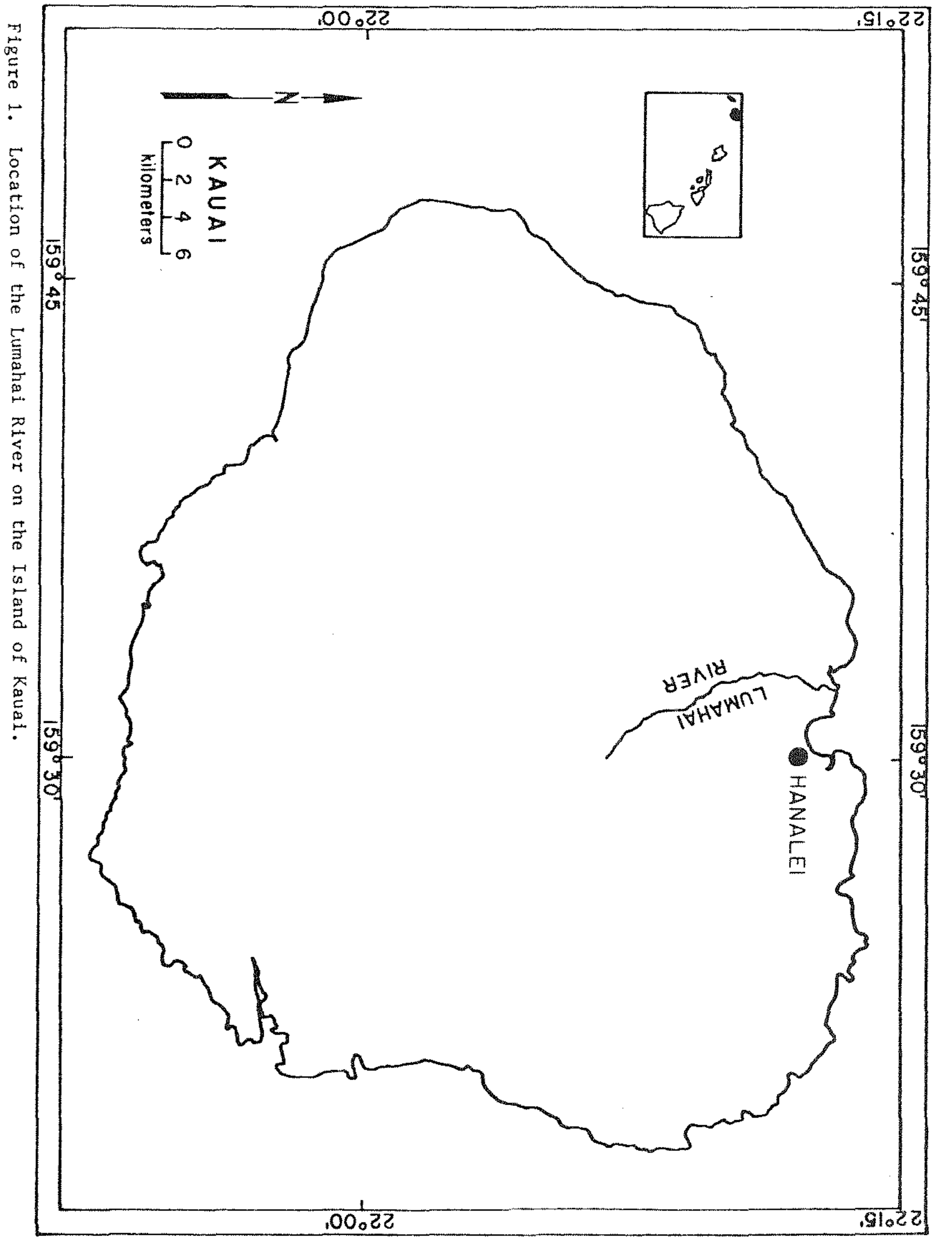


Figure 1. Location of the Lumahai River on the Island of Kauai.

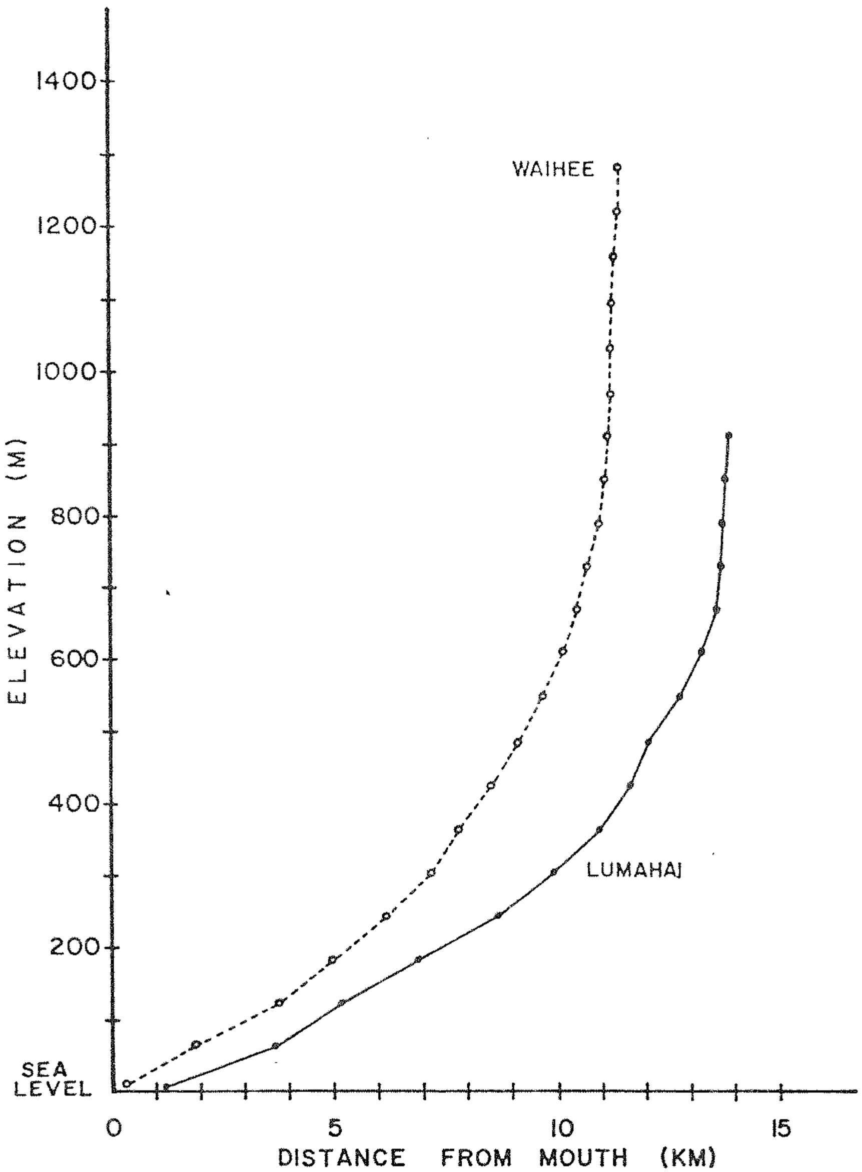


Figure 2. Profiles of the Lumahai River Island of Kauai and the Waihee River, Island of Maui. Slope Slope gradient (m/km): Lumahai = 68, Waihee = 125.

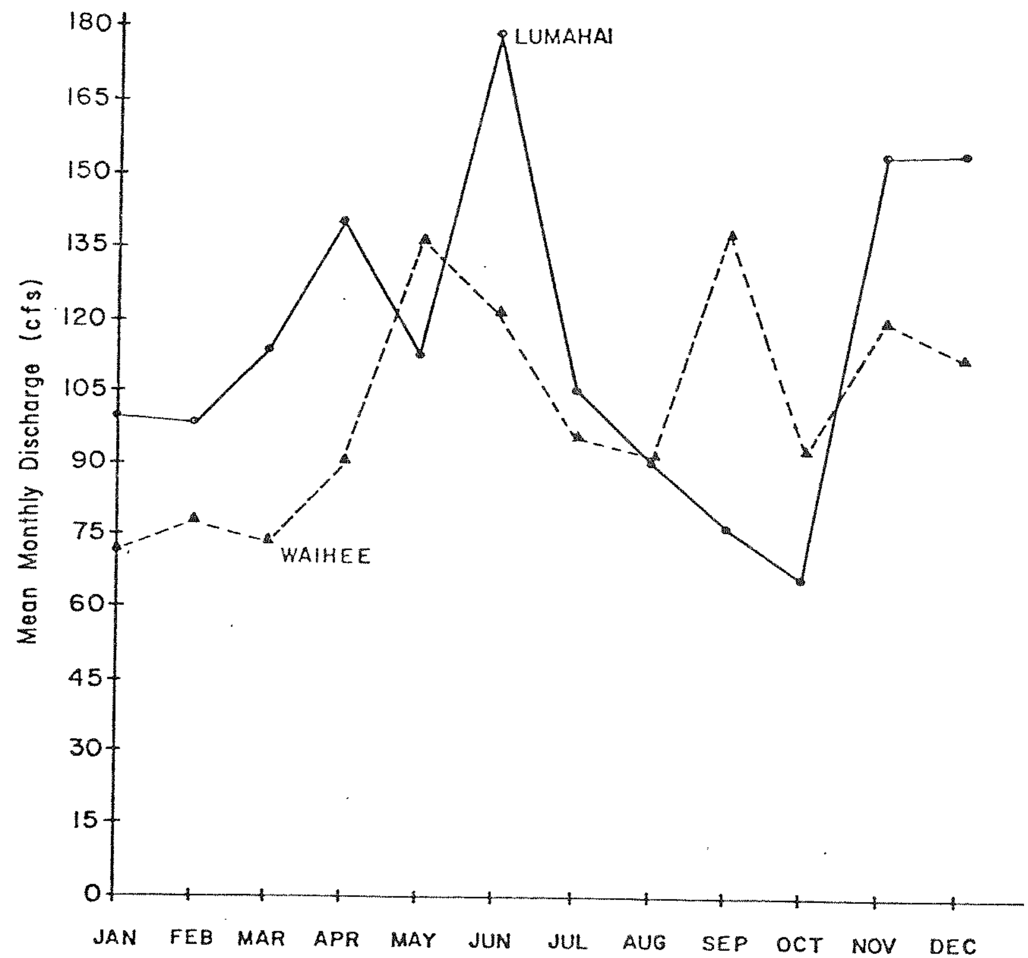


Figure 3. Monthly patterns of discharge at Lumahai River, Island of Kauai, and Waihee River, Island of Maui. (Data taken from USGS 1925, 1926, 1927, 1928, 1929, 1930 for the Lumahai River; and USGS 1913, 1914, 1915, 1916, 1917 for the Waihee River. $\overline{x}$ monthly flow = $\overline{x}$ of monthly flows for these periods respectively).

sites. Therefore abundance counts at these stations were made using a face mask.

Additional observations and counts were made adjacent to the transect line to obtain a more complete species list. These observations were included in the macrofauna but not in the calculation of diversity indices.

Water depths exceeding 5 meters were encountered at site 6 on the Lumahai River. Therefore sampling at this site was limited to observations made by Ecological Services biologists and Dr. John Maciolek (U.S. Fish and Wildlife Service, University of Hawaii Cooperative Fishery Unit). They are included in the abundance table for this watershed, but were not used to compute diversity indices. Mollusks were hand collected within the transect, using a face mask for sighting. These specimens were identified in the field, counted and measured alive for volume to the nearest milliliter and released in the stream.

Macrobenthos were sampled with a modified surber sampler. The surber net extended downstream of a 0.2 m^2 frame from which the collection was made. Large stones were picked up, scraped and discarded and the substrate was thoroughly agitated to wash any burrowing forms into the net. Samples taken were identified and measured volumetrically using the displacement method. Measurements were taken to the nearest milliliter.

References used to identify macrobenthic insects were Wirth (1046) and Cowles (1977). Macrobenthos data presented in the results and appendices are for 20 m^2.

In Tables 2 and 3, abundances are illustrated as:

●	=	abundant, specimens collected range from 6 to 100.
◐	=	common, specimens collected range from 2 to 5.
○	=	uncommon, only one specimen was collected.

None of the species sampled are listed or have been formally proposed for Federal Endangered Species status in accordance with regulations set forth in the Endangered Species Act of 1973. However, one species, o'opu alamo'o (<u>Lentipes concolor</u>) has been recommended for listing by Dr. John Maciolek. In addition, this and several other species of stream macrofauna have been recognized in recent literature as being "depleted" and/or "rare", (Miller 1972, Maciolek in press). For the purposes of this report, these terms are defined as follows:

Depleted =	The organism is still found in numbers adequate for survival although it has been depleted and continues to decline substantially (Miller 1972).
Rare =	Equivalent to uncommon, occurs in small numbers (Miller 1972).

Number and biomass diversity indices were calculated using the Shannon-Wiener index presented in Pielou (1975):

$$H' = -\sum p_i \log p_i$$

Where p_i = proportion of the i^{th} species in the sample
log = natural logarithm

Results and Discussion

Hawaii's native stream biota are characterized by a high degree of endemicity. This is readily seen in its macrofaunal components (Table 1). Because Hawaii's native stream macrofauna are good indicators of the biological 'health and wealth' of this ecosystem, and are observed readily, their abundance in species richness and numbers was evaluated to assist in determining the comparative biological value of streams included in this and Timbol's (1977) survey.

Several of Hawaii's native stream macrofauna have diadromous life cycles involving passive larval migration to the sea where they pass through a developmental cycle and return as post larvae to the stream habitat from whence they originated. These species include the gobies (o'opu),

Table 1. Characteristic aquatic macrofauna of large Hawaiian streams (Adapted from Timbol 1977).

Scientific Name	Common Name	Status
Annelids (worms)		
Nemalycastis abiuma	polychaete worm	indigenous
Hirudinea	leech	unknown
Insects		
Coleoptera:		
Dytiscidae	water bettles	endemic
Diptera:		
Chironomidae	midges	endemic
Tipulidae	craneflies	endemic
Odonata:		
Anax strenuus	dragonfly	endemic
Megalagrion heterogamius	damselfly	endemic
Megalagrion nigrohaumatum	damselfly	endemic
Megalagrion blackburni	damselfly	endemic
Trichoptera:		
Cheumatopsyche analis	caddisfly	introduced
Mollusks		
Helisoma duryi	flat snail	introduced
Melania sp.	thiarid snail	indigenous
Neritina granosa	hihiwai	endemic
Pseudisidora rubella	pond snail	endemic
Crustaceans		
Atya bisulcata	opae kala'ole	indigenous
Macrobrachium grandimanus	opae oeha'a	endemic
Macrobrachium lar	Tahitian prawn	introduced
Procambarus clarkii	crayfish	introduced
Fishes		
Awaous genivittatus	o'opu naniha	indigenous
Awaous stamineus	o'opu nakea	endemic
Clarias fuscus	Chinese catfish	introduced
Eleotris sandwicensis	o'opu okuhe	indigenous
Gambusia affinis	mosquito fish	introduced
Kuhlia sandvicensis	aholehole	endemic
Lentipes concolor	o'opu alamo'o	endemic
Lepomis macrochirus	bluegill sunfish	introduced
Micropterus dolomieui	smallmouth black bass	introduced
Misgurnus anguillicaudatus	dojo	introduced
Poecilia reticulata	wild guppy	introduced
Sicydium stimpsoni	o'opu nopili	endemic
Tilapia mossambica	Tilapia	introduced
Xiphophorus helleri	swordtail	introduced

shrimp (opae) and a mollusk (hihiwai). Their distribution within perennial streams varies. For example the goby o'opu alamo'o (Lentipes concolor) is found in small streams at high elevations whereas o'opu naniha (Awaous genvittatus) is restricted to lower elevations. Access to the entire stream system is mandatory for the continued perpetuation of Hawaii's full complement of diadromous species.

Since the advent of occidental man, stream ecosystems have been subject to significant disturbance through direct alteration and destruction (diversion, channelization), pollution (agricultural, industrial, and domestic), the introduction of exotic species and overharvest. Timbol and Maciolek (1976) found that of a total of 27 species found in Hawaii streams, only 11 were native. Both native and introduced stream macrofauna provide fishing opportunities for recreation and food (Titcomb 1972). However, it appears that several introduced species may prey on native stream fauna particularly diadromous macrofauna having a juvenile migratory stage (Tomihama 1972, Couret 1976). Although the destructive results of these factors have been studied and reported, relatively little is known about the biological requirements of Hawaii's stream macrofauna (Timbol and Maciolek 1978, U.S. Fish and Wildlife Service 1977).

As noted earlier, the results of this survey, as Timbol's (1977), are based on a one time, one season sampling effort at each station. Although the data gathered provides some indication of the biota currently inhabiting these streams, it does not, in some cases, display their biological potential. For example, during the 1960's, electroshocking efforts on the Waihee River just below the Spreckels Tunnel diversion yielded several o'opu nakea in excess of 8 inches (Maciolek, p.c.). Although water was diverted during this period, flows were sufficient to maintain riverine habitat in the river reaches below both diversions (Maciolek, p.c.). During the course of this study, the riverbed immediately below both diversions was dry except for isolated pools.

Fauna Inventory

An inventory of aquatic stream macrofauna was prepared from data collected during this study. This information is presented in Appendices C and D for the Lumahai River and Waihee River, respectively.

In the Lumahai River, 11 of the 17 organisms found are native to Hawaii's streams. Awaous stamineus (o'opu nakea) and Sicydium stimpsoni (o'opu nopili), listed as depleted and rare, respectively (Miller 1972), were found in abundance. The native mollusk, Neritina granosa (hihiwai) also found in great abundance in the Lumahai, is considered depleted in Hawaiian streams (Maciolek, in press).

In the Waihee River, 8 of the 13 species found are native. As in the Lumahai Stream, o'opu nakea (depleted) and o'opu nopili (rare) were found. In addition, juvenile Lentipes concolor (o'opu alamo'o) were observed to be relatively abundant in the isolated pools located in upper portion of Station 7. This species has been recognized as rare and endangered by Miller (1972) and Maciolek (in press) and has been recommended for listing as a federally-declared endangered species. During the course of Timbol's (1977) and the Service's surveys for the potential hydroelectric development study, the Waihee River is the only stream in which this species was found. However, Shima (p.c.) indicated that Lentipes had been found in the Lumahai River during stream macrofauna surveys performed by Hawaii Division of Fish and Game during the mid - 1960's.

As noted in Timbol (1977) electroshocking as a sampling method produces variable results. Its success is dependent upon the sensitivity of the species, water depth and quality, and the ability of the collector to capture these animals, particularily those able to escape from the study area or those hiding under cover. Some species such as Hawaii's native and introduced crustacea and o'opu okuhe (Eleotris sandwicensis) are sensitive to shocking as a collection method. However, the remaining gobies often were observed fleeing the sample area, particularily in the deep, rapidly flowing Lumahai River. Therefore their biomass was underestimated significantly.

Lumahai River

The distribution and abundance of stream macrofauna are presented in Table 2. The Lumahai River is characterized by three distinctive features, the abundance of native stream fauna, limited introduced species, and its lower, apparently seasonal, estuary.

Table 2. Distribution and abundances of macrofauna in Lumahai River and tributaries, Island of Kauai, July 1978. Abundances : - = abse 0 = uncommon, ◐ = common, ● = abundant

	Sampling Stations Relative To Dam						
	Immediate Below			Mid Elev.		Low Elev	
	1	Trib	2	3	4	5	6
Species Elevation (m/msl)	114	91	102	11 -	6	6 -	70
Insects							
Native							
Diptera							
Chironomidae	●	–	●	–	–	–	–
Odonata							
Megalagrion heterogamius	●	–	–	–	–	–	–
Exotic							
Trichoptera							
Cheumatopsyche analis	●	●	●	●	●	●	–
Mollusks							
Native							
Neritina granosa	●	–	●	●	●	●	–
Pseudisidora rubella	–	◐	–	–	–	–	–
Theodoxus vespertina	–	–	–	–	–	–	●
Crustaceans							
Native							
Atya bisulcata	●	◐	●	–	–	–	–
Macrobrachium grandimanus	–	–	–	◐	◐	◐	–
Exotic							
Macrobrachium lar	–	–	–	●	●	●	●
Fishes							
Native							
Awaous genivittatus	–	–	–	●	●	●	–
Awaous stamineus	●	–	●	●	●	●	●
Sicydium stimpsoni	◐	–	◐	◐	–	–	–
Eleotris sandwicensis	–	–	–	●	●	●	●
Kuhlia sandwicensis	–	–	–	●	–	●	●
Exotic							
Xiphorous helleri	–	–	–	●	–	●	–
Amphibians							
Rana catesbeiana	●	◐	●	●	●	●	●
Bufo marinus	–	–	–	–	●	–	–

Table 5. Cont'd

Potential Impact	Magnitude	Duration	Areal Extent
6. Should the dam/pool act as a trap, nutrients required to maintain downstream productivity may be depleted from the stream system.	L	L	B
7. Should a pool be created, insolation could result in increased downstream and estuarine temperatures (Lekmkuhl 1972). Diadromous species such as o'opu naniha and o'opu hakea have exhibited a low tolerance when exposed to a high temperature for an extended period (Maciolek and Timbol 1977).	M	L	B
8. Riparian clearing would result increased insolation of stream habitat. This could be particularily critical during low flow periods when stream macrofauna may be confined to isolated pools within the stream.	L-M	L	W,B
9. Water level fluctuations resulting from project operation could prevent stabilization of the pool and limit its biological productivity (Hynes 1961, Estes 1972, Hunt and Jones 1972).	H	L	W
10. Since diadromous species orientation is positively rheotaxic, flow releases at the proposed power plant could result in entrainment of upstream migrating juvenile organisms (Boreman 1977).	H	L	A,W

Table 5. Cont'd

Potential Impact	Magnitude	Duration	Areal Extent
11. Increased mixing and pressure could cause nitrogen supersaturation at and below the turbines. This could result in fish kills below the plant site.	L	L	B
12. A long, deep lake behind the dam could also prevent orientation of diadromous organisms migrating upstream (Spence and Hynes 1971 a,b).	H	L	A,W
13. Alteration in river flow regimes could prevent orientation and upstream migration of native diadromous species including o'opu (gobies), opae (freshwater shrimp) and hihiwai (freshwater mollusk). There is virtually no information available on key flows required for upstream migration by these organisms.	H	L	A,W,B
14. Alteration of streamflow regime, particularily in the Lumahai River, could alter the estaurine salinity pattern. As noted earlier, the 'cueing' needs for upstream migration of diadromous species are unknown at the present time. The maintenance of an estuarine 'barrier' such as found in the lower portion of the Lumahai River could prevent or reduce upstream migration of diadromous fauna.	H	L	A,W,B

The introduced caddisfly (Cheumatopysche analis) was found at Stations 1 through 5, including the tributary site. However, the damselfly (Megalagrion heterogamius) only was found at Station 2. Stream macrofauna sampling in the small tributary station revealed the only observed specimens of the endemic pond snail, Pseudisidora rubella.

Atyid shrimp, hihiwai, o'opu nakea, and the introduced caddisfly were extremely abundant at the two upper stations. Several of the o'opu nakea were estimated to be over 8" and one large individual, approximately 12". O'opu nopili was also observed, but in fewer numbers, at both upper Stations 1 and 2 and in the mid-Station 3. Hihiwai found at Stations 1 and 2 represented the smoother-shelled form of this species associated with their mid-elevation distribution in river systems.

The Tahitian prawn (Macrobrachium lar), opae oeha'a (Macrobrachium grandimanus), o'opu naniha, o'opu okuhe, and aholehole (Kuhlia sandwicensis) were not found above Station 3. Similarily the introduced swordtail (Xiphophorus helleri) was limited to deep pools and quiet water in and below this station. Hihiwai collected at Stations 3-5 were "rough" shell variety. In addition to adults of this species, migrating young were found in abundance (over 50 per 8 inch stone) though in spotty distribution at Stations 3-5.

O'opu okuhe were collected in greatest number at Station 5 and were frequently observed in the lower estuarine area.

Although salinity readings ranged between 0-0/00 and 1.0-0/00 at Site 6, the presence of the shells of Theodoxus vespertina (brown wi), a species generally confined to brackish water, and marine polychaete worm tubes, indicate that the river reach in and below this station is a seasonal estuary. The bodies of spawned out o'opu nakea, as well as live individuals, were observed in this reach. Aholehole also were observed here. Large bullfrog tadpoles were collected or observed at all the sample stations.

Waihee River

Distribution and abundance of stream macrofauna in this river are presented in Table 3. Two distinctive features

Table 3. Distribution and abundances of macrofauna in the Waihee River and tributaries, Island of Maui, July 1978. Abundances: — = absent, 0 = uncommon, θ common, ● = abundant.

	Sampling Stations Relative to Dam							
	Above	Within	Middle			Low Elevation		
	1	2	3	4	5	6	7	8
Species Elevation (m/msl)	250	216	182	—	159	91	91-80	23
Annelids (unknown origin)								
Hirudinea	—	—	—	—	—	●	—	—
Insects								
Native								
Diptera								
Chironomidae	●	●	●	θ	●	●	—	—
Odonata								
Megalagrion blackburni	θ	θ	—	—	—	—	—	—
Megalagrion nigrohaumatum	θ	θ	—	—	—	—	—	—
Anax strenuus	—	—	—	—	θ	—	—	—
Exotic								
Trichoptera								
Cheumatopsyche analis	●	●	●	●	●	●	●	●
Crustaceans								
Native								
Atya bisulcata	●	●	●	●	●	●	●	●
Exotic								
Macrobrachium lar	—	—	—	θ	●	●	●	●
Fishes								
Native								
Awaous stamineus	—	—	—	—	—	—	θ	θ
Sicydium stimpsoni	—	—	—	—	—	—	●	—
Lentipes concolor	—	—	—	—	—	—	●	—
Exotic								
Poecilia reticulata	—	—	—	—	—	—	—	●
Exotic								
Amphibians								
Rana catesbeiana	—	—	—	—	●	—	—	—

are seen: Of all the streams surveyed during this study, including Timbol (1977), this is the only one in which the rare and endangered* o'opu alamo'o (Lentipes concolor) was observed, and no mollusks were seen. The impacts of the two diversions on stream habitat also were observed.

The stream habitat of the Waihee River has been affected significantly by stream diversion. The stream is completely dewatered during low-flow periods as was observed in the course of this survey. Not only is aquatic habitat lost, but upstream migration of diadromous species is significantly impaired for many of these crustaceans and fish. No fish were seen above the Spreckel's diversion except for one o'opu sighted just below the Waihee Tunnel diversion. Isolated pools below the Spreckels diversion (Site 7) contained the largest number and diversity of fish observed during the Waihee River survey. Both adult o'opu nakea and o'opu nopili and juvenile o'opu alamo'o were collected. The greatest concentration of juvenile o'opu alamo'o was located in a pool at the base of the Spreckels Tunnel diversion. Of the pools located below the Spreckels diversion, those nearest the dam contained the greatest abundance of macrofauna. Between the Spreckels and Waihee Tunnel diversions opae kala'ole (Atya bisulcata) and Tahitian prawn were collected. Tahitian prawn were limited to a few large (15 cm) specimens. These two crustacea also were found below the Spreckels Tunnel diversion. No opae oeha'a were observed at any of the sampling stations in this river system. This may have resulted from one or a combination of factors. Limited flows in some sections and no flow in others may have prevented their habitation of the stream at this time. In addition, predation by and competition with the Tahitian prawn may have contributed to the decline of opae oeha'a populations.

Macrofauna above the Waihee Tunnel diversion was limited to native insects, opae kala'ole and the introduced caddisfly (Cheumatopsyche analis). This latter species was found at all the stations sampled.

*"endangered" as defined by Miller (1972)

Station 8, located at the Route 33 bridge was the only station where an exotic fish, the wild guppy (Poecilia reticulata), was found. The water at this station was turbid making observations and sampling difficult.

Composition and Diversity

To provide a measure of the stream macrofauna diversity within the streams sampled and maintain data interpretations consistent with the earlier stream surveys (Timbol 1977), the Shannon-Wiener index was used. The index of species diversity generated is a measure of the amount of uncertainty attached to the specific identity of any randomly selected individual. The greater the number of species and the more equitable the distribution among them, the higher the H' (index of species diversity) generated (Krebs 1972).

Diversity indices have been calculated for the number of individuals collected and for their biomass. The sampling methods used were adequate for measuring variation in the relative number of species found. However, since it was difficult to obtain accurate biomass measurements for gobioids found in the study, their biomass component used to calculate the diversity index is low. H' (biomass) for the Lumahai River, in particular, is low.

Lumahai River

Native crustaceans and exotic insects were the principal components of stream macrofauna sampled in the upper two mainstem stations in the Lumahai River watershed. However, native crustaceans and mollusks comprised most of the biomass at these upper stations. While exotic insects and native mollusks together were the principal constituents of the middle station, exotic insects alone held this place in the lower stations. Native fish maintained approximately the same proportion of the animal community except for the lower station where it rose slightly. Native mollusks made up the principal biomass in the three lower stations.

However, as noted earlier, the gobioids were under-represented because of sampling bias.

Although exotic insects made up the greatest proportion (55.3 percent) of the total number of species encountered, native stream fauna composed about 86 percent of the biomass. Appendix F summarizes the species composition and diversity data for the Lumahai River.

Waihee River

Stream macrofauna at the upper and middle mainstem and upper tributary stations was composed primarily of native insects and crustacea. However, it is difficult to ascribe a pattern to the diversity in species numbers and biomass below Station 4. Stream habitat was highly variable in amount, condition and accessibility below this station. Below the Spreckels diversion, native species still were the principal constituents in both number and contributors to the biomass. However, here endemic fish comprised most of the biomass. At the lowest station, exotic species were highest in number and biomass. By number, the diversity was relatively low in the upper mainstem stations, highest where native fish were found immediately below the Spreckels diversion, and had decreased to its former level at the lower station. By biomass, diversity was lowest in the upper tributary and highest just above the Spreckels Tunnel diversion where several large exotic crustacea were found and in the lower station where exotic crustacea were the principal contributors to the biomass. Appendix E summarizes species composition and diversity data for the Waihee River.

Summary and Conclusions

Fauna Inventory

Species richness is usually a good indication of habitat diversity. However, in the case of island biota with its vulnerability to competition with introduced species and man-associated impacts, the number of native species present is perhaps a more apt criterion to measure habitat quality. On this basis the Lumahai River with native species composing 64 percent of the total found ranks first of the two streams samples. The Waihee with 62 percent ranks second. When compared with other streams included in Timbol's (1977) report, these two streams ranked third and fourth respectively. Excluding amphibians, not recorded in Timbol's (1977) survey, these two streams rank second and fourth respectively.

Based on the presence of depleted and rare species both the Waihee and Lumahai Rivers rank high. O'opu nakea and o'opu nopili are found in these streams. However, the Waihee River also has o'opu alamo'o, a species being recommended for federal endangered species status. While this species was not found at Lumahai River stations during this survey, it was found in this drainage during earlier surveys by Hawaii Division of Fish and Game (Shima, p.c.).

Distribution and Abundance

Because opae kala'ole occurred in all the streams sampled, Timbol (1977) selected this species as a measure of abundance of native species. This species also occurred in the two streams sampled during this study. The Waihee, with an average of 467.8 opae kala'ole per station, ranked first among the two streams sampled and the Lumahai, with 400 per station, ranked second. Both these streams ranked higher than those included in Timbol's survey. However, it should be noted that calculations for the Lumahai River may be low since proportionally fewer of the total number of sampling stations were located in the upper reaches where this species occurs.

Although o'opu nakea and o'opu nopili are found in both streams, they are by far in greater abundance in the Lumahai River. A comparision with the results of Timbol's (1977) survey could not be made because numerical ratings were not given.

Composition and Diversity

Using the criteria that a good quality stream has a high percentage of native animals, the Waihee River ranks first in number of native organisms with 90.7 percent and the Lumahai second with 43.5 percent. Ranked against streams in Timbol's survey, the Waihee River ranked first and the Lumahai fifth. However, it should be noted that by number, native insects constituted about 81 percent of the total in the Waihee River, while native and exotic insects combined composed approximately 62 percent of the Lumahai River's stream macrofaunal population. Both the Waihee, with 88 percent, and the Lumahai, with 86 percent of the biomass recorded being composed of native species, ranked above streams included in Timbol's (1977) survey.

Diversity indices calculated for species numbers and biomass showed an inverse relation when compared with Timbol's (1977) survey. Based on these combined findings, the Lumahai ranks first with respect to numbers (H' numbers = 1.26) and fifth with respect to biomass (H' = 1.06), and the Waihee ranks sixth for both factors (H' numbers = 0.97; H' biomass = 0.65).

Conclusion

Table 4 summarizes stream quality rankings based on criteria presented in the preceding section. By summing the scores under each criterion and weighting them equally, it is possible to obtain some idea of the relative ecological quality of these streams. However, it must be emphasized that these findings are based on a one-time sampling effort.

With a possible high quality score of 8 and low score of 48, five of the streams surveyed can be ranked above the mean score of 28 (numerical score less than 28). They are, in order of the score achieved, from high quality to low, the Wainiha River (Kauai), Hanalei River (Kauai), Lumahai River (Kauai), Waihee River (Maui), and Wailoa River (Hawaii).

Additional factor analysis are required to assess adequately the value of these streams with respect to their stream macrofauna support potential under without-the-project conditions. They include the current and projected utilization of the stream. Based on current utilization schedules, Timbol and Maciolek (1978) assigned ecological quality status rankings for Hawaii's perennial streams. These rankings were assigned according to slightly modified status-use categories listed in the proposed water quality standards (Hawaii Department of Health 1977) as described below:

I. Pristine-Preservation. High environmental and biological quality: use range from no consumptive,

Table 4. Stream Quality Ranking using selected, unweighted criteria where 1 is the highest rank per/factor possible and 6 the lowest. The total score is the sum of Individual Factor Rankings 1, 3, 4, 6 - 11. (*) indicates a category not included in the total score and ( ) is a score based on U.S. Fish and Wildlife findings only.

	RANKING CRITERIA														
River/Island	FAUNAL INVENTORY	1. Species Number	2. Percent Native Species (Total)*	3. Percent Native Species (Excluding Amphibians)	4. Rare and/or Depleted Species	5. Quantity Rare and Depleted Species*	DISTRIBUTION AND ABUNDANCE	6. $\overline{X}$ opae kala'ole / sample station	7. $\overline{X}$ o'opu nakea and o'opu nopili / sample station*	COMPOSITION AND DIVERSITY	8. % Number Native Species	9. % Biomass Native Species	10. Diversity (Number)	11. Diversity (Biomass)	TOTAL SCORE
Waihee River, Maui		6	4	4	1	(2)		1	(2)		1	1	6	6	26+
Lumahai River, Kauai		5	3	2	1	(1)		2	(1)		6	2	1	5	24+
Hanalei River, Kauai		3	1	1	1			3			3	5	4	3	23+
Wainiha River, Kauai		1	2	3	2			4			2	3	2	1	18+
Wailua North Fork River, Kauai		4	6	6	3			6			5	6	5	4	39+
Wailoa River, Hawaii		2	5	5	1			5			4	4	3	2	26+

degrading or modifying to special exploitive (but non-degrading).

II. Limited Consumptive. Moderate to high quality water or natural values: controlled use to prevent excessive modification.

III. Exploitive-Consumptive. Moderate to low natural and/or water quality (well exploited, modified or degraded): used for water related recreational activities.

IV. Construct-Alter. Low environmental and biological quality: may be restricted to public for health or safety reasons.

Factors adversely affecting many of the biological quality of these streams include diversion, channelization and pollution (primarily agricultural and domestic).

Diversion of Hawaii's streams is probably the single greatest factor adversely affecting their biological potential at the present time.

The ecological rankings of streams included in the hydroelectric potential study and the number of diversions found in each of these systems are listed below:

STREAM/ISLAND	ECOLOGICAL QUALITY STATUS RANK	NO. OF DIVERSIONS
Waihee Stream, Maui	II	5
Lumahai River, Kauai	II	0
Hanalei River, Kauai	II	6
Wainiha River, Kauai	II	19
Wailua River, North Fork, Kauai	III	32
Wailoa River, Hawaii	II	7

The Lumahai River did not receive the highest stream macrofauna rating, however, of all the stream systems evaluated, it is the only one not diverted at the present time. Although it does receive a small amount of agricultural runoff from adjacent pastureland and a limited amount of sedimentation from some slightly eroded cattle watering areas, it is a relative pristine stream.

It should be noted that in a memorandum dated 5 July 1978 from the Service's Hawaii Administrator to the Regional Director (Portland, Oregon), the lower portion of the Lumahai River was included as one of seven areas to receive top priority for preservation under the Unique Wildlife Ecosystem Program.

Water being diverted from streams included within this study is largely used in sugar cane production. Future water use may include diversified agriculture. Should the sugar industry decline, and water needs lessen, the number of diversions or amount of water diverted could decrease. Should this happen within the proposed project life, biological improvement of streams such as the Waihee probably would occur.

Stream macrofaunal surveys performed by Service biologists revealed large populations of two depleted endemic gobies, o'opu nakea and o'opu nopili, in the Lumahai River. Although these two species were found in limited numbers in the Waihee River, Dr. John Maciolek (p.c.) indicated that they were abundant during prolonged high flow periods. In addition, o'opu alamo'o, being recommended for federal endangered species status, was found in relatively large numbers. However, current diversion practices limits its distribution within the Waihee River system. Should low flow releases be established for the Waihee River and fish passageways employed, the Service projects the return of native fish populations to reaches above the existing diversion site.

Construction of hydroelectric power facilities requiring stream diversions and/or dams designed to store water for release during low flow period are expected to produce adverse impacts on Hawaii stream ecosystems.

Relatively little is known about the specific responses of Hawaii stream macrofauna to environmental factors. Therefore many of the projected impacts are based upon best available data and responses observed in mainland stream ecosystems. Timbol (1977) noted several potential impacts directly or indirectly resulting from hydropower development. These together with additional concerns are summarized in Table 5.

The sum and synergistic effect of these adverse impacts would result in the significant degradation of prime stream habitat in the hitherto undiverted Lumahai River and extend adverse impacts along approximately 0.5 km in the already diverted Waihee River. In the case of the Lumahai River, stream macrofauna immediately impacted at the diversion/dam would include native and exotic fish, crustacea, insects, and amphibians; in the Waihee, the proposed diversion would affect native crustacea and native and exotic insects. Construction of the proposed hydroelectric power facilities would reduce the possibility of restoring existing stream habitat.

Recommendations

Hawaii's native stream macrofauna together with its other native natural resources are a unique biological legacy of National and statewide importance. Federal legislation including the Fish and Wildlife Coordination Act (P.L. 85-624) and the Endangered Species Act of 1973 (P.L. 93-205) has been enacted which assists in preserving this legacy. These acts provide for the equal consideration of fish and wildlife resources when evaluating water resource development projects, and prevention of federal actions contributing to the further endangerment of federally declared endangered species, respectively.

The Service did not have an opportunity to include streams previously sampled by Timbol (1977) in its impact analyses. Therefore this preliminary impact analysis and subsequent recommendations are limited to the Waihee and Lumahai Rivers. Based on data obtained during a one time survey of stream macrofauna, the Service makes the following recommendations:

1. No hyrdoelectric power project be sited on the Lumahai River, Island of Kauai.

2. Should hydroelectric power development be pursued in the Waihee River watershed, the proposed project be held in abeyance pending a determination of the federal endangered species status of the goby, o'opu alamo'o (*Lentipes concolor*).

Moderate (M) and Low (L); Duration as Short Term (S), Moderate (M) and Long Term (L); and the Areal or Geographic Extent of the Impact as Affecting the Area Above (A), Within (W) and Below (B) the Proposed Dam/Diversion Site.

Potential Impact	Magnitude	Duration	Areal Extent
1. Increased sedimentation during feeder road, diversion flume, dam and hydropower plant construction, and should a retention pool be required, the clearing of vegetation within the pool area. The latter result is expected to have long term consequences (King and Ball 1964, Tebo 1955).	M-H	M-L	W,B
2. Potential reduction of primary productivity resulting from increased turbidity could result in a loss of algae and potentially, organisms required as food by stream macrofauna.	M	M	W,B
3. Introduction of chemical pollutants during the construction phase from materials and vehicles.	L-M	L-M	W,B
4. Concentration of silt and nutrients may result in eutrophication of the pool behind the dam.	M-H	L	W,B
5. Top-water releases both downstream and into the flume at the dam site, increased release of organic matter and extensive algae development at the base of the dam or in the flume could result in a mild form of pollution (Neel 1963).	L	L	B

3. Should hydroelectric power development be pursued in the Waihee River (Maui), or other Hawaii streams, the following be implemented prior to or during project development:

   a. No reservoir be constructed on stream reaches with diadromous organisms. Instead water must be diverted directly to the proposed generator site and a low flow channel constructed and maintained to permit migration of diadromous stream macrofauna.

   b. Stream maintenance and attraction flows must be determined for diadromous species. From these determinations flow release schedules must be implemented below the diversion site and fish passage facilities installed.

   c. A thorough multi-seasonal stream macrofauna survey must be conducted on any stream selected for hydroelectric power development.

   d. Feeder roads must be limited. Helicopters should be used for the transportation of men and materials.

   e. Channelization or other disruption of the stream channel must be avoided.

   f. Riparian clearing must be avoided.

   g. Entrainment prevention devices must be installed at both the upstream diversion site, and the point of water re-entry into the main stream below the hydropower plant turbines.

4. Future aquatic stream surveys estimate the biomass of the stream at the sample site.

Should a hydroelectric power project be pursued on the Waihee River or any other Hawaii stream, the Service must be funded and allocated sufficient time to perform a complete

Potential Impact	Magnitude	Duration	Areal Extent
15. The proposed project dam and/or diversion could prove a barrier for the active or passive downstream passage of eggs, larvae and adult diadromous stream macrofauna and the upstream movement of post-larvae of these species.	H	L	A,W
16. If the diversion is complete and the stream reach between the dam site and water release from the power plant is totally dewatered for all or part of the year, impacts to stream macrofauna would result from three effects (1) the loss of stream habitat during the period dewatered (2) loss in quality of stream habitat resulting from the need for it to re-stabilize once water begins to flow in this stream reach and (3) the impact this 'dry' reach would have as an extended barrier to habitation by and upstream migration of diadromous stream macrofauna.	H	L	A,W,B
17. Reduction of stream flow could prevent flushing or purging of organic debris from the stream reach below the dam.	M-H	L	B

biological impact analysis. The foregoing recommendations will be amended and augmented as necessary at that time.

Sincerely yours,

Maurice H. Taylor

Maurice H. Taylor
Field Supervisor

cc: HA
AE(Environment) Portland, OR.

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