# HAWAII DEEP WATER ELECTRICAL TRANSMISSION CABLE DEMONSTRATION PROGRAM

# PHASE I

# PROGRAM REVIEW



Department of Planning and Economic Development

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Department of Planning and Economic Development

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TABLE OF CONTENTS

## LIST OF FIGURES

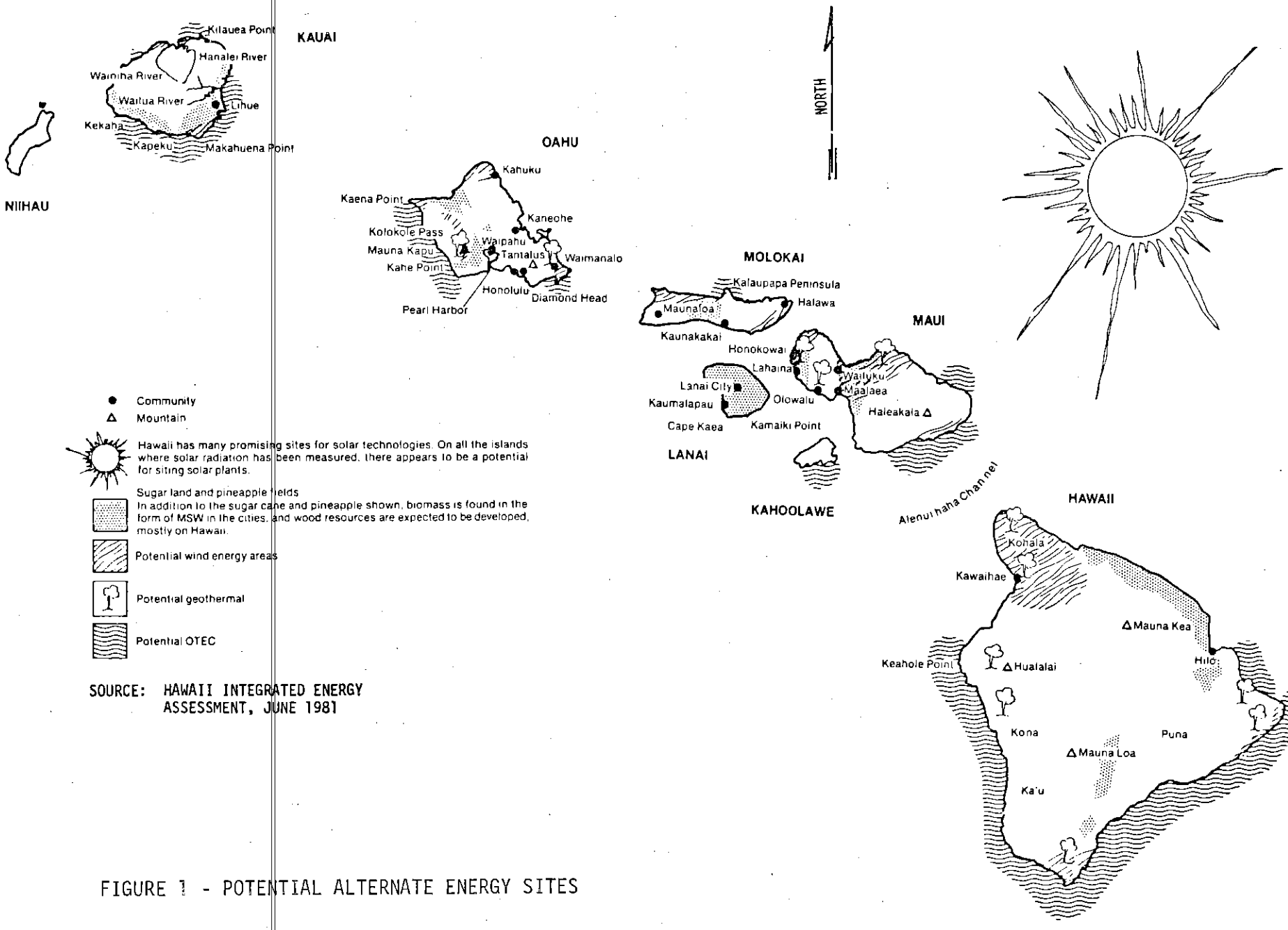
## INTRODUCTION

This Program Review for the Hawaii Deep Water Electrical Transmission Cable Demonstration Program (HDWC Program) has been prepared to provide background information on the history and overall purposes of the Program that is currently in progress; to summarize the work that has been performed to mid-January 1982; and to identify future work tasks that will be required to successfully complete the Program. Also provided are financial data for the on-going work. Stated in other terms, this document is a progress report only and has been prepared to inform appropriate agencies and groups of the progress of the HDWC Program.

The following sections of this report provide a brief overview of Hawaii's alternate energy resources and the resource development programs that are in progress; describe the need for and history of the Hawaii Deep Water Cable Program; review the present status of HDWC Program work in progress; and provide cost information for the present work. Also provided are brief descriptions of future Program work tasks and the estimated costs of those tasks.

## OVERVIEW OF HAWAII'S ALTERNATE ENERGY RESOURCES

Hawaii is one of the few areas in the world with abundant indigenous renewable alternate energy resources. As shown on Figure 1, on the island of Hawaii (Big Island) a sizeable geothermal resource is known to exist, as do potential sites for wind turbine, ocean thermal energy conversion (OTEC), hydroelectric and biomass conversion facilities. The geothermal resource found in the Puna District has been estimated to have the capacity to generate 1,000 MW of electricity. On Maui, potential geothermal resources, OTEC, wind, biomass conversion and hydroelectric sites are found. Similarly, a potential large wind turbine site is located on Molokai as are potential OTEC and biomass conversion sites. On Oahu, potential wind, OTEC, biomass and geothermal resources are known or thought to exist; and on Kauai, OTEC, biomass and hydroelectric sites exist.




SOURCE: HAWAII INTEGRATED ENERGY ASSESSMENT, JUNE 1981

FIGURE 1 - POTENTIAL ALTERNATE ENERGY SITES

In contrast to the above, Figure 2 indicates present methods of electrical power generation in Hawaii. As shown, the major portion (over 90 percent) of Hawaii's electrical energy is presently produced by generating plants using fuel-oil. Only on the Big Island and Kauai, are significant amounts of electrical energy presently generated by renewable resources. As of December 1981, approximately 50 percent of the Big Island's electrical power demands were met by biomass conversion and hydroelectric generating sources. On Kauai, over 45 percent of the power demand is presently supplied by hydro, biomass, solar or wind alternate energy resources. It is projected that by the year 2005, over 90 percent of Kauai's electrical energy could be produced by nonfuel-oil sources.

Present alternate energy resource research and development programs are being conducted on every major island. The most visible of these programs are the geothermal resource activities on the Big Island, wind turbine projects on Oahu, Molokai and the Big Island, biomass conversion projects on the Big Island, Oahu and Molokai and large scale solar projects on Kauai and Molokai.

On the Big Island, following the lead of the electricity producing HGP-A well and power plant, three private geothermal resource development companies are performing resource confirmation and development work and will, over the next three to five years, expend $25 to $30 million. This work is expected to culminate in the development of approximately 25 MW of electrical power. On Oahu, a large wind turbine, located in Kahuku, has been undergoing tests for the past year and one-half and has formed the basis of a proposed 80 MW wind farm. Similar tests are on-going on both Molokai and the Big Island. All of these programs are important and necessary steps if Hawaii is to maintain its position as a world leader in alternate energy resource development and reduce its dependence on high-cost imported fuel-oil.

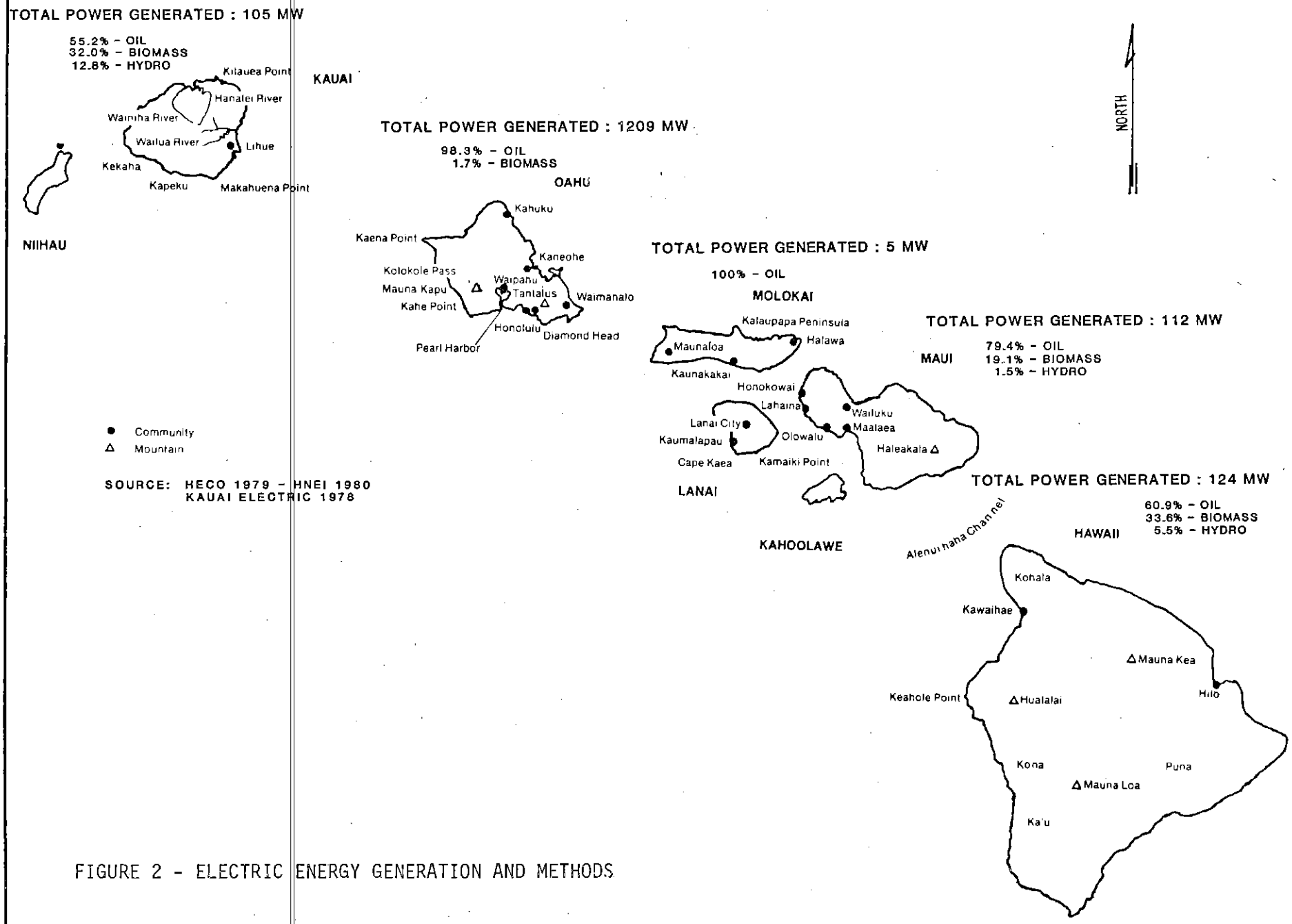



FIGURE 2 - ELECTRIC ENERGY GENERATION AND METHODS

For the above-noted renewable alternate energy resources to be developed to the maximum extent practicable, there must be a means of transmitting the power produced to the major load center, Oahu. At present, and for the foreseeable future, over 80 percent of the State's electrical power demands will be on Oahu. As noted above, the geothermal resource found in the Puna District of the Big Island has been estimated to have the capacity to generate 1,000 MW of electricity. However, the Big Island's projected power demands over the next 30 to 40 years are expected to increase by only 40 to 50 MW, while on Oahu, approximately 400 MW of electrical energy generated by renewable resources could be accepted immediately.

In terms of economic impact, also as noted above, it has been estimated that, at present, private geothermal resource developers are spending or will spend $25 to $30 million on the Big Island in the next three to five years for geothermal exploration and development purposes. If 400 MW of geothermal resources are developed on the Big Island, for export purposes, it is estimated that $1.2 to $1.5 billion would be expended over the next ten to 15 years for construction of well sites, steam gathering systems and power plants. This is in addition to the exploration and development costs. This is money that would be expended within the State rather than being spent on imported fuel-oil and going outside the State and nation.

From the above in-progress or planned alternate energy resource development activities, the Hawaii Deep Water Electrical Transmission Cable began to take shape. In the following section, a brief overview of the need for and purposes of the HDWC Program are provided, as is a brief history of the Program.

## NEED FOR THE HDWC PROGRAM

As noted previously, in order for Hawaii's abundant renewable alternate energy resources to be developed to the maximum extent practicable, there must be a means of transmitting electrical energy between the islands. Such a system will allow power to be cost-effectively transmitted to those

areas where it is needed most at any given time and, thereby, greatly assist in the reduction of the amount of imported fuel-oil presently used to generate electrical power on each island. Such a system also would enable the electric utilities to continue to reliably supply electrical energy to all customers and help stabilize electric energy costs through the use of renewable energy sources rather than fuel-oil.

## PURPOSES OF THE HDWC PROGRAM

While the idea of an interisland transmission system is easily discussed, the actual accomplishment and implementation of such a system presents unprecedented challenges to submarine power cable engineers. In mid-1979, literature searches and discussions with submarine power cable installers, owners and operators were conducted and it was found that, to date, the deepest and longest submarine power cables are located in Europe and were developed by European interests. These cables, commonly called the Skagerrak Cables, are deployed to a depth of approximately 1,800 feet, over a distance of about 78 miles and electrically link Norway and Denmark. In Hawaii, however, between the Big Island and Maui, the Alenuihaha Channel is approximately 7,000 feet deep and between Molokai and Oahu, the Kaiwi Channel is approximately 2,200 feet deep. The total distance between the Big Island and Oahu is approximately 150 miles, while the most practical all underwater cable link would be approximately 170 miles long. If an island-hopping scheme is adopted for an interisland cable system, the most practical underwater link between the Big Island and Maui appears to be approximately 90 miles (Figure 3).

In order to accomplish the necessary planning, engineering and submarine cable qualification tests and studies that are required prior to establishing an interisland cable system, an unsolicited proposal for the technical evaluation or demonstration program was prepared and submitted to the U.S. Department of Energy (DOE) Assistant Secretary, Dr. Ruth M. Davis, on June 2, 1980 by Governor George R. Ariyoshi and Mr. Richard E. Bell, Vice President, Engineering, Hawaiian Electric Company. This

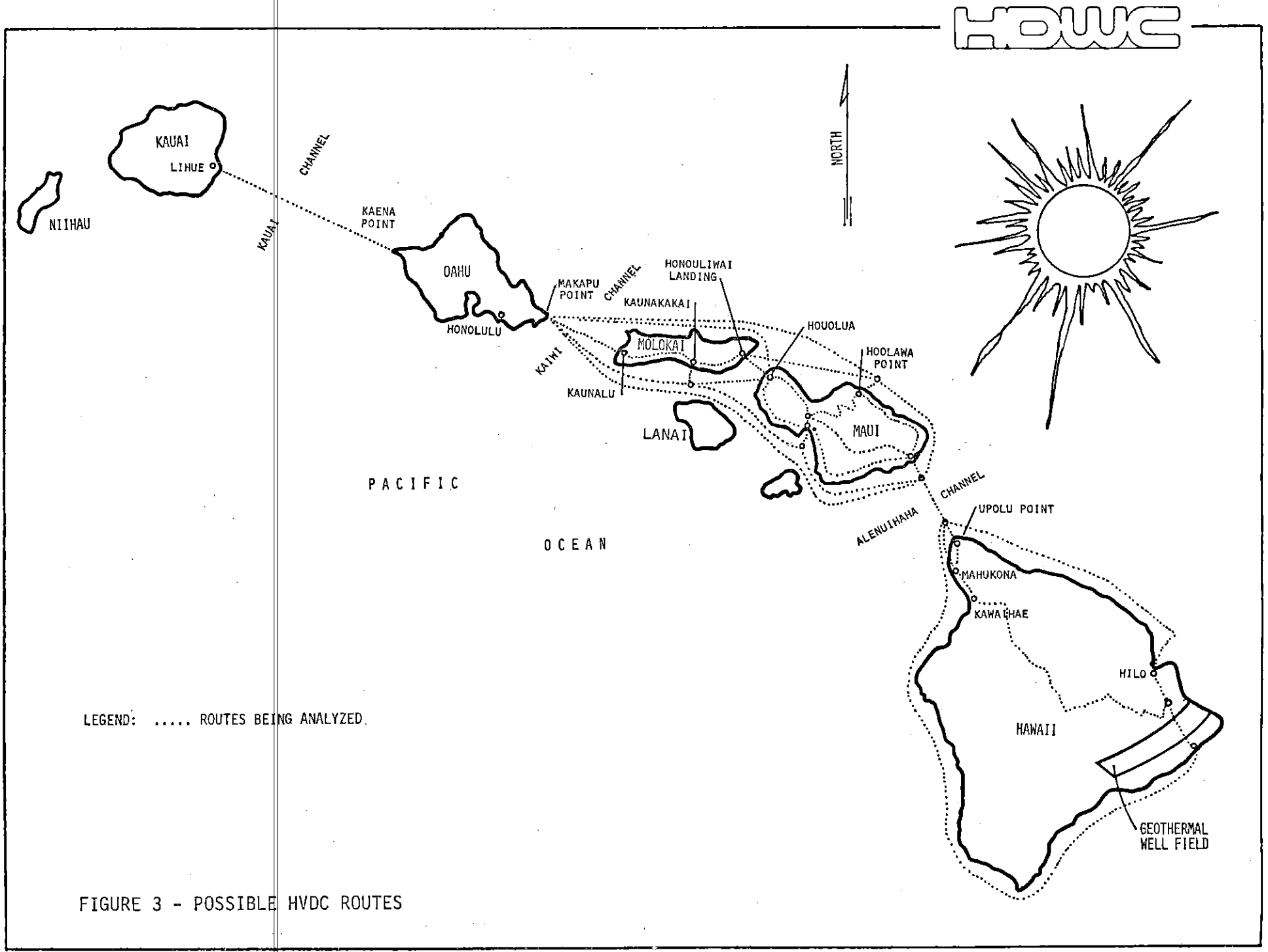



FIGURE 3 - POSSIBLE HVDC ROUTES

presentation took place in Senator Spark M. Matsunaga's Washington D.C. office. Included in the proposal were supporting letters from the mayors of the Big Island, Maui and Honolulu. Additional supporting letters were forwarded directly to DOE by key State Legislators.

The immediate purposes of the program are (1) the determination of the technical and economic feasiblity of electrically intertying the Hawaiian Islands into a unified, electric grid system via a high voltage direct current (HVDC) submarine electrical transmission cable; (2) the determination of the ocean engineering problems and solutions of deploying, retrieving and repairing a deep water cable in the Hawaiian environment; and (3) the development of a commercial cable criteria that can be used by public or private agencies for the design, installation and maintenance of deep water HVDC cables.

Since the submittal date, several significant events have occurred. First, in December 1980, Senator Daniel K. Inouye succeeded in securing from President Jimmy Carter the immediate release of $200,000 and the release of an additional $2.5 million in early January 1981. Upon assuming office, President Reagan rescinded those funds. However, shortly thereafter during the 1981 session of the Hawaii State Legislature, $300,000 for the HDWC Program was authorized and appropriated for fiscal year (FY) 1981-1982 and an additional $300,000 authorized for FY 1982-1983. These actions were taken because of the farsighted interest of the Legislature to facilitate the development of the State's alternate energy resources and the keystone nature of the HDWC Program to the development of those resources to the maximum extent practicable. The initial $300,000, administered through the Department of Planning and Economic Development (DPED) Capital Improvement Program (CIP) budget, was released by Governor Ariyoshi in July 1981 and initial work started in October 1981. Also in July 1981, the experimental HGP-A geothermal power plant in Puna District began producing approximately 3 MW of electrical power.

Following the above-noted rescission by President Reagan, Hawaii's entire congressional delegation has managed to retain the HDWC Program in the Federal FY 1982 budget and on December 4, 1981, President Reagan signed into public law the Energy and Water Resources Appropriations Bill. This bill contains $1.5 million for the HDWC Program and Program participants are presently attempting to secure the release of those funds, as well as to assure that additional funding for the Program is included in the FY 1983 DOE budget.

As a result of the above-noted release of DPED CIP funds by Governor Ariyoshi, several major Program work tasks have been initiated. The following sections describe the overall Program work phasing and tasks and the work that is in progress and has been performed to mid-January 1982.

## HDWC PROGRAM PHASES AND TASKS

The HDWC Program is presently organized into two discrete phases. Phase I, or the Preliminary Definition Phase, consists of eight separate major work tasks that are described in detail below. Phase II consists of three subphases (A, B and C) with varying numbers of work tasks in each subphase. The following is a brief listing of the phases and work tasks:

### Phase I - Preliminary Program Definition

Task 1. General Management

Task 2. Management Support

Task 3. Preliminary Route Survey Analysis

Task 4. Preliminary Prototype Cable Design Criteria

Task 5. Preliminary Cable Vessel Inventory and Capability Survey

Task 6. Preliminary Definition of Legal and Institutional Constraints

Task 7. Preliminary Computer Simulation Model Tests

Task 8. Prepare Phase I Summary Report

Phase IIA - Final Program Definition

Task 1. At-Sea Route Surveys

Task 2. EA/EIS Preparation and Submission

Task 3. Environmental Permit Application Preparation and Submission

Task 4. Final Cable Design

Task 5. Develop Design for Repair Splice

Task 6. Preliminary Cable Vessel Modification Design

Task 7. Define and Develop Cable Handling Support Systems

Task 8. Define and Design Public Information and Educational Program

Task 9. Final Definition of Legal and Institutional Constraints

Task 10. Perform Computer Simulation Model Tests of Cable Mechanical and Structural Properties

Task 11. Electrical Grid System Integration Investigations

Task 12. Program Management Support

Phase IIB - Design and Test

Task 1. Manufacture Test Lengths of Cable and Laboratory Test

Task 2. Manufacture and Test Repair Splice

Task 3. Final Cable Vessel Design and Cable Vessel Modification/ Construction

Task 4. Continue Electrical Grid System Integration Investigations

Task 5. Conduct Public Information and Educational Program

Task 6. Continue Program Management Support

Phase IIC - System Validation and Cable Operations and Test

Task 1. Manufacture Test Length of Cable

Task 2. Deploy Test Length of Cable

Task 3. Perform *In-Situ* Cable Tests

Task 4. Retrieve, Examine and Retest Cable

Task 5. Continue Public Information and Educational Program

Task 6. Complete Electrical Grid System Integration Investigations

Task 7. Prepare Commercial Cable Criteria

Task 8. Complete Program Management Services

At the conclusion of all of the above tasks, the overall purposes of the Program will have been fulfilled. That is, the technical and economic feasibility of electrically intertying the Hawaiian Islands will have been determined and a cable design criteria will have been produced. In addition, at-sea qualification tests of the cable will have been conducted and the necessary cable vessel and cable handling equipment will be available and will have been tested at-sea during actual operations.

## STATUS OF PHASE I IN-PROGRESS WORK

At present, work is proceeding on all Phase I work tasks. The following is a brief description of the work that has been accomplished as of mid-January 1982:

Task 1: General Management. Work under this task has included the initiation of the preparation of a Program Management Plan, the preparation of a Draft Quality Assurance Plan, and the initiation of work on a Program Mobilization Plan and Program Detail Work Breakdown Structure.

Task 2: Management Support. Work under this task has included the preparation of contract documents for all Phase I Program participants, initial future HDWC Program definition and costing, initial interisland cable system costs and scheduling, attendance and coordination of Program participant meetings and meetings regarding future Program funding.

Task 3: Preliminary Route Survey Analysis. Work under this task has included an analysis of several candidate routes for an interisland cable system and the preparation of a draft report detailing the results of the analyses conducted. The route survey work conducted is presently being utilized by cable design and cable vessel engineers during their work on the following two tasks.

Task 4: Preliminary Prototype Cable Design Criteria. Work under this task has included literature searches and a complete investigation of previously developed cable designs. This work was followed by detailed examinations of 16 different cable designs and the reduction of those 16 designs down to the five most promising. The analyses conducted have included computer modeling of structural and mechanical characteristics, as well as the electrical characteristics of the various designs. The culmination of all Prototype Cable Design Criteria work will be the preparation of a Cable Construction Memo, from which test lengths of cable can be manufactured for laboratory testing in the next phases of work.

Task 5: Preliminary Cable Vessel Inventory and Capability Survey. Work under this task has included a complete literature search of existing and planned cable vessels, a field survey of appropriate vessels on the U.S. mainland and the preparation of a draft report detailing the above activities.

Task 6: Preliminary Definition of Legal and Institutional Constraints. Work under this task is still in the discussion stages with actual work expected to begin within the next few weeks. At present, it is anticipated that the work will be performed by University of Hawaii Law School staff and students. By performing the work in this manner, law school students will be involved in a real world situation and program that could have a significant impact on their professional careers and personal lives. This method of accomplishing the work also appears to be the most cost-effective means of performing the required tasks.

Task 7: Preliminary Computer Simulation Model Tests. Work on this task has been completed by HNEI and included a brief analysis of the mechanical and structural properties of various cable designs. The primary purpose of this work was to test existing computer programs for applicability to the HDWC Program. This work was successfully accomplished within budget and on schedule.

Task 8: Prepare Phase I Summary Report. Work under this task is being held in abeyance pending completion of all other Phase I work tasks. A final Summary Report will be prepared and submitted to appropriate agencies and groups on or before April 1, 1982.

As of mid-January 1982, approximately 60 percent of Phase I work has been completed. Of the remaining 40 percent, approximately 50 percent will be completed by the end of February 1982, with the remainder being completed by April 1, 1982.

## HDWC PROGRAM PHASE I COSTS

The following is a brief summary of Phase I costs and funding sources:

PROGRAM BUDGET SUMMARY

| Work Item | | DPED-CIP Funds (From FY 81-82 Budget) | Cost Share Amount[a/] | Total Costs |
|---|---|---|---|---|
| ~~Task 1.~~ | ~~General Management~~ | ~~$ 72,642~~ | ~~$ 22,289~~ | ~~$ 94,931~~ |
| Task 2. | Management Support | 72,642 | 22,289 | 94,931 |
| Task 3. | Preliminary Route Survey Analysis | 55,032 | 16,885 | 71,917 |
| Task 4. | Preliminary Prototype Cable Design Criteria | 42,313 | 11,403 | 53,716 |

| | | | | |
|---|---|---|---|---|
| Task 5. | Preliminary Cable Vessel Inventory and Capability Survey | 22,984 | 6,193 | 29,177 |
| Task 6. | Preliminary Definition of Legal and Institutional Constraints | 15,000 | 5,000 | 20,000 |
| Task 7. | Preliminary Computer Simulation Modeling | -- | 25,000 | 25,000 |
| Task 8. | Phase I Summary Report | 19,387 | 6,010 | 25,397 |
| | TOTAL | $300,000 | $115,069 | $415,069 |

a/ Cost sharing amount equals 38.35 percent of $300,000.

## FUTURE WORK REQUIREMENTS AND SCHEDULING

The future work tasks that will be required to successfully complete the HDWC Program have been listed above under Phase II tasks and are not repeated here. However, it is noted that the various tasks shown for the three subphases are currently being examined in detail and it is possible that some tasks may be shifted to earlier or later subphases, depending on future funding and the progress of previous work tasks. All work has been planned such that each task is a logical progression from one step to the next. As such, most tasks must follow one another in order to successfully and completely accomplish succeeding tasks. However, other tasks are sufficiently independent of each other that they may be accomplished at almost any time during the Program.

At present, Phase I work efforts will be completed by April 1, 1982. Assuming funding is available for Phase II work, Phase IIA will begin immediately following Phase I, and continue until December 31, 1984. Specifically, Phase II work is presently scheduled as follows:

Phase IIA - April 2, 1982 to July 30, 1983
Phase IIB - August 1, 1983 to March 31, 1984
Phase IIC - April 1, 1984 to December 31, 1984

Phase IIC demobilization, final report writing and other Program clean-up items may continue until January 31, 1985. All of the above is tentative at this time and will be further defined and refined during the latter part of Phases I and IIA work efforts.

One of the most difficult tasks in the HDWC Program has been to accurately identify the costs associated with the various work tasks. Some of the task costs can be readily estimated. However, others, such as the at-sea cable tests and deployment, the cable vessel design and modifications and the cable handling equipment, have eluded reliable estimates due to the unknown and unprecedented nature of the work. As previously noted, the HDWC Program represents an extension of the state-of-the-art knowledge regarding submarine power transmission cables. As such, the newness and unique character of many items do not allow a comparison to be made with other projects or a baseline to be established from which cost estimates can be generated. Nevertheless, costs must be defined and the following represents the best estimate at this time.

The total HDWC Program is presently estimated to cost approximately $20 million. This includes all costs including cost sharing amounts that will be contributed by private sector participants. Detailed cost estimates for future Program phases are being prepared during current Phase I work efforts.

At present, it is thought, and it is the intention of all Program participants, that Phase II costs will generally follow the same pattern as Phase I costs, with the private sector organizations contributing approximately 10 percent of the overall dollar volume of work performed by the private sector groups and other participants contributing in-kind services or actual dollars. It is noted that the total program costs noted above are tentative at this time and will be further refined at the conclusion of Phase I work.

## CONCLUSION

The HDWC Program is being conducted to determine the technical and economic feasibility of intertying the Hawaiian Islands into a unified, electrical grid system. An interisland electrical transmission cable system will result in cables being deployed at depths over three times greater than previously deployed power cables and over longer distances than any other planned or operating cable system. Such a system requires a technical evaluation program that will increase the state-of-the-art of submarine power cable design, deployment procedures and equipment. The Program has been conceived and developed to provide a means whereby Hawaii's abundant, indigenous renewable alternate energy resources can be developed to the maximum extent practicable. This will allow the State to reduce its dependence on imported fuel-oil, stabilize electric power rates and greatly assist in the overall State goal of electrical energy self-sufficiency to become a reality. The Program is scheduled to be conducted over a three and one-half year period with total costs presently estimated to be approximately $20 million. The Program is being conducted by a team of public agencies, privately held public utility and private sector companies. The results of the Program will be directly applicable to other alternate energy technologies, such as OTEC, and other areas of the world that are separated by deep bodies of water. For example, deep water cable projects to cross the Cabot Straits to bring Canadian hydropower to the northeastern U.S.; to intertie Alaskan areas; and to intertie the Bahama Islands and Florida are in the planning stages and could use the cable technology that will be developed during the HDWC Program.