State of Hawaii

THE NATURAL ENERGY LABORATORY OF HAWAII

Keahole, North Kona, Hawaii

FINAL SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT

ALTERNATIVE METHODS OF SEAWATER RETURN FLOW DISPOSAL

March 1987

MCM PLANNING 320 Ward Avenue, Suite 106, Honolulu, Hawaii 96814

FINAL

SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT

MODIFICATION OF PROPOSED ACTION

TO PERMIT ALTERNATIVE METHODS OF SEAWATER RETURN FLOW DISPOSAL

AT THE NATURAL ENERGY LABORATORY OF HAWAII

Keahole, North Kona, Hawaii

Prepared for the

STATE OF HAWAII
NATURAL ENERGY LABORATORY OF HAWAII

Jack P. Huizingh
Executive Director

Prepared By
MCM PLANNING
Honolulu, Hawaii

March 1987

FINAL
SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT
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PROJECT:	DEVELOPMENT PLAN FOR THE HAWAII OCEAN SCIENCE & TECHNOLOGY PARK AND EXPANSION OF THE NATURAL ENERGY LABORATORY OF HAWAII: MODIFICATION OF PROPOSED ACTION TO PERMIT ALTERNATIVE METHODS OF SEAWATER RETURN FLOW DISPOSAL AT THE NATURAL ENERGY LABORATORY OF HAWAII
LOCATION:	KEAHOLE POINT, NORTH KONA ISLAND OF HAWAII STATE OF HAWAII
PROPOSING AGENCY:	STATE OF HAWAII - NATURAL ENERGY LABORATORY OF HAWAII CENTRAL PACIFIC PLAZA, SUITE 1280 220 SOUTH KING STREET HONOLULU, HAWAII 96813 CONTACT: MR. JACK P. HUIZINGH EXECUTIVE DIRECTOR TELEPHONE: (808) 548-7017
ACCEPTING AUTHORITY:	GOVERNOR, STATE OF HAWAII
CONSULTANT:	MCM PLANNING P.O. BOX 27506 HONOLULU, HAWAII 96827 CONTACT: MARILYNN C. METZ, AICP TELEPHONE: (808) 732-7143

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The Natural Energy Laboratory of Hawaii (NELH) was established by the Hawaii State Legislature in 1974 to manage and operate a research facility on approximately 322 acres of state-owned land at Keahole Point on the island of Hawaii (TMK 7-3-43:42) for research, development and demonstration of natural energy resources. The Keahole site was selected for NELH because of the nearby availability of cold, deep ocean water; a warm ocean surface layer not subject to strong seasonal cooling; high annual solar insulation; accessibility to logistical support through airports, harbors, and highways; and the presence of adjacent, suitable undeveloped land. The unique characteristics of the site make it an excellent environment for conducting ocean related research such as Ocean Thermal Energy Conversion (OTEC).

An environmental impact statement for the Development Plan for the Hawaii Ocean Science and Technology Park and Expansion of the Natural Energy Laboratory of Hawaii (HOST/NELH FEIS) was accepted by the Governor in September 1985 (HTDC, 1985). Among the actions assessed in the statement was the disposal of 42,000 gpm of seawater return flows from ocean thermal energy conversion (OTEC) and mariculture operations at NELH by means of trench, well, canal and mixed-water discharge pipe. At the time the HOST/NELH FEIS was accepted, the State of Hawaii planned to install a cold water pipe and pump system for HOST Park and the U.S. Department of Energy (DOE) was planning to fund a cold and warm water system for OTEC research. Subsequently, the DOE learned that it would be unable to fund the proposed expansion of OTEC facilities at NELH to the level they had originally proposed. Rather than installing separate seawater pipe systems, DOE and the state entered into a cooperative cost-sharing agreement to provide the required ocean water for both projects with one seawater system.

OTEC is a power generating system that uses the temperature difference between warm surface water in the tropical ocean and the cooler water at depth to run a heat engine. Research on two types of operating cycles, closed (CC) and open (OC), is presently being conducted at NELH. The U.S. DOE is developing a research experiment to establish the feasibility of producing significant amounts of net power from an OC OTEC system. The demonstration plant experiment proposed for NELH is sized at 165 kW of gross power and is anticipated to be in operation in 1991, after approximately four years of heat and mass transfer experiments at the site.

Expansion facilities to support this research program will be constructed by the State of Hawaii with the financial support of the U.S. DOE. These new expanded facilities are planned to include: (1) an ocean water supply system (pipes and pumps) capable of delivering 16,100 gpm of mixed warm and cold seawater; (2) a water system test facility for developmental research for open-cycle OTEC; and (3) an expanded facility for experiments with OTEC-related mariculture.

The 165 kW demonstration plant, when operational, will discharge approximately 16,100 gpm of seawater. The seawater will be mixed in a ratio of 1 part cold to 1.5 parts warm. Because the mixed-water discharge pipe that was originally proposed as the means to dispose of the projected seawater return flows will not be funded at the present time, alternative, less costly methods of disposal were evaluated.

The alternative disposal facility recommended for OTEC discharges is a shallow trench located within the NELH compound. The recommended trench orientation is roughly perpendicular to and approximately 250 feet from the shoreline at its closest point. This facility would initially serve as a research trench for discharge quantities in the range of 3,000 to 5,000 gpm. During the 3 to 4 year heat and mass transfer experiment period, an intensive water quality monitoring program would be undertaken in conjunction with the trench disposal in order to determine the actual impacts associated with the discharge flow. In the event that unacceptable impacts occur, alternative disposal facilities can be constructed and the water diverted to the new system.

Research at NELH has proven the value of the pure cold ocean water for the production of mariculture products such as abalone and microalgae. Legislation passed in May 1984 amended the NELH enabling legislation to allow on-site commercialization of successful research and development projects. Based on the experience of the past three to four years, it appears that significant potential exists for commercialization of several species of aquatic plants and animals at NELH. These include: microalgae, macroalgae, marine mollusks, crustaceans and finfish.

At full development of NELH it is projected that an additional 25,900 gpm of seawater return flows from mariculture operations will be generated. The consitutents of the discharge water will depend on the culture organism and its intended use.

The disposal facility recommended for return seawater from mariculture operations is a trench located makai of the NELH access road, parallel to and approximately 900 feet from the shoreline at its closest point. Because it is anticipated that there will be a gradual increase in volumes of water used, the proposed monitoring program can provide early detection of any adverse impacts so that alternative disposal methods can be instituted if they occur.

Potential Adverse Impacts

- The disruption and displacement of the existing brackish water lens for some distance inland and along the coast. In the long term, trees with deep root systems that reach groundwater level may not be able to survive the change in salinity caused by the ocean water plume. This can be mitigated by planting trees with a greater tolerance to salinity.

- As a result of disposal into shallow trenches, the aquifer surrounding Keahole Point is expected to experience reduced temperatures, increased salinity, increased solute concentrations, and greater localized groundwater. Groundwater salinities in the areas of anchialine ponds are expected to rise from present condition to something close to normal seawater (i.e. 35-36 ppt). In field observations suggest that negative impacts due to salinity increases may be non-existent for adults of the known obligate anchialine species present in the NELH ponds. The potential impacts associated with increased salinity on the fecundity of survival of juvenile stages of these species is unknown.

o OC OTEC discharges containing reduced concentrations of oxygen may tend to depress metabolic activity of the coastal community, but trench disposal will considerably diffuse entry of these waters to the sea and rapid mixing at entry would tend to minimize this impact. Reoxygenation by aeration is a suggested mitigating measure for this potential impact.

  If the discharge from OC OTEC experiments is not reoxygenated, it is possible that many of the anchialine species in the ponds situated at NELH may disappear. Continuous monitoring of the ponds is recommended in order to identify this impact early, if it should occur, so appropriate mitigating measures can be undertaken to reverse the situation.

o Nutrient concentrations in OTEC discharges would be elevated over those of receiving waters. The offshore benthic algal community is maintained at a very low standing crop by grazing and physical stresses. Nutrient subsidies would be expected to increase macroalgal biomass because grazing is inhibited in the surge zone. The adverse impact would be aesthetic, however, the effect would be localized. Nutrient enrichment of the offshore waters could be beneficial to the local fishing industry.

o In OC OTEC research where lysing occurs, the usability of nutrients in the discharge is expected to increase. In addition, dissolved oxygen is expected to decrease. An increase in organic material could result in increased rates of biofouling and could affect on-going heat exchanger experiments being conducted by private firms at NELH.

o Disposal of mariculture discharges into a shallow trench may result in some stimulation of the algal turf along the shore due to restricted opportunities for grazing by herbivorous fishes. Visual impact could be significant to some observers. This impact is anticipated to be localized in the general vicinity of discharge facility.

o Chemicals and waste products from mariculture operations in harmful concentrations could negatively impact nearshore marine organisms and anchialine biota. Discharges of known toxic materials would be prohibited at NELH and regulations would be enforced. In addition, discharges would be monitored in order to ensure that toxic concentrations of substances are not present in the discharge waters.

Certain chemical additives used in mariculture operations, unknown at the present time, could potentially impact the marine environment. The nature of all new chemicals should be reported and investigated prior to introduction into the discharge system as it may impact the resident epifauna.

Proposed Mitigation Measures

- Monitoring: Potential degradation of water quality parameters is a negative impact to the extent that biota are affected or that human use and enjoyment of the environment is compromised. A proposed water quality monitoring program has been designed to provide insights to an understanding of these impacts. Present plans for NELH include a gradual increase in volumes of water to be used. This will allow the monitoring program to provide early detection of any impacts. In addition, the potential impacts are reversible. That is, if discharges are halted, the affected ecosystems could be expected to revert to baseline conditions.

  The water-quality monitoring activities at NELH will enhance knowledge of coastal and ocean processes and facilitate the development of standards for mariculture and other ocean-related research and development activities throughout the state. This item is top priority because preservation of the integrity of the cold and warm ocean water resources is fundamental for the continued growth and success of the proposed projects. If the water is degraded, the projects will no longer have the unique resource necessary to attract the energy and mariculture activities important to their success.

- Reoxygenation: Dissolved oxygen could be substantially lowered if one or both of the source water streams are degassed prior to use in OC OTEC research. Reoxygenation through aeration is recommended to mitigate impacts on the environment from discharging oxygen-poor water. According to some scientists contacted by Oceanit Laboratories, reaeration could be easily accomplished by a fountain or any other turbulent motion in the air. However, it would be environmentally and economically beneficial to reinject the removed gases into the water prior to discharge. Reinjection studies will be part of the research effort at NELH.

  In any event, monitoring will be an important consideration of any research done on this problem as the degree of environmental impact of discharging oxygen-poor water is unknown. The proposed monitoring program should provide early detection of any adverse impacts so that alternative disposal methods can be instituted if they occur. Any adverse impacts on the environment are reversible and the ultimate mitigating measure would be to cease discharging oxygen poor water in a manner that affects the nearshore environment.

Alternatives Considered

Alternative disposal methods considered in this SEIS include: direct disposal via canal with ponding area; disposal into shallow trenches; and disposal into deep lined injection wells. A mixed discharge pipe for OC OTEC seawater return flows was assessed in HTDC, 1985.

Theoretically, discharge into a canal with ponding area appears to be an environmentally acceptable method of disposing of OC OTEC return flows. However, before the same type of ponding area that is currently in use can be used for larger discharge volumes, additional investigations would be required to determine the physical characteristics that cause the existing pond to act as a "reactor vessel" that adds oxygen, removes nutrients and increases the discharge water temperature to approximately that of the ambient seawater. For this reason, and the fact that the land area for a ponding area might be prohibitively large in relation to the area available to NELH, discharge of 16,100 gpm of OC OTEC waters via canal was determined to be unfeasible at the present time.

Of the alternative methods and locations for disposal of the OTEC water analyzed, the most environmentally benign is deep injection. As proposed, the deep injection wells would provide the greatest residence time, about three months, and would create seepage through the bottom between -300 and -400 feet depths. While this would avoid potential biostimulation of the algal turf at the shoreline it would come at substantial additional cost.

A cost comparison between trenches and deep injection wells indicates that, in general, deep injection wells are approximately 15 times more costly to construct and operate than disposal by trench within NELH. Without empirical data from monitoring a trench system, the theoretical minimal improvement in avoiding impacts to the environment by disposing via injection wells does not appear to warrant the additional cost.

Disposal of OTEC water via a mixed-water discharge pipe was assessed in the HOST/NELH FEIS. This option is still available should the intensive monitoring program prove that unacceptable environmental impacts occur as a result of using other less-costly methods of disposal.

In terms of this SEIS, the project is defined as on-land disposal of discharge from OC OTEC experiments at NELH. No project would mean no further funding by the U.S. DOE for both the proposed ocean water supply system and future research programs for OC OTEC at NELH until such a time as funds became available and a mixed-water discharge pipe could be designed and constructed. U.S. DOE OC OTEC research at NELH could be delayed for several years.

No project would also mean that research opportunities to monitor low-cost disposal methods would be lost. This could be significant in that a potential opportunity to transfer cost-effective, reliable disposal technology to foreign countries would be lost. In addition, the State of Hawaii is actively seeking high-tech mariculture enterprises to diversify the economy of the State. A cost-effective disposal technique might make the difference between success and failure for these "state-of-the-art" fledgling businesses.

Unresolved Issues

- o Various approaches to reoxygenation of degassed OC OTEC waters are being discussed. The process is in the research stage. The specific process for this mitigating measure is unresolved and will be the subject of research. Monitoring of effects of degassed discharged water on nearby marine communities will serve to minimize the potential of adverse impacts until this is accomplished.

- o Future mariculture crops and processes are currently undefined, although most are anticipated to be similar to those described previously in this SEIS. Various mitigating measures, as suggested in Part IV of this SEIS, could be instituted if adverse impacts should occur. Mitigation could include diverting discharge to an alternative disposal system.

- o There is very little credible biological information on anchialine flora and fauna. Therefore, conclusions regarding significance of impacts are "best guesses" based on qualitative and observational (field) information.

  The proposed monitoring program is intended to provide additional information to resolve the above issues. Because discharge quantities are expected to increase gradually, both for OC OTEC and mariculture, the trench disposal system is still recommended, even though some issues remain unresolved.

Compatibility With Land Use Plans

- o State Land Use Law: The NELH site is in the Urban District, therefore there is no conflict.

- o Hawaii Coastal Zone Management Objectives and Policies: Coastal Zone Consistency Certification is being addressed through the U.S. Army Corps of Engineers permitting process.

- o Conservation District Policies and Regulations: A Conservation District Use Permit (CDUP) for use of approximately 2940 acres of ocean waters and submerged lands for ocean research, alternative energy and mariculture research, and commercial mariculture and energy activities and facilities, including construction of up to 15 additional warm and cold water intake pipelines, was approved by the Board of Land and Natural Resources on July 23, 1986. Conditions on this permit require monitoring of anchialine ponds -- as described in this SEIS -- and approval of an acceptable seawater disposal system for OC OTEC water.

- o Hawaii Water Quality Standards and Permits: Coastal water quality is protected by the federal Clean Water Act (33 USC 1251 et. seq.)

and the State Environmental Quality Act (Chapter 342, HRS), administered by the Hawaii State Department of Health. The two applicable regulations are Water Quality Standards and Water Pollution Control, Chapters 54 and 55 of Title 11, Administrative Rules.

The waters off Keahole are classified as AA in the Water Quality Standards. The objective of this class is to keep these waters in their natural pristine state as nearly as possible with an absolute minimum of pollution. Uses to be protected in this classification include oceanographic research.

Discharge into a trench is not covered by any specific environmental regulation. However, Section 33 of Chapter 342 contains a general prohibition against the discharge of any pollutant into state waters, which by definition include ground water. Although a specific permit would not be required, the proposed trench disposal system would need review by and approval of the Department of Health before it is implemented.

o Hawaii County General Plan: In conformance.

o Hawaii County Special Management Area: The County of Hawaii Planning Department has reviewed the alternative disposal methods and and determined that NELH Permit #77 should be amended.

The Hawaii State Plan: Objectives and policies (Part I) and priority guidelines (Part II) in relation to the economy, energy, etc., as described in the HOST/NELH FEIS.

Environmental Policy: Chapter 344, HRS - State Environmental Policy Act - Conforms

Air Quality: Federal Clean Air Act, as amended (42 U.S.C. 1857h-7 et seq. and State Environmental Quality Act (Chapter 342 HRS) - No effect expected

Fish and Wildlife Habitat: Fish and Wildlife Coordination Act (16 U.S.C. Sec.661 et seq.) - Coordination is being accomplished through U.S. Army Corps of Engineers permit process.

Historic and Cultural Properties: National Historic Preservation Act of 1966, as amended (16 U.S.C. 1251 et seq.) - No historic sites will be disturbed by construction of disposal facilities.

Necessary Reviews and/or Approvals

The following list of necessary reviews and/or approvals does not include compliance activities to be undertaken by the U.S. DOE.

Federal

Clean Water Act (33 USC 1251 et. seq.)
-Administered by the State. See Department of Health

Federal Aviation Agency (FAA)
-Notice of construction within 20,000 feet of airport runways (14 CFR 77)

U.S. Coast Guard
-If required, license to construct facilities on Coast Guard land.

State of Hawaii

Department of Agriculture
-Mariculture operations culturing exotic species: Permit to import non-indigenous species.

Department of Health
-Trench Disposal: Review and approval for compliance with Section 33, State Environmental Quality Act (Chapter 342, HRS)
-Disposal Via Canal: Existing National Pollution Discharge Elimination System (NPDES) Permit must be modified if discharge exceeds 1500 gpm.
-Underground Injection Wells (UIC): Permit required even though proposed site is in an exempted aquifer area.
-Mariculture operations involving shellfish: Shellfish Sanitation Certificate.
-Individual domestic wastewater disposal systems: Permit required.

Department of Land and Natural Resources
-Satisfaction of and request to remove condition #8 -- approval of an acceptable seawater disposal system for 16,100 gpm of OTEC water -- from CDUA HA-1862.
-Historic Sites review.
-Approval of plans for construction within the Conservation District.
-Approval of all NELH tenants' subleases.

Hawaii County

Special Management Area (SMA) Use Permit
-Amend existing SMA #77 if required.
Subdivision Application and Approval.

Plan Approval and Various Construction Permits.

PART I: INTRODUCTION

A. NATURAL ENERGY LABORATORY OF HAWAII

The Natural Energy Laboratory of Hawaii (NELH) was established by the Hawaii State Legislature in 1974 by Act 213 to manage and operate an outdoor research facility on approximately 322 acres of state-owned land at Keahole Point on the island of Hawaii for research, development and demonstration of natural energy resources (Figure I-1). Legislation passed in May 1984 amended the NELH enabling legislation (Ch. 227, HRS) to allow on-site commercialization of successful research and development projects. NELH is governed by a managing board consisting of seven ex-officio voting members. NELH is placed within the Department of Planning and Economic Development (DPED) for administrative purposes.

The Keahole site was selected for the NELH facility because of the nearby availability of cold, deep ocean water; a warm ocean surface layer not subject to strong seasonal cooling; high annual solar insolation; accessibility to logistical support through airports, harbors, and highways; and the presence of adjacent, suitable undeveloped land. The unique characteristics of the site make it an excellent environment for conducting ocean related research such as Ocean Thermal Energy Conversion (OTEC) and aquaculture.

OTEC is a power generating system that uses the temperature difference between warm surface water in the tropical ocean and the cooler water at depth to run a heat engine. Research on two types of operating cycles, closed and open, is presently being conducted at NELH. In closed-cycle (CC) OTEC, a low-boiling point working fluid (ammonia or Freon) flows through a series of components in a closed loop. The main components are two heat exchangers, a turbo generator and a feed pump. The working fluid is vaporized by heat from the warm seawater and passed through a turbo generator to generate electricity. To complete the cycle, the fluid is then condensed by the cold seawater which has been transported to the surface via a cold water pipe.

In open-cycle (OC) OTEC, warm surface water is used as the working fluid. Prior to evaporation the water is degassed, removing dissolved oxygen, nitrogen, carbon dioxide, and trace gases from the water. Steam is produced after a partial vacuum is created over the warm seawater. The steam, after passing through a turbine, is condensed using cold ocean water. If condenser tubes are used, fresh water can be produced; otherwise, the condensate is discharged with the cold seawater.

The U.S. Department of Energy (U.S. DOE) is planning to expand its funding of OC OTEC research at NELH. Expansion facilities to support this research program will be constructed by the State of Hawaii with the financial support of the U.S. DOE. Expanded

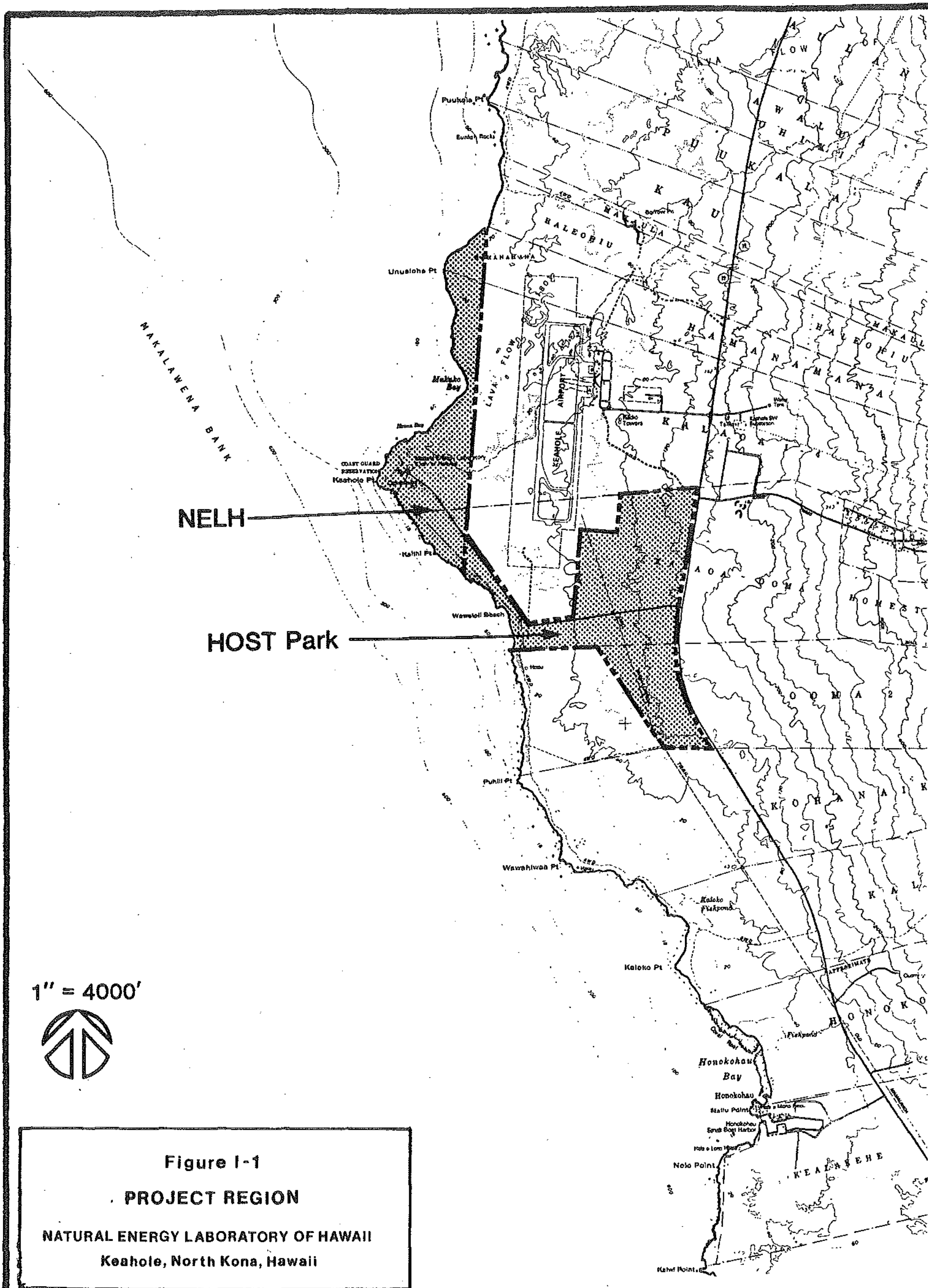


Figure I-1

PROJECT REGION

NATURAL ENERGY LABORATORY OF HAWAII

Keahole, North Kona, Hawaii

facilities would include: (1) a water system test facility for developmental research for OC OTEC; and (2) an expanded facility for experiments with OTEC-related mariculture.

An operating open-cycle demonstration plant will be built at NELH upon completion of approximately 3 to 4 years of heat and mass transfer experiments. It is currently planned that this plant, which will provide a gross output of approximately 165 kW, will utilize 16,100 gpm of warm and cold seawater (NELH, 1985).

The availability of high-quality deep cold seawater used for OTEC experiments has also made possible many types of aquaculture with commercial potential. The cold water, which is continuously pumped ashore at NELH, has proven attractive for aquaculture operations because of its abundance of nutrients, low level of pathogens, and desirable temperature range for high-value temperate species. As a result of the success of Hawaiian Abalone Farms (HAF) and the Cyanotech Corporation, which have demonstrated the suitability of the cold water for abalone culture and the commercial production of algae for use as food supplements, fertilizers and pharmaceuticals, aquaculture activities have become as great an interest to potential researchers and developers as the energy-related projects of the facility.

B. RELATIONSHIP TO THE HAWAII OCEAN SCIENCE AND TECHNOLOGY PARK

To demonstrate Hawaii's commitment to the development of high technology enterprises, the 1983 Hawaii State Legislature created the High Technology Development Corporation (HTDC). HTDC is empowered to develop and administer industrial parks for high technology use and issue special purpose industrial revenue bonds to finance their construction. In the early 1980s, the NELH Board and staff recognized the need for providing additional sites when successful projects at the laboratory would expand into commercial operations. As a result one of the corporation's first development projects is the Hawaii Ocean Science and Technology (HOST) Park, which broke ground in November 1986, on 547 acres of state-owned lands located adjacent to NELH (Figure I-1). A major reason for developing this particular site for ocean-related "high tech" activities is its proximity to NELH.

The State of Hawaii (through HTDC) is the developer and owner of the property, and will offer 35-year leases to qualified tenants. The entire area is master-planned for industrial use. A major objective in marketing HOST Park is to target industries that can utilize the unique resources of the Keahole Point area which NELH has demonstrated to be valuable for ocean-related high technology development. The types of companies that were identified as being prospective occupants of the park are high intensity aquaculture, alternate energy, marine biotechnology, pharmaceutical development, oceanography and tropical agriculture.

Developing HOST Park on property adjacent to NELH is intended to facilitate the transition from demonstration to full-scale commercial operations. NELH will act as as an "incubator" for projects as they grow from the research stage to large-scale commercial production. Together, the NELH and the HOST Park will be offered as an attractive and complementary package to high technology corporations which may be interested in establishing their operations in Hawaii.

C. PURPOSE AND NEED FOR PROPOSED MODIFICATIONS

An environmental impact statement for the Development Plan for the Hawaii Ocean Science and Technology Park and Expansion of the Natural Energy Laboratory of Hawaii (HOST/NELH FEIS) was accepted by the Governor in September 1985 (HTDC, 1985). Among the actions assessed in the statement was the disposal of 42,000 gpm of seawater return flows from OTEC and mariculture operations at NELH at full development and the disposal of 100,000 gpm from fully developed commercial operations at the proposed HOST Park. NELH discharge would be disposed of on-site by trench, well, canal and/or mixed-water discharge pipe, and HOST Park seawater return flows would be disposed of in trenches on the park site.

At the time the HOST/NELH FEIS was accepted, the State of Hawaii planned to install a cold water pipe and pump system for HOST Park and the DOE was planning to fund a cold and warm water system for OTEC research. Subsequently, the U.S. DOE learned that it would be unable to fund the proposed expansion of OTEC facilities at NELH to the level they had originally proposed. Rather than installing separate seawater pipe systems, the U.S. DOE and the state entered into a cooperative cost-sharing agreement to provide the required ocean water for both projects with one seawater system. This combined system will include cold and warm water intake pipelines and a pump station to service both NELH and HOST Park activities.

The large-diameter (48-inch) mixed-water discharge pipe that was originally proposed as the means to dispose of the projected OTEC seawater at a depth of -200 feet MSL proved to be very expensive and cannot be funded at the present time. Alternative, less costly methods of disposal for a projected 16,100 gpm of warm and cold OC OTEC seawater flows were then investigated. These included direct disposal via canal, disposal into shallow trenches, deep lined injection wells and/or a combination thereof.

Because of NELH's concern for the preservation of the pristine quality of the intake waters, detailed assessments of the effects of OC OTEC discharges on nearshore and offshore water quality, including an evaluation of impacts on the biological environment, were prepared. Cumulative impacts of OC OTEC seawater return flows plus other on-site discharges, such as from mariculture, were also evaluated prior to recommending alternate method(s) to be used to dispose of OC OTEC water.

D. ENVIRONMENTAL COMPLIANCE

In accordance with Section 11-200-27 of the Environmental Impact Statement Rules, a request for determination regarding the proposed modification to the methods of seawater return flow disposal at NELH (as disclosed in HTDC, 1985) was submitted to the State of Hawaii, Office of Environmental Quality Control (OEQC). After review of the Request for Determination and the subject FEIS, OEQC determined, pursuant to the responsibility delegated to the accepting authority as stated in Section 11-200-27, Environmental Impact Statement Rules, that a supplemental statement was required because the alternative disposal methods for OC OTEC seawater flows may have different impacts than those described in the accepted FEIS.

This supplemental environmental impact statement has been prepared to comply with Chapter 343, Hawaii Revised Statutes and with Section 11-200-27 of the Hawaii State Environmental Impact Statement Rules regarding supplemental statements. The accepted HOST/NELH FEIS is incorporated into this document by reference. The information contained herein is also intended to provide the basis for, but not substitute for, any environmental compliance activities required by the Federal government.

PART II: PROJECT DESCRIPTION

A. ENERGY PROGRAMS AND PROJECTS

(See Appendix A for a more detailed description of energy programs and projects.)

1.0 Ocean Energy Technology

The U.S. DOE has identified the development of ocean energy technology as one of its long-range missions. Research to date at NELH has been associated with OTEC operating systems and related research. Development of the pumping facilities necessary for a CC OTEC experiment involved much research into corrosion of equipment and cables in seawater, bio-fouling counter-measures, heat transfer, and water quality analysis.

The following areas have been identified for future ocean energy technology research (U.S. DOE, 1985): (a) research and analysis on thermodynamics; (b) experimental verification and testing of components; (c) materials and structural research; and (d) oceanographic, environmental and geotechnical research.

2.0 OC OTEC

OC OTEC power is generated by a large low pressure turbine driven by water vapor produced from the evaporation of warm surface seawater. The evaporated seawater, the working fluid, is later condensed by cold deep seawater. To increase the efficiency of the evaporator, dissolved gasses, primarily oxygen and nitrogen, should be removed from the warm seawater before it reaches the evaporator.

OC OTEC research currently being conducted at NELH is concerned with heat and mass transfer and gas sorption kinetics experiments which relate to degassifying warm and cold seawater. In the degassification process the available forms of organic carbon and other nutrients change due to lysing of plankton and other microorganisms on the low pressure environment.

The U.S. DOE is planning to test OC OTEC components using a Heat and Mass Transfer Scoping Test Apparatus (HMSTA) which was designed by the Argonne National Laboratory. These tests are programmed to commence in early 1987. In general, the experiments will focus on development of optimal removal techniques for degassing both warm and cold seawater. The apparatus will be varied from 0 up to 100% degassing in order to determine the limits of the process. At the present time it is predicted that 50 to 60% of the gasses, primarily oxygen, will be removed. Reaeration techniques will also be tested (Penney, 1986). Additional OC OTEC experiments anticipated for NELH include tests of direct contact and conventional heat exchangers; studies of non-condensible gases including basic sorption kinetic studies and their effects on heat transfer; tests on turbine materials; and, evaluation of the mist lift cycle (NELH, 1985).

It is anticipated that mixed seawater flows required to carry out the OC OTEC heat and mass transfer experiments will range from 3,000 to 5,000 gpm. The duration of each experiment is expected to range from a few hours to a few days.

3.0 165 kWe Open-Cycle Demonstration Plant

The U.S. DOE is also developing a research experiment to establish the feasibility of producing significant amounts of net power from an OC OTEC system (Figure II-1). The experiment is sized at 165 kW of gross power and will be used to evaluate turbine performance and system process interactions for projection to a commercial market entry system of 5 to 15 mW of electrical power (SERI, 1985). Figure II-2 presents a schematic illustration of large-scale OC OTEC experimental equipment anticipated to be installed at NELH.

It is anticipated that heat and mass transfer experiments will continue for approximately 3 to 4 years. The 165 KWe OC demonstration, projected to be operating in 1991, is expected to run 24-hours a day for days to weeks extending over a period of 8 months to one year (Lewis, 1986).

4.0 Seawater Return Flows from Planned OC OTEC Experiments

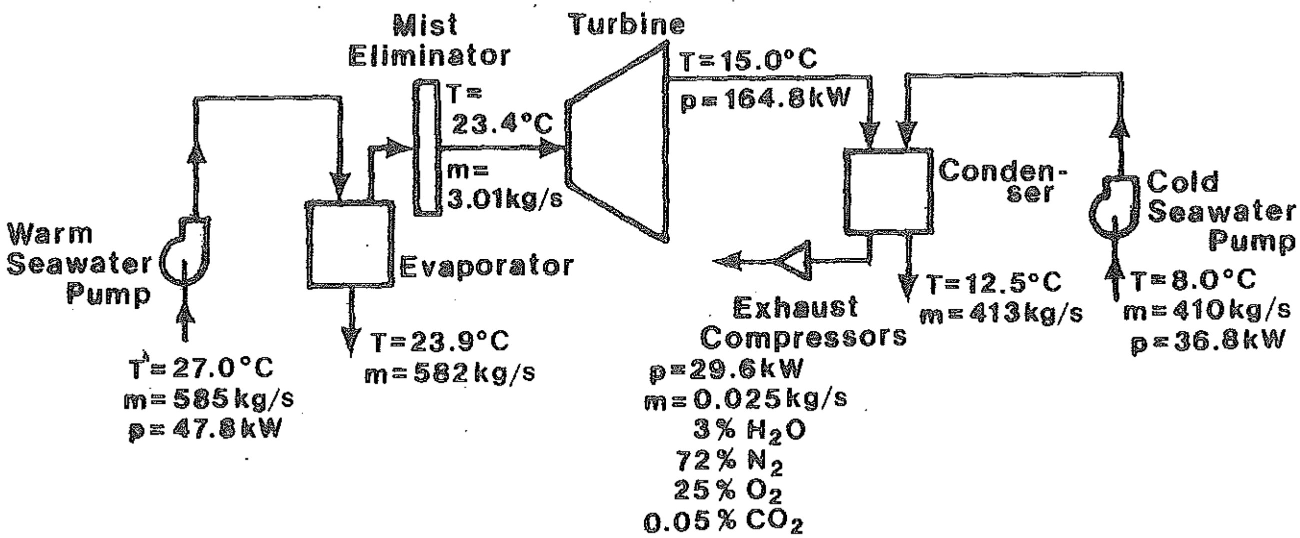
When the OC OTEC 165 kW demonstration plant is in operation, approximately 16,100 gpm of mixed seawater is anticipated to be discharged. The seawater will be mixed in a ratio of (cold:warm) 1:1.5. At the discharge point the temperature would be approximately 19°C; some additional warming will occur before the water reaches the ocean. These ratios and temperatures will vary during the initial 3,000 to 5,000 gpm experiments.

5.0 Recommended Method of Seawater Return Flow Disposal

5.1 Discharge Into a Trench Within the NELH Compound

The disposal facility recommended for OC OTEC discharges is a shallow trench located within the NELH compound (Figure II-3). The recommended trench orientation is roughly perpendicular to and approximately 250 feet from the shoreline at its closest point. The specific location of the trench within the NELH compound will be determined after a more detailed site analysis is undertaken.

A trench with the capacity to dispose of 16,100 gpm of OTEC water can be either 5-foot-wide by 5-foot-deep by 193-foot-long or 10-foot-wide by 10-foot-deep by 79-foot-long. In order to allow for non-homogeneity of the hydrogeologic characteristics of



Net Power = 164.8 − 47.8 − 29.6 − 38.6 = 46.8 kW

Source: SERI, 1985

Figure II-1
OC OTEC
EXPERIMENTAL FLOW DIAGRAM
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

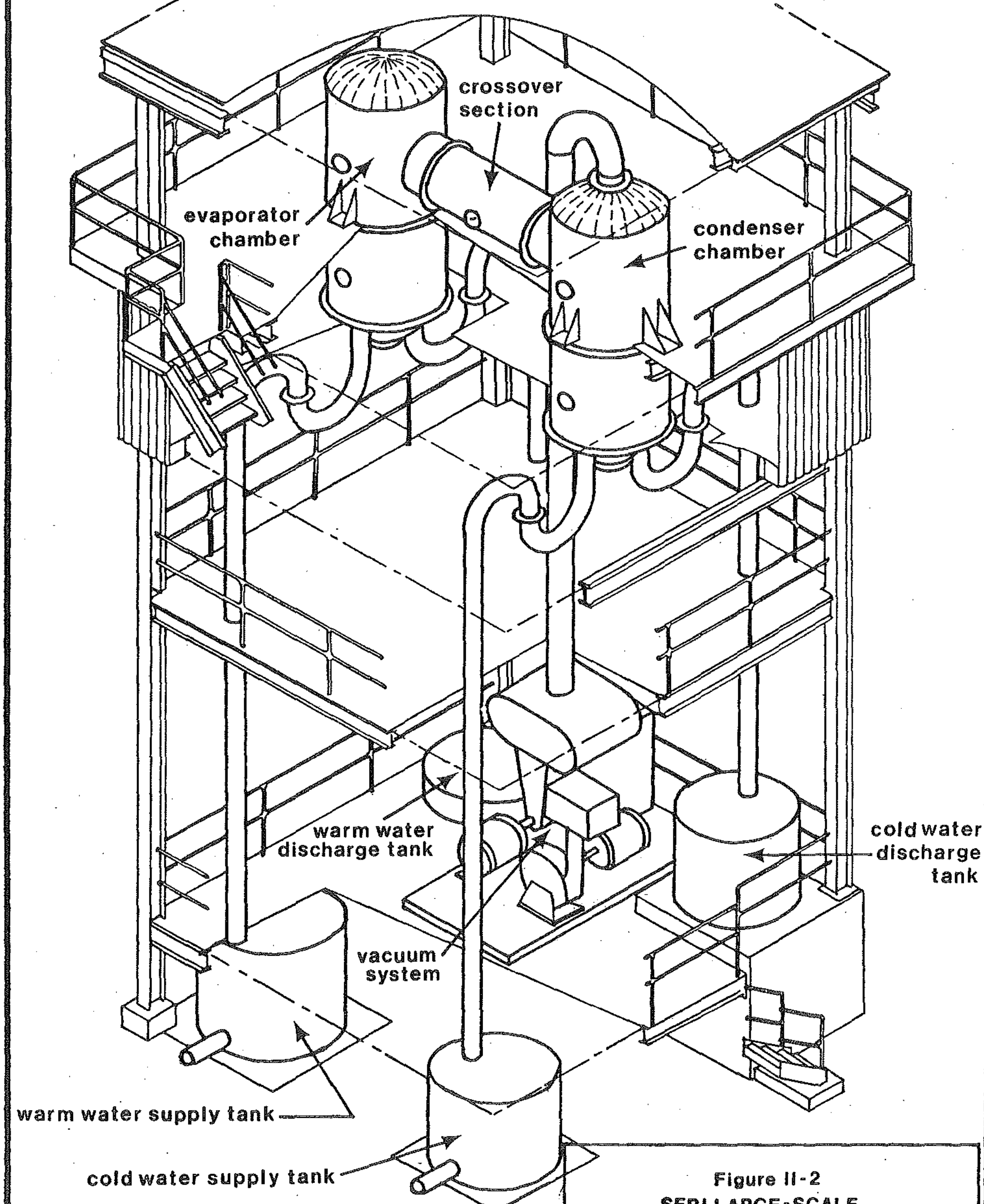


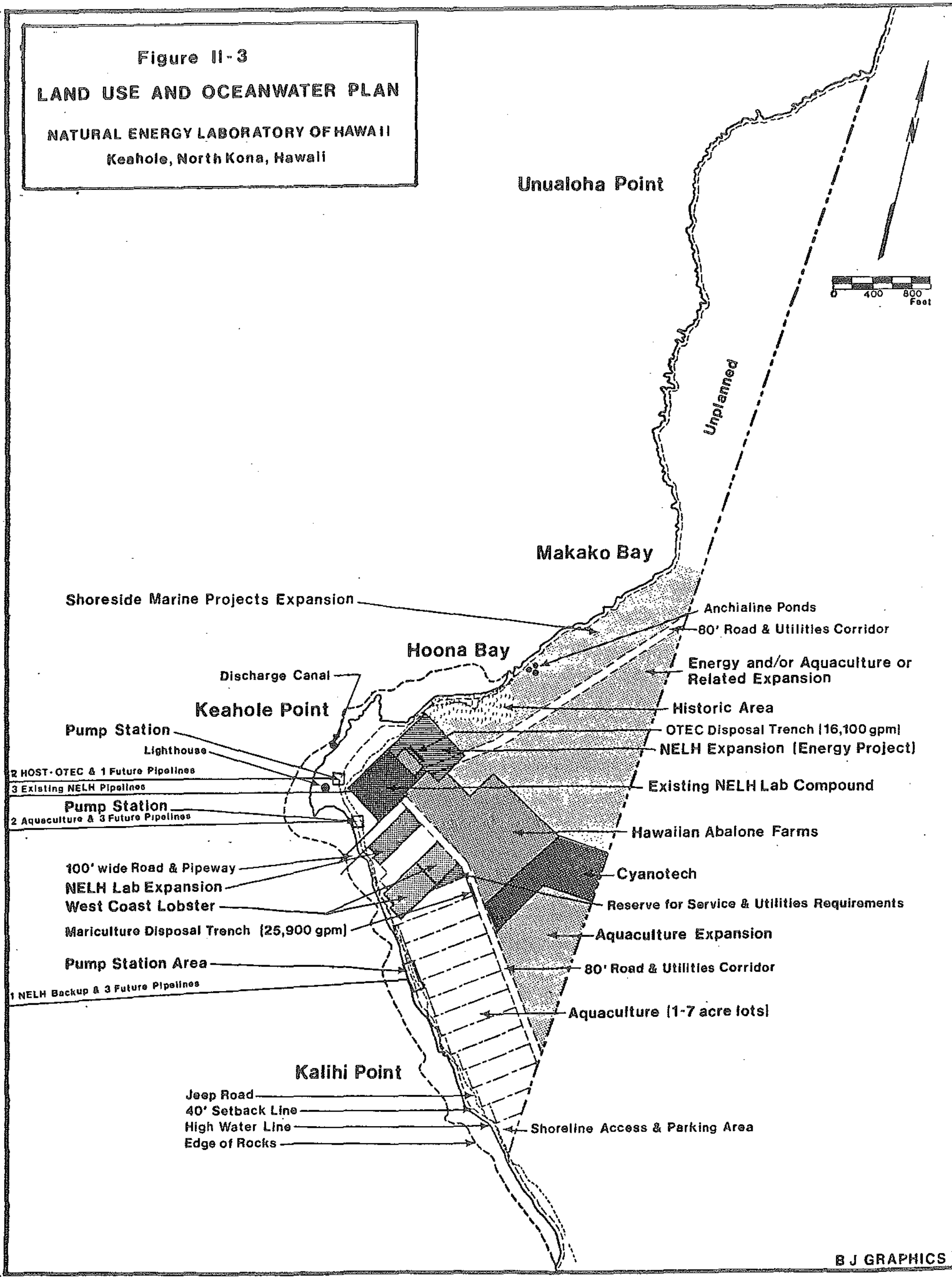
Figure II-2
SERI LARGE-SCALE
OPEN-CYCLE OTEC EXPERIMENT
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

Figure II-3

LAND USE AND OCEANWATER PLAN

NATURAL ENERGY LABORATORY OF HAWAII

Keahole, North Kona, Hawaii



the disposal area subsurface materials and to mitigate silting and clogging problems that may occur in the initial start up stage, the actual excavation should probably be twice the required trench length. The exact dimensions of the trench will be determined during the design of the facility. If the full trench is not required for testing of the ocean water supply system, a smaller trench might be tested and monitored with lesser initial flows and the trench size could be modified based on this experience. A cross-section of a proposed disposal trench utilizing a perforated pipe and boulder or crushed lava backfill is presented in Figure II-4.

5.2 Monitoring

An important consideration for any on-land disposal method is monitoring. Because there are unknowns associated with OC OTEC discharge water and its impact on the environment, it is recommended that a water quality monitoring program be instituted as soon as possible and continue throughout the 3,000 to 5,000 gpm heat and mass transfer experiments. The data collected in this program should be continually evaluated during this three to four-year period and alternative disposal facilities, such as deep injection wells, should be constructed if adverse impacts become evident. Because the identified potential impacts are generally reversible (Part IV), the risk to the environment and future OTEC research under these conditions is expected to be minimal.

Monitoring should take place at the disposal site and other onshore locations, at the warm water intake and offshore. Because trench disposal could also affect the brackish water lens, the anchialine ponds north of NELH should also be monitored. A proposed water quality monitoring program is presented in Appendix B of this SEIS.

Operations of the trench should be monitored to collect operation and maintenance data. The ultimate size of the trench would be determined by research and experience with lesser flows associated with the preceding phases of the experimental process. Testing and monitoring accomplished in the earlier phases could indicate that smaller trenches are acceptable. This could be another test objective of the phased OTEC expansion program at NELH.

B. MARICULTURE PROJECTS

1.0 Future Mariculture Projects

The availability of high quality deep cold seawater makes possible many types of aquaculture with considerable commercial

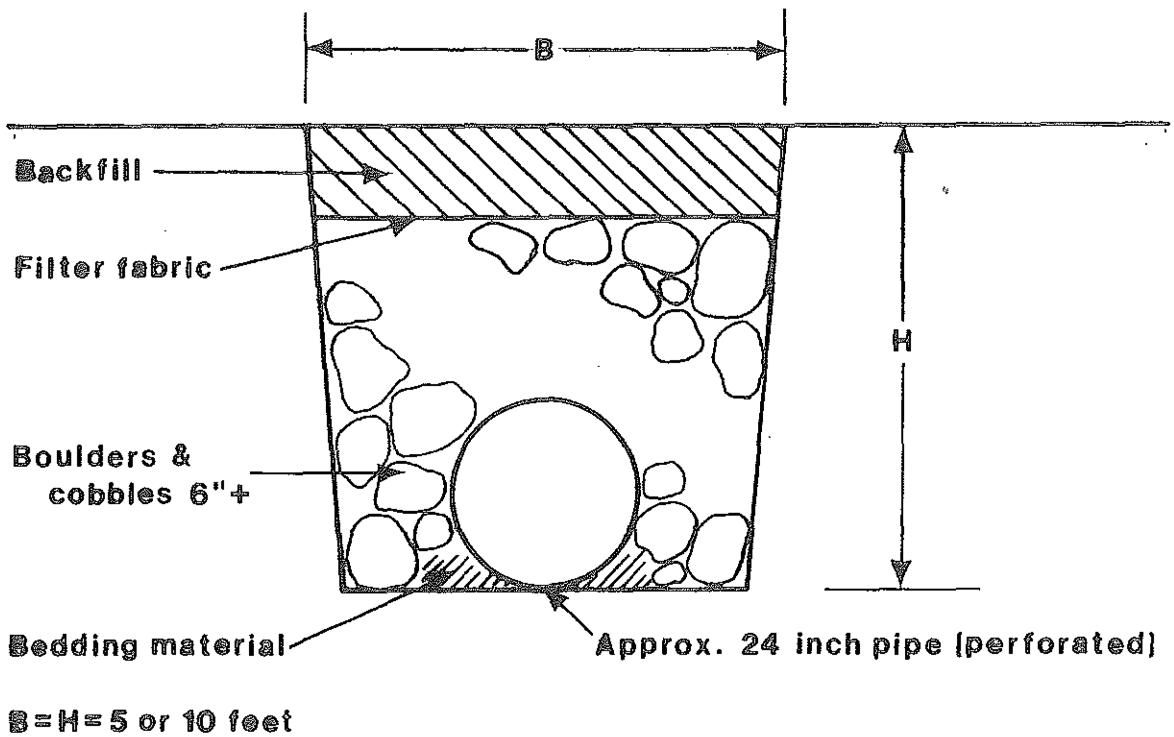


Figure II-4
DISPOSAL TRENCH CROSS SECTION
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

Dames & Moore

potential. Based on the experience of the past three to four years, it appears that significant potential exists for commercialization of several species of aquatic plants and animals, utilizing the properties of low temperature, high nutrient content and lack of pathogens that are found in the deep cold water. Appendix A in the HOST/NELH FEIS (HTDC, 1985) recommends various mariculture projects suitable for NELH and for the adjacent HOST Park. The species described below, and possibly others, could be grown as intermediate products for consumption by other cultured species; as agricultural feed supplments; for human consumption; for water treatment purposes; for marketable seed stock; or for by-products such as beta-carotene or agar. Briefly, they are:

- o **Microalgae**, such as Chaetoceros, Dunaliella, Tetraselmis, Spirulina, and Phaeodactylum;
- o **Macroalgae**, such as Gelidium, Gracilaria, Laminaria, and nori seaweed (Porphyra tenera);
- o **Marine Mollusks**, abalone (Haliotis sp.), oysters (Crassostrea, Ostrea), clams (Tapes, Mercinaria, Tridacna), and opihi (Celana sp.);
- o **Crustaceans**, such as shrimp (Penaeus) lobster (Homarus, Panulirus) and brine shrimp (Artemia);
- o **Finfish**, such as coho salmon, steelhead trout, rainbow trout, mullet, tilapia, carp and mahimahi.

2.0 Seawater Return Flows from Projected Mariculture Operations

At full development of NELH it is projected that an additional 25,900 gpm of seawater return flows from mariculture operations will be generated. The constituents of the discharge water will depend on the culture organism and its intended use. The overall warm and cold seawater mix is assumed to be 1:4.

3.0 Seawater Return Flow Disposal (25,900 gpm)

3.1 Discharge Into a Trench Makai (Seaward) of NELH Access Road (Figure II-3)

The disposal facility recommended for return seawater from mariculture operations is a trench located adjacent to and makai of the NELH access road. A potential location for this facility about 1,000 feet southward of the NELH compound, parallel to and approximately 900 feet from the shoreline at its closest point, is evaluated in Part IV of this SEIS. Because distance to the shoreline from the access road increases towards the HOST Park site, relocation of the trench in this area would result in lower concentrations of discharge at the shoreline and less potential for biostimulation of the algal turf than if the trench were located closer to the NELH compound.

Disposal trench dimensions for the projected quantity of mariculture discharge at full development of NELH (25,900 gpm) are approximately 5-foot-wide by 5-foot-deep by 362-foot-long. If necessary the length of the trench could be shortened by digging a deeper trench. As with the trench recommended for the OC OTEC discharges, the exact dimensions of the mariculture disposal trench will be determined during the design of the facility. Monitoring and maintenance considerations described for OC OTEC water disposal would also be applicable to mariculture discharges. The mariculture trench would be similar in cross-section to that presented in Figure II-4.

3.2 Other Methods of Mariculture Discharge Disposal

Based on the analyses of the efficiency of algal mats for treatment of OTEC and mariculture discharges prior to disposal (GK & Associates, Appendix B), and data from the existing canal and ponding areas (HTDC, 1985), it is possible that low volumes of mariculture discharge (less than 1,000 gpm) could be disposed of via canal and pond systems without significant environmental impact. These systems would require approval of the Department of Health.

C. NELH DEVELOPMENT PLAN

The proposed NELH Land Use and Ocean Water Plan is presented in Figure II-3. Figure II-5 illustrates proposed improvements and expansion of the NELH laboratory compound (otherwise known as the Seacoast Test Facility (STF)).

1.0 STF Upgrades

As discussed in the HOST/NELH FEIS (HTDC, 1985), the U.S. DOE and the state are currently in the planning and design phases of upgrading the energy research and testing capabilities of the STF. The purpose of the expanded test facility is to support experimental research on critical elements of advanced OTEC cycles as described in Section A. The facility is also being designed to support environmental, oceanographic and ocean engineering experiments to aid the development of diverse ocean energy supply operations. These upgrades will include:

- An experimental test facility to be located within the present laboratory property, occupying a space of approximately 1 acre;

- An improved road and new 24-foot wide driveway on the ocean side of the laboratory property;

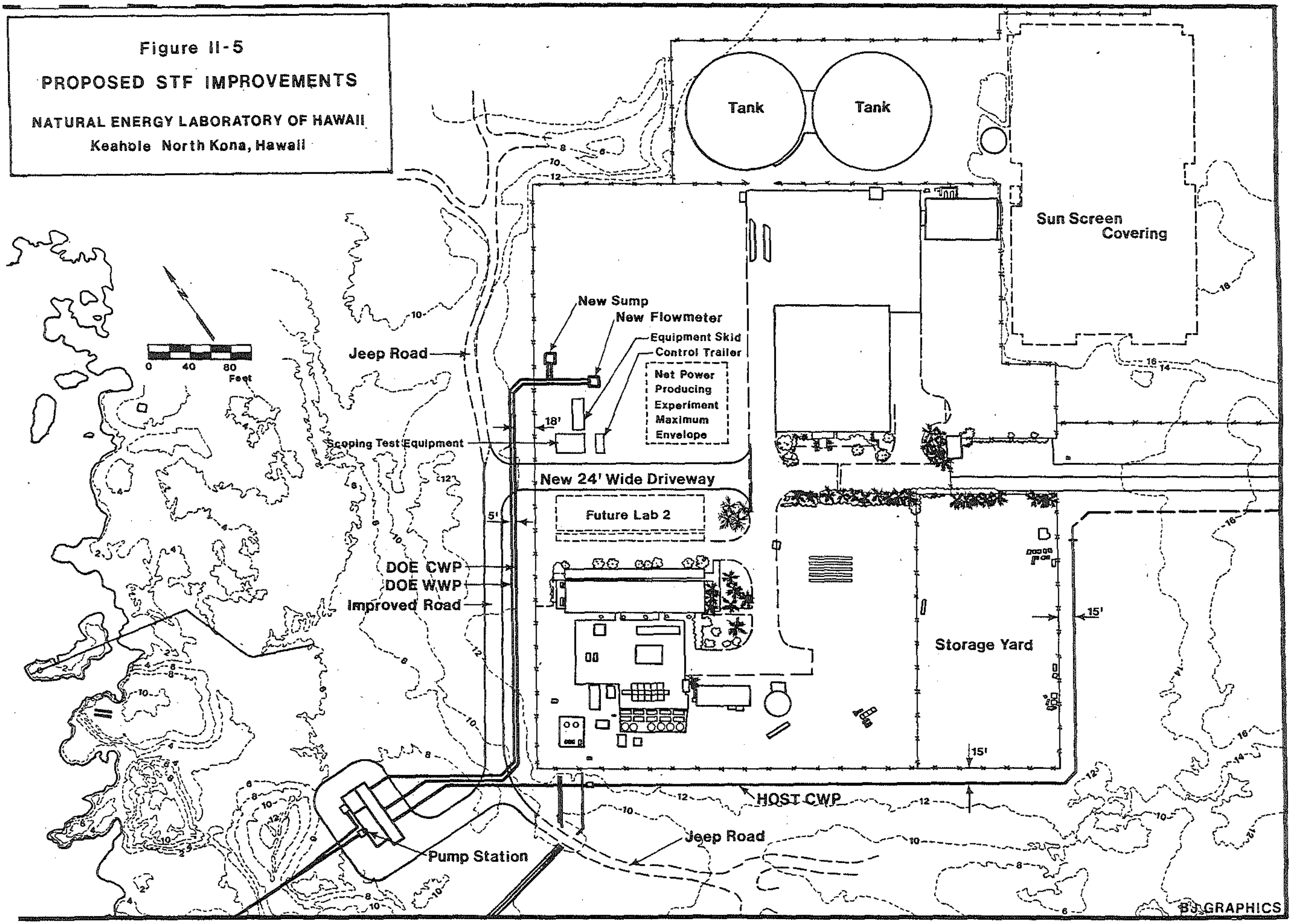
- Four holding tanks (to maintain the appropriate pressures needed for the open-cycle experiment);

Figure II-5

PROPOSED STF IMPROVEMENTS

NATURAL ENERGY LABORATORY OF HAWAII

Keahole North Kona, Hawaii



- A control building to house electrical power controls and a pumping station;

- Two ocean water intake pipes (1 warm and 1 cold), capable of delivering 9,500 gpm of warm surface seawater and 13,300 gpm of deep cold seawater -- 6,800 gpm of cold seawater will be diverted to the adjacent HOST Park for use in commercial aquaculture and other ocean-related industries (Figure II-6);

- An ocean water pump station;

- Ocean water distribution lines from the pump station to the facility;

- A seawater return flow disposal facility for OTEC water; and

- New electrical power and control lines installed in underground ducts to the pumping station and within the NELH facility.

2.0 Future NELH Laboratory Compound Expansion

The proposed land use and ocean water plan (Figure II-3) allocates an additional three acres north of the existing compound fence for future energy project expansion. The laboratory will also expand three acres to the south of the existing compound. The storage area will be moved to this new location so that more space is available near the laboratory building for initial research and development of mariculture projects.

3.0 R & D Aquaculture Expansion

It is planned that mariculture companies would initially conduct research and development activities to determine appropriate mixes, temperatures and other water conditions for their products within the laboratory compound, moving outside the compound fence after the testing phases are completed. Approximately 60 acres, south of the laboratory fence and makai of the NELH access road, will eventually be subdivided into one to seven-acre lots for use or lease by R & D firms.

4.0 Mariculture Commercial Demonstration Modules

Two major commercial demonstration projects are currently in operation on the NELH property: Hawaiian Abalone Farms (HAF), 21.3 acres and Cyanotech, 15 acres. An additional 18 acres (plus an optional 42) has been allocated for future use as commercial modules. These areas will be subdivided into 5 to 10 acre lots for lease to qualified entreprenuers.

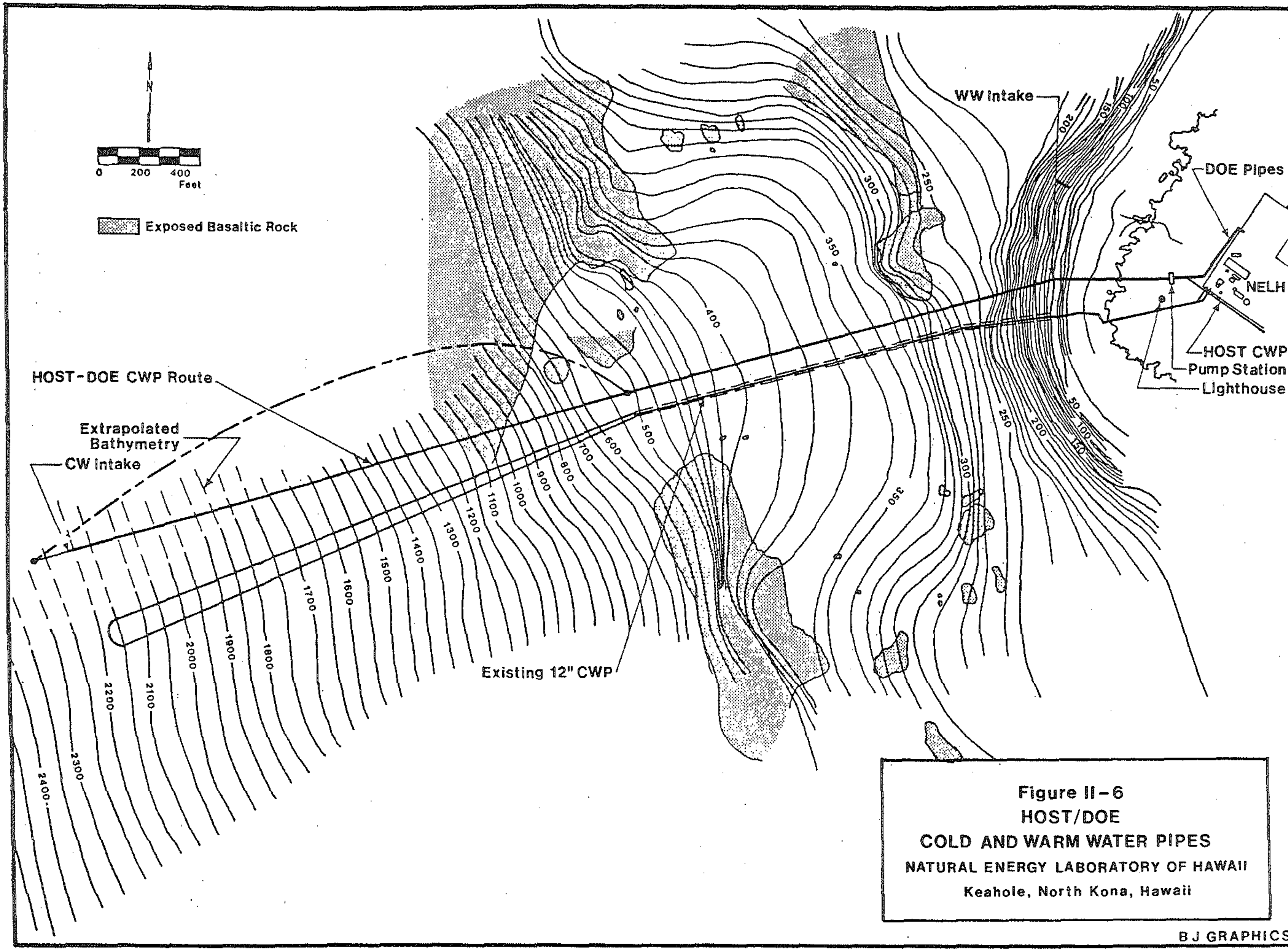


Figure II-6
HOST/DOE
COLD AND WARM WATER PIPES
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

5.0 Seawater Disposal Facilities

The preferred method of seawater disposal is via trenches behind the shoreline. Other methods, such as injection wells, algal ponds for pretreatment, and/or possibly some direct discharge canals, could be employed in the future if monitoring results indicate their adequacy, desirability or necessity.

6.0 Shoreside Marine Projects Expansion

Approximately 21 acres has been allocated for future shoreside marine projects such as solar ponds, wave energy conversion, and marine biomass energy.

7.0 Public Shoreline Access

An area of approximately one acre at the southern boundary of NELH (Figure II-3) is planned for future development as a public parking area to accommodate approximately 15 to 20 vehicles. Funding would also be requested from the Legislature for public restroom facilities at the time the parking area is constructed.

An additional small parking area for approximately 5 to 10 vehicles may be located at the northern terminus of the jeep trail, near Hoona Bay. This parking area, which would be used by fishermen who utilize the nearby shoreline for both day and night fishing, would not be graded or surfaced but merely delineated by poles or barrels and identified by a sign.

8.0 Infrastructure and Utilities

Based on forecasted needs of committed projects, NELH projects a demand for 100,000 gpd of fresh water by the end of 1995. This requirement could triple at full development of the facility. Because of the expected increase in activity at the site, NELH will request a water commitment from the County of Hawaii for up to 300,000 gpd.

When required for facility expansion, a new road will be constructed to the northern portions of the site. At that time, power and communication lines will be buried along the road.

PART III: DESCRIPTION OF THE EXISTING ENVIRONMENT

A. LOCATION AND LAND USE

1.0 The Region

NELH is situated at Keahole Point, the westernmost portion of the island of Hawaii, within the North Kona District of the County of Hawaii (Figure III-1). According to the 1980 Census, North Kona had a resident population of 13,748 people (DPED,1983). The major urban center on the leeward side of the island, Kailua-Kona, is located in the District. The basic industries in North Kona are tourism, agriculture, and construction. The North Kona Coast is the County's major visitor destination area.

2.0 Land Use Designations

The NELH facility is located immediately makai of the Keahole Airport building restriction line; the property is situated within portions of the ahupua'a (land divisions) of Kalaoa 1-4, and 'O'oma 1, in Tax Map Key 7-3-43:42 (Figure III-2). It is within the State Land Use Urban District as reflected on State Land Use District Map H-2 (Keahole). The County of Hawaii General Plan Land Use Pattern Allocation Guide (LUPAG) Map designates the property as "Industrial" and it is zoned General Industrial (MG-3a). The property lies within the County of Hawaii's Special Management Area (SMA) and existing activities at NELH are currently permitted under SMA Permit #77. A Conservation District Use Permit (HA-1862) was recently approved by the BLNR authorizing NELH use of 2900 acres of offshore and submerged lands as an ocean use corridor.

3.0 Adjacent Land Uses (Figure III-3)

3.1 HOST Park

HOST Park is located to the south of NELH. The 547-acre site is being developed by the State of Hawaii High Technology Development Corporation (HTDC). All except 39 acres of ocean front land at the Park site have been classified Urban by the State Land Use Commission. The County of Hawaii General Plan Land Use Pattern Allocation Guide (LUPAG) Map designates the property as "Industrial" and the Hawaii County Council recently approved rezoning of the Urban portions of the parcel from Open to Industrial (ML-3A and MG-3A). Because the area is in the County of Hawaii Special Management Area, an SMA Permit (#239) was obtained. Proposed uses within the State Conservation District were approved by the BLNR in July, 1986 (CDUA HA-1862).

HOST Park is planned as a subdivision development with improvements, including access roads, roadway lighting, cold and warm ocean water systems, and potable water and electrical

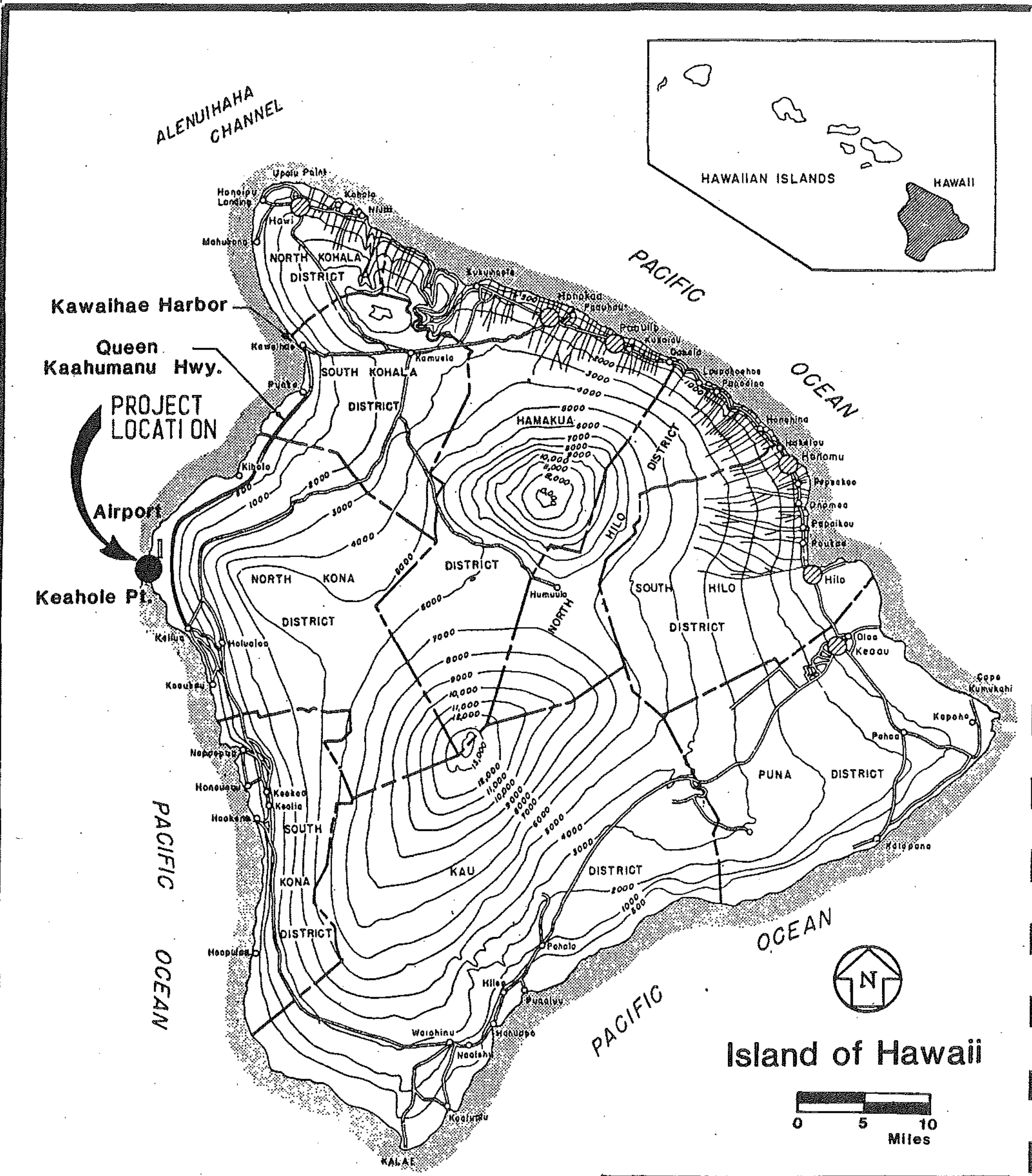


Figure III-1

PROJECT LOCATION

NATURAL ENERGY LABORATORY OF H NAII

Keahole, North Kona, Hawaii

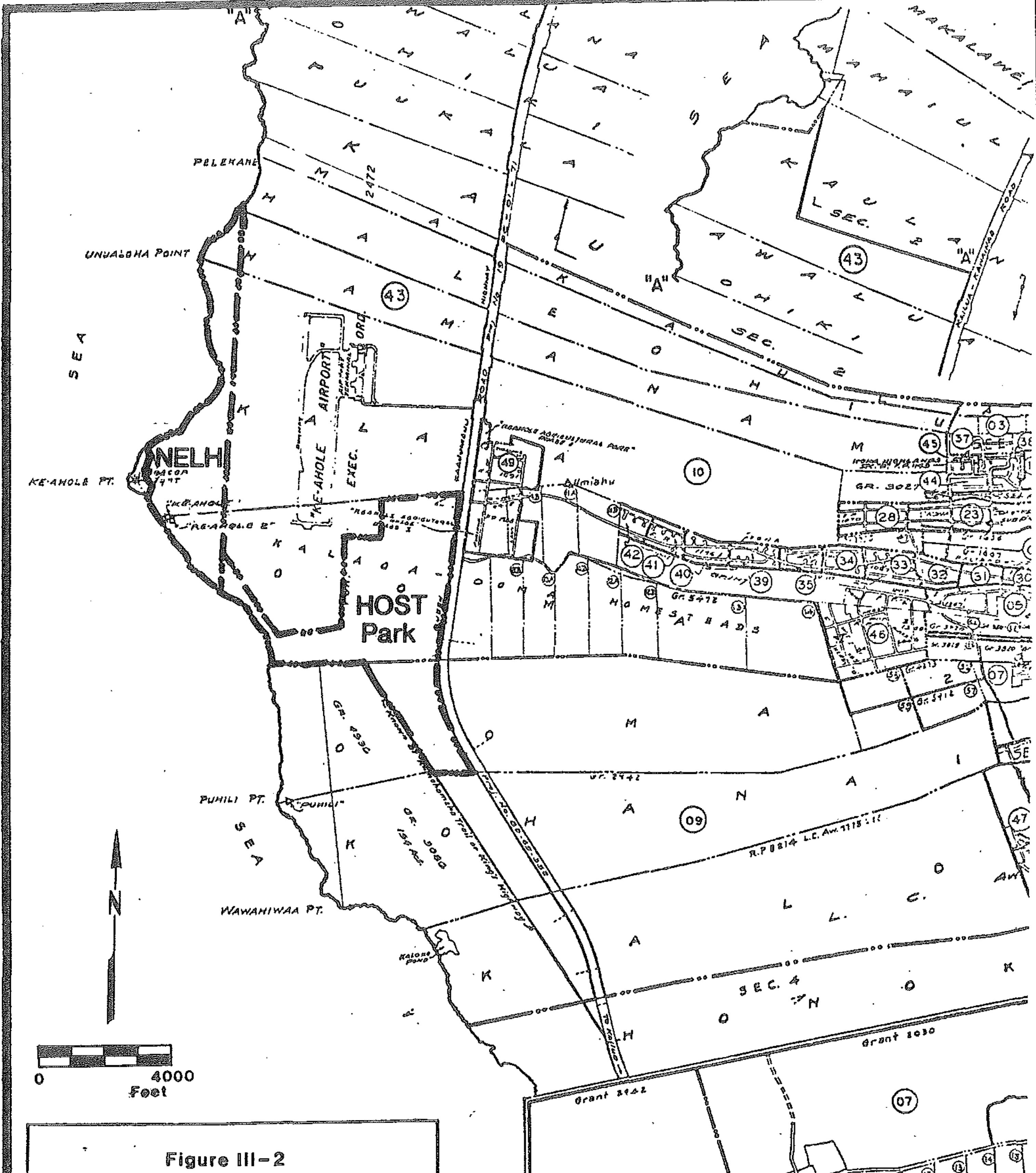


Figure III-2

TAX MAP KEY (7-3-43:42)

NATURAL ENERGY LABORATORY OF HAWAII

Keahole, North Kona, Hawaii

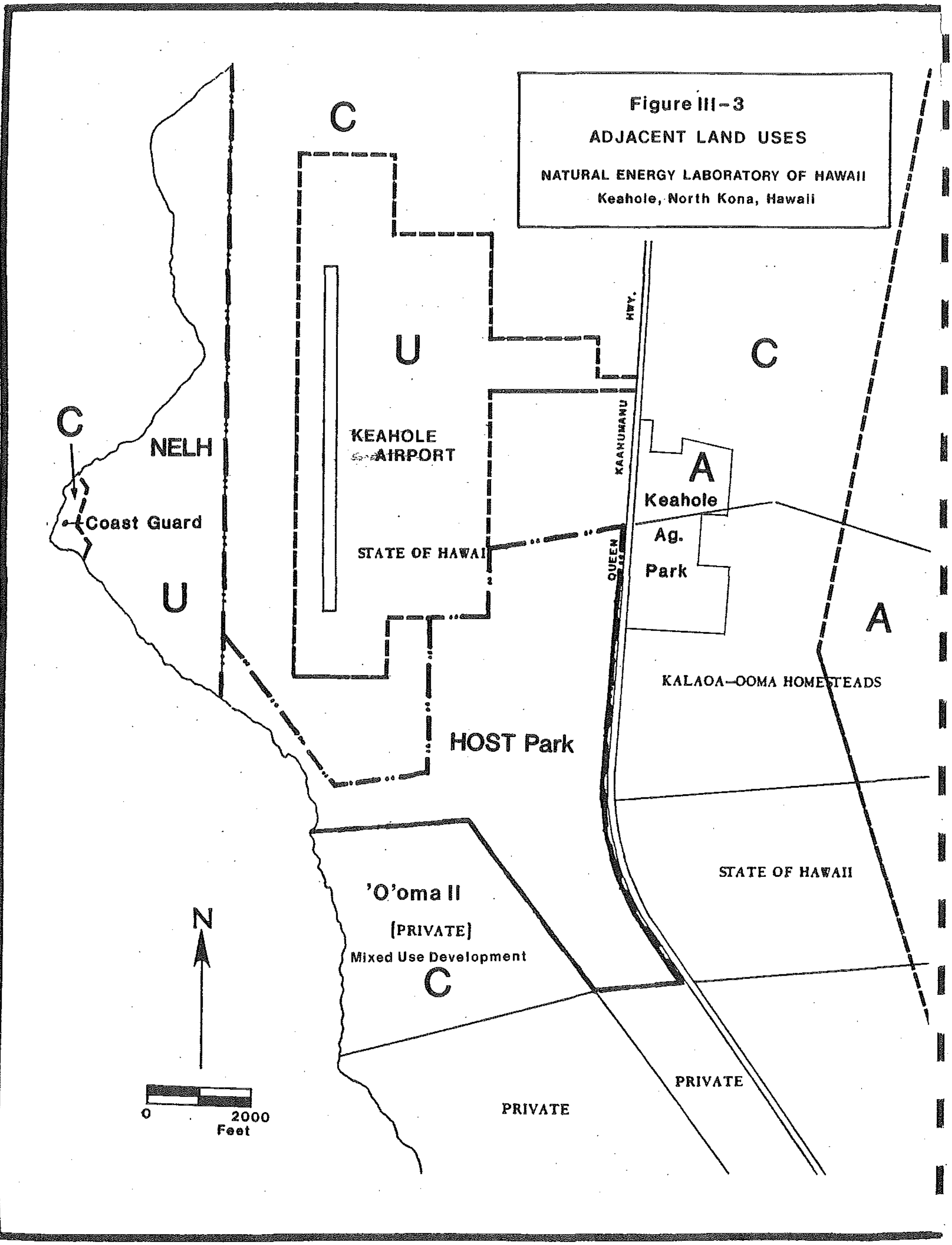


Figure III-3
ADJACENT LAND USES
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii
C
U
C
C
NELH
Coast Guard
U
KEAHOLE
AIRPORT
STATE OF HAWAII
HWY.
KAAHUMANU
QUEEN
A
Keahole
Ag.
Park
A
KALAOA—OOMA HOMESTEADS
HOST Park
STATE OF HAWAII
'O'oma II
(PRIVATE)
Mixed Use Development
C
N
0
2000
Feet
PRIVATE
PRIVATE

services. As shown on Figure III-4, the property will be subdivided into 25 lots of approximately 3+ acres for an approximate total of 80 acres, and 16 lots of approximately 20+ acres for an approximate total of 350 acres. The lots in the subdivision will be leased to approved tenants by the HTDC. Each tenant will construct his own on-site improvements in conformance with the standards and criteria set forth in the Development Rules for the project. Construction of the first phase of infrastructure improvements is scheduled to begin in November, 1986. The primary users of HOST Park are anticipated to be mariculture operators producing a variety of high-value mariculture products such as: microalgae; macroalgae; crustaceans; and mollusks.

3.2 Other Uses of Adjacent Government Land

A lighthouse operated by the U.S. Coast Guard occupies the tip of Keahole Point, seaward of NELH, and the Keahole Airport lies to the east of NELH. The State's Keahole Agricultural Park is located mauka of Queen Kaahumanu Highway in an easterly direction.

3.3 'O'oma II - Mixed Use Development

According to the Final EIS for 'O'oma II (Helber, Hastert et al., 1986), the landowner proposes to develop a multi-use complex on the approximately 314-acre site. The proposed development will consist of a self-contained "intermediate resort" area including a hotel, multi-family residential units, an 18-hole golf course and clubhouse, and a marine park/visitor center. In addition, a major part of the development will be oriented toward growth of high-technology/aquaculture in the Keahole area, with land planned for light industrial uses and an office park.

A request to amend the Hawaii County General Plan to add 'O'oma II to the list of Intermediate Resorts and to change the existing Land Use Pattern Allocation Guide (LUPAG) Map from Open and Conservation to Intermediate Resort, Medium Density Urban and Industrial designations was submitted to the County of Hawaii in April, 1986. Shortly thereafter, a petition was filed with the State Land Use Commission to reclassify the property from State Conservation District to State Urban District (N. Nishikawa, 1986).

A CDUA (HA-1936) for consolidation and resubdivision of the parcel within the Conservation District has been accepted for processing by DLNR. This CDUA was submitted by the landowner in order to support a proposal to exchange 85 acres of the northernmost portion of 'O'oma II with the State of Hawaii for 85 acres of the existing HOST Park site. HOST Park lots affected by the exchange are anticipated to be lots 15, 16, 27 to 31 and a portion of 12 (Figure III-4). Environmental impacts of this land

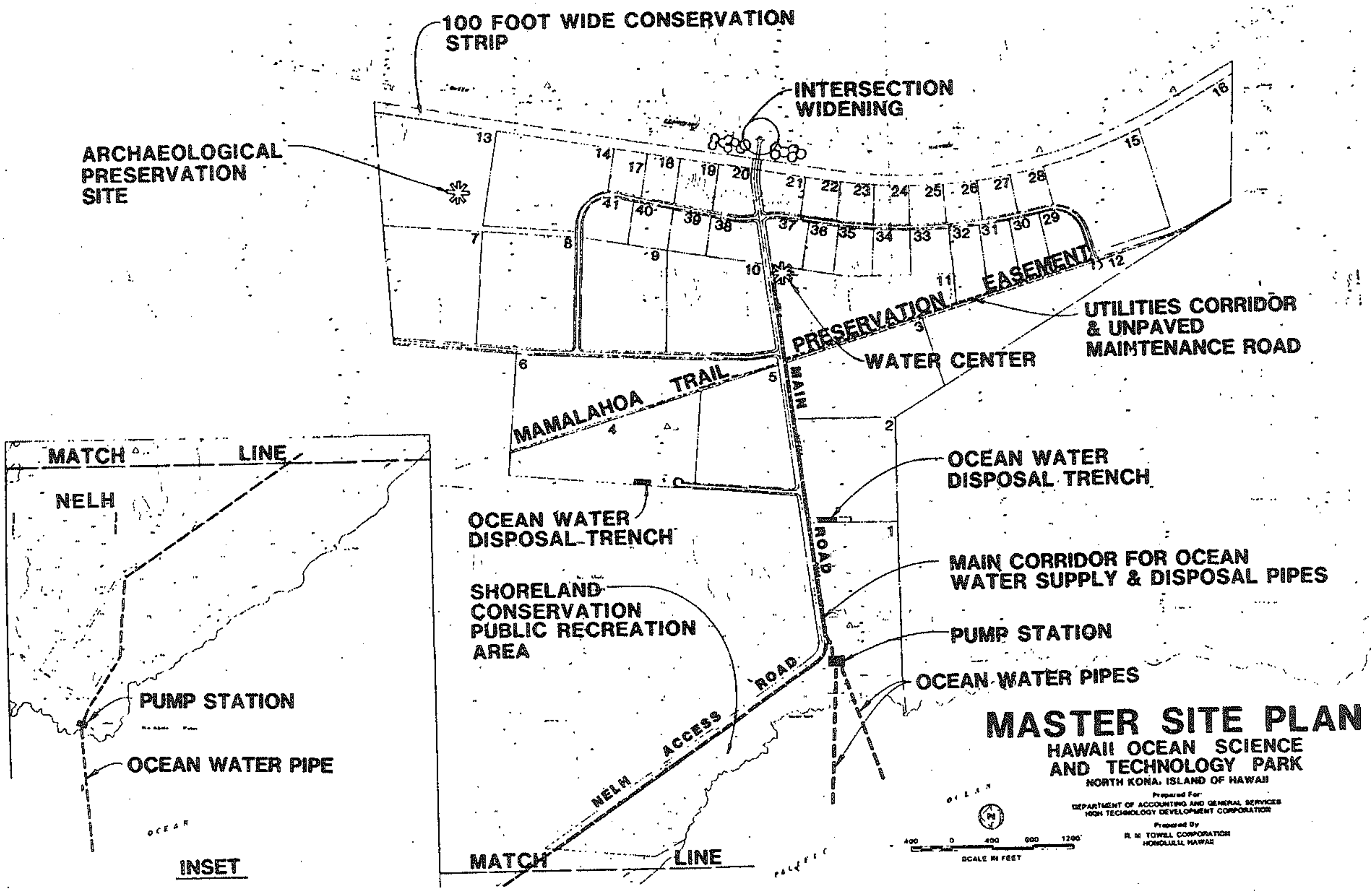


Figure III-4

NATURAL ENERGY LABORATORY OF HAWAII

Keahole, North Kona, Hawaii

exhange are addressed in the 'O'oma II Final EIS (Helber, Hastert et al., 1986).

4.0 Existing Land Use, Facilities and Projects at NELH

(Figure III-5 illustrates the existing conditions at NELH)

4.1 Energy Projects and Facilities

Much of the current research at NELH is associated with open and closed cycle OTEC systems and related research. Closed-cycle projects currently underway at NELH include the following (NELH, 1985):

- The Argonne Test Project which is testing biofouling as a function of heat transfer fouling resistance. Also, materials selection research is being conducted to find an aluminum alloy or aluminum alclad alloy that will allow a low heat transfer fouling resistance and provide resistance to corrosion attack.

- A large-scale test of aluminum heat exchanger elements by Alcan Aluminum, Inc. Several multi-tube heat exchangers of various alloys have been installed in the laboratory for continuous monitoring of heat transfer and corrosion with 6 ft/sec flow of both warm and cold water.

- The ALCOA Project which is conducting tests to find a corrosion resistant aluminum material for closed-cycle heat exchangers.

Open-cycle projects on-going or anticipated at NELH include:

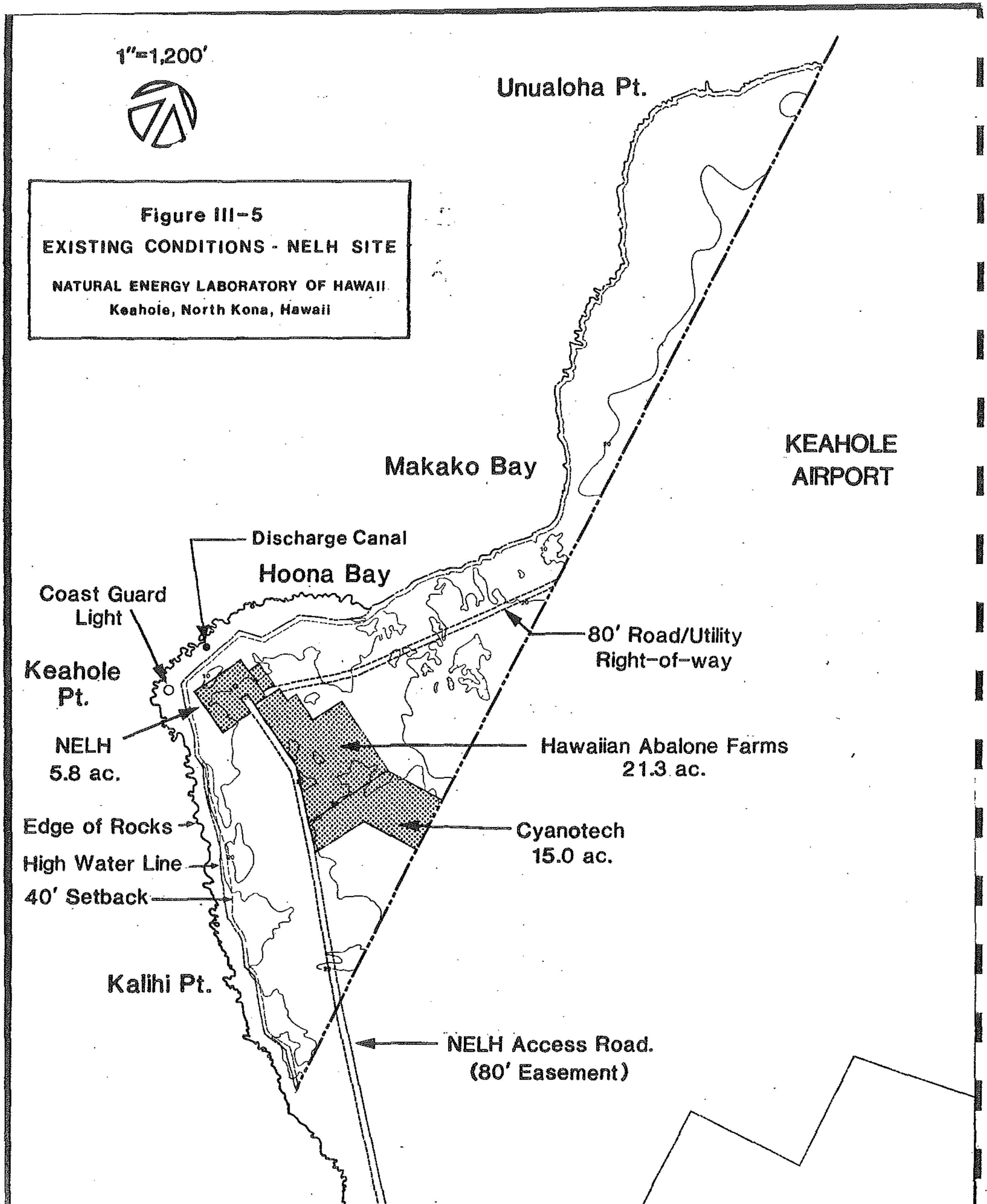
- Research on gas desorption processes for the degassification of seawater. This project is designed to demonstrate the difference between degassification of fresh water and seawater.

- Research to solve problems of foaming and the release of non-condensable gases;

- Research on evaporator/condenser efficiency as a function of spout size, length, configuration and fluid velocity;

- Testing effects of evaporator and condenser configurations; and,

- Testing of gas desorption from seawater (Larsen-Bassee, 1983; 1985).


1"=1,200'
Figure III-5
EXISTING CONDITIONS - NELH SITE
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii
Unualoha Pt.
Makako Bay
KEAHOLE AIRPORT
Discharge Canal
Hoona Bay
Coast Guard Light
Keahole Pt.
80' Road/Utility Right-of-way
NELH 5.8 ac.
Hawaiian Abalone Farms 21.3 ac.
Cyanotech 15.0 ac.
Edge of Rocks
High Water Line
40' Setback
Kalihi Pt.
NELH Access Road. (80' Easement)
HOST PARK

Additional research includes:

- Materials research for the Hawaii Deep Water Cable Program; and,
- The DUMAND (Deep Underwater Muon and Neutrino Detection) project which plans to deploy a large array of sensors in the deep ocean off Keahole Point.

Operational support facilities at NELH include:

- An extensive water quality laboratory to monitor flow, temperature, salinity, suspended solids, pH and alkalinity, nutrients, dissolved oxygen and residual chlorine; and,
- Monitoring of environmental factors such as wind temperature and solar insolation on a multi-channel data logger.

Additional related project support activities include:

- Science education, using the unique resources of the laboratory;
- Personnel training;
- Environmental studies;
- Equipment storage; and,
- Project staging for submersible and research vessel cruises.

4.2 Mariculture Projects and Facilities

4.2.1 Research and Development

Facilities for mariculture research are located in the main laboratory compound. Aquaculture tanks, which are plumbed with both warm and cold seawater, include: ten 600-gallon fiberglass tanks, five 100-gallon plastic lined steel tanks, ten 800-gallon tanks divided into one cubic meter sections, and various tanks, larval basins and growout baskets for the culture of Maine lobsters which are housed in a 1000 square foot inflatable building.

Several species of macroalgae are currently produced at NELH. They are: *Macrocystis pyrifera* (giant kelp), *Porphyra tenera* (*nori*) and a mixture of species used for stripping inorganic ions from wastewater. Research is ongoing to determine depth, flow and harvest manipulations necessary for optimization of nutrient stripping in shallow channels (Robichaux, 1986).

NELH has completed negotiations with the West Coast Lobster Company for a 24-month facilities use agreement with NELH with an option to negotiate a commercial sublease when appropriate. The company initially proposes to use 2 acres of land with an option to expand into an additional 3 acres if their project progresses well and the NELH Board approves. The firm will first conduct research and development activities to determine appropriate mixes, temperatures and other water conditions for their lobster. In addition, negotiations have been completed for an opihi culturing project and several more university-sponsored projects.

4.2.2 Commercial Demonstration

Hawaiian Abalone Farms (HAF) has leased 21.3 acres on the NELH site and is is currently operating a commercial demonstration module. HAF facilities include two large million-gallon kelp tanks (each 15 feet high and 105 feet in diameter) and several acres of shade cloth structures covering abalone tanks. HAF is currently expanding its kelp growing capacity by constructing four 4-acre ponds.

Following one year of research and development, Cyanotech, Inc. has begun production of various marine microalgae at NELH. Their facilities, located on a 15-acre parcel adjacent to HAF, include lined raceways aerated by paddlewheels and a field house/processing facility where water is extracted and the algae is dried for packaging and shipment. The firm is initially producing Spirulina, a microalgae in great demand as a health food supplement. Although Spirulina is normally grown in fresh water, the company scientists have demonstrated that it will grow in the pure seawater at NELH. The company is also culturing microalgae for the production of Beta-carotene and EPA/Omega-3.

4.3 Ocean Water Supply and Disposal Systems

4.3.1 Ocean Water Supply Systems

There are three 12-inch diameter ocean water intake pipes offshore Keahole Point serving NELH. These include two warm water intake pipes (WWP) and one cold water pipe (CWP). All of the intake pipes terminate at the shoreline near the Keahole Point Lighthouse. Three pumps are currently located in the waters just offshore of NELH, for the purpose of bringing cold water from 2,000 feet below sea level. Four pumps located onshore bring warm water to the facility from nearshore waters.

A total of 15 future cold and warm water pipes were approved in CDUA HA-1862. The maximum size of any pipe is not to exceed 48-inches and the maximum total flow of all pipes is not to exceed 142,000 gpm. Figure III-6 shows the offshore corridors for the future pipelines.

Of these 15 pipes, two CWP (one 36 - 40 inches in diameter and one 18 inches in diameter) and one WWP (24 - 28 inches in diameter) are presently being designed. Construction of the 18-inch CWP is planned for Spring 1987; the 36 - 40-inch CWP and the 24 - 28-inch WWP are anticipated to be deployed in Summer 1987. A pump station to service the larger cold and warm water pipes will be constructed makai of the NELH compound (Figure II-5); the pump station for the 18-inch pipe will be located offshore.

4.3.2 Seawater Disposal Systems

The existing discharge from OTEC experiments at NELH consists of approximately 1,000 gpm of extracted seawater used in heat exchanger experiments. Up to 0.01 mgd of the discharge is used in biofouling experiments; a maximum 10,800 gallons per day of the discharge receives chlorination at a rate of 70 ppb for one hour per day. The extracted seawater enters Class AA waters via a natural, rough canal approximately 60 meters long and 15 meters wide which is located next to the laboratory facility. Discharge is permitted under National Pollutant Discharge Elimination System (NPDES) Permit No. HI 0020893 which expires March 31, 1991. The discharge is monitored daily in accordance with conditions of the NPDES permit.

Approximately 800 gpm (1.2 mgd) of ocean water used by Hawaiian Abalone Farms is disposed of into two injection wells which are located just behind the shoreline fronting the NELH facility. Approximately 200 gpm (0.3 mgd) of ocean water used in other mariculture operations is disposed of through surface spreading through a cinder layer placed over graded lava (HTDC, 1985).

4.4 Utilities

4.4.1 Electricity and Telephone

Electrical power to the area is supplied by the Hawaii Electric Light Company, Inc. (HELCO) via a conduit running under the runway from the substation at the Keahole Airport to the makai airport boundary fence. Electrical power is distributed to the NELH facilities via an overhead 12.47 KV line running along a utility corridor from the makai airport boundary to the NELH power center in the main compound.

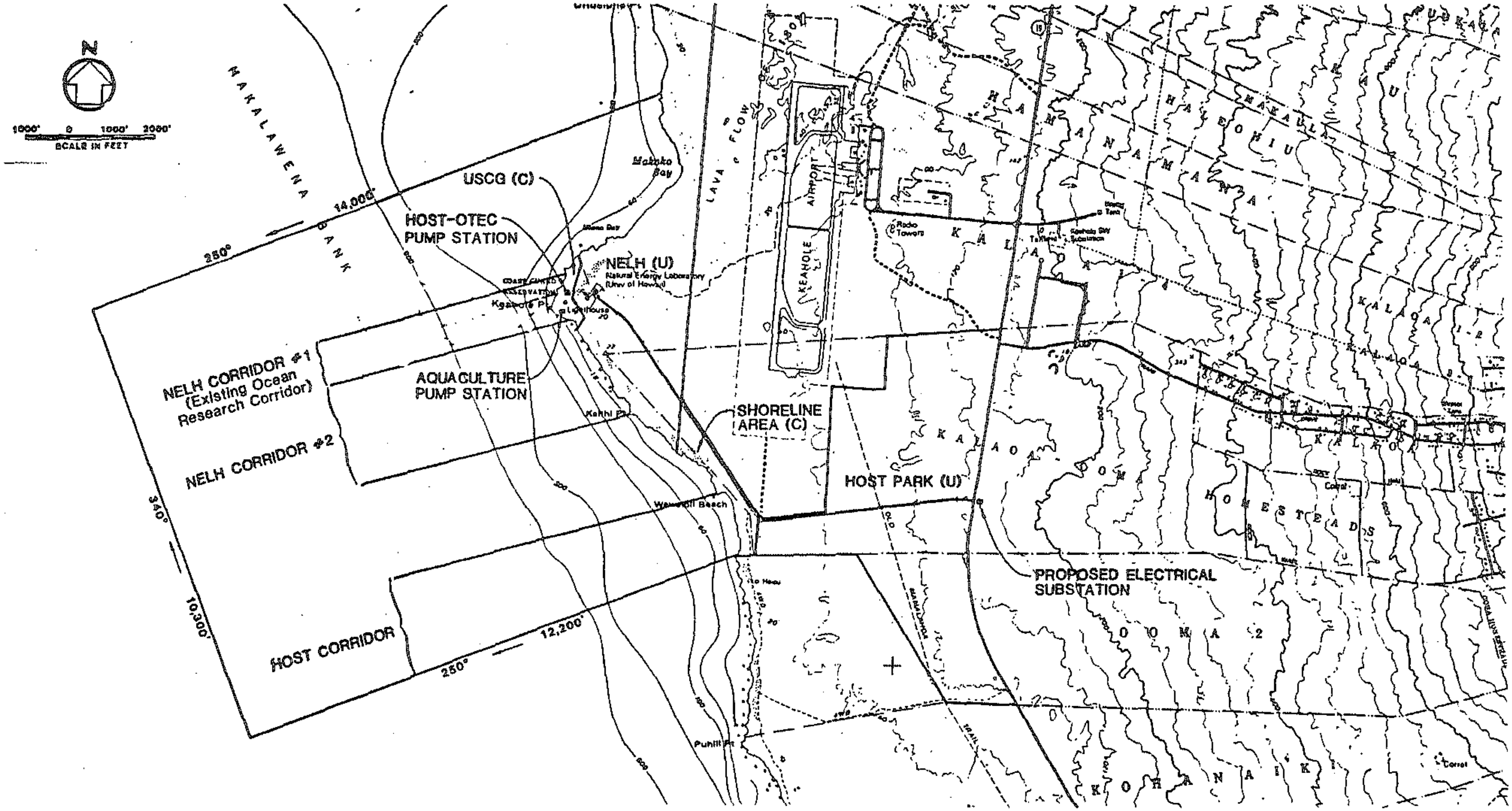


Figure III-6
PROPOSED
OFFSHORE PIPELINE CORRIDORS
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

R. M. TOWILL CORP.

Hawaiian Telephone Company has an existing 3-inch conduit serving the NELH facilities.

4.4.2 Water and Sewage

Fresh water for domestic use and fire protection is supplied by the Department of Water Supply, County of Hawaii, via a 4-inch water line connected to the 12-inch diameter transmission main located along Queen Kaahumanu Highway which conveys water from the Kahaluu water storage tanks to a 0.5 million gallon (MG) reservoir near the entrance to Keahole Airport. The capacity of the 4-inch diameter pipeline is approximately 200 to 400 gpm, 300,000 to 600,000 gpd. The current fresh water usage at NELH is approximately 25,000 gpd. There is no county sewer system in the area, and septic tanks are used.

4.4.3 Access

Access to NELH is via a two-lane 24 foot-wide asphaltic concrete paved road with an 80-foot easement width. The road is approximately two miles long from its intersection with the Queen Kaahumanu Highway to the NELH laboratory gate. There is no road to the northern portions of the NELH site and a jeep trail is the only other access to the coastal areas. The Queen Kaahumanu Highway intersection is currently unimproved and direct right and left turns are allowed there. There is a gate at the highway which is open during the day and closed at night.

B. THE TERRESTRIAL ENVIRONMENT

1.0 Geology, Topography and Soils

The Keahole Point region consists of primitive basalts of the Hualalai volcanic series, the principal effusive rock of Hualalai volcano (Stearns and MacDonald, 1946). The series is composed of heterogeneous, poorly-layered, laterally and vertically restricted units of aa, clinker, and pahoehoe lavas consisting predominantly of basalts and olivine basalts. Individual units extend laterally no more than several hundred feet and vertically less than 100 feet. The average lava flow thickness is about 10 feet. A late trachyte effusion from Puu Waawaa occurs about 15 miles northeast of Keahole. No unusual structural features exist in the region. The nearest rift zone is at least five miles to the north. There is no evidence of faulting or other regional deformation (Dames & Moore, Appendix C).

The topography of the NELH site at Keahole Point is generally level and varies from sea level to approximately 20 feet above MSL. The coastline is rocky and contains intermittent coral and basaltic (black) sand beaches, as well as basalt boulder beaches. The shoreline varies from level areas to elevations up to 15 feet which drop steeply into the ocean to depths of -10 to -20 feet. The nearly vertical areas of the shoreline have numerous caves and lava tubes extending horizontally under them (HTDC, 1985).

The U.S. Department of Agriculture Soil Conservation Service Soil Survey report for the area designates soil types as aa (rLV) and pahoehoe (rLW) lava flows. These lava flows have practically no soil covering and are bare of vegetation except for mosses, lichens, ferns and a few small ohia trees.

2.0 Climate

The climate in the Keahole region is arid in the coastal area but changes gradually to humid in the Hualalai undissected upper slope. The average temperature at the Keahole Airport is 75°F with a maximum recorded temperature of 89°F and minimum of 54°F. The area receives little tradewind rainfall; instead, much of the moisture is accounted for by orographic showers that form within sea breezes which move onshore and upslope. The mean annual rainfall in the coastal region is less than 20 inches, with the wetter periods of the year occurring between May and September (HTDC, 1985).

Pan evaporation is typically high, in the general range of 0.18 inches per day for the winter and 0.36 inches per day for the summer as measured at Anaehoomalu (Kay, et al., 1977). There are no pan evaporation data for the Keahole region.

The land masses of Mauna Loa, Mauna Kea and Hualalai block the prevailing northeast trades, and a land/sea breeze system predominates in the area. The resulting winds are gentle offshore breezes during the night, switching to onshore during the day due to the heating of the land. Typical velocities range from 3 to 14 knots. The exception to this pattern occurs during the periods of so called "kona" weather during the winter months when low pressure fronts may cause strong southerly winds, in some instances approaching 30 to 40 knots (R.M. Towill, 1976).

Solar radiation at the site is constant, with the days cloud-free an estimated 95% of the year. The average daily total radiation on a horizontal surface is 2,019 BTU per square foot (HTDC, 1985).

3.0 Hydrology

Groundwater recharge in the area comes primarily from the small residual of rainfall after abstraction by evapotranspiration in the upland area and to a lesser extent from the infrequent cyclonic-storm rain affecting the entire area. All groundwater discharges are natural as there is no groundwater development of any kind. These discharges are primarily diffused and not usually visible along the shoreline (Dames & Moore, Appendix C).

An unconfined Ghyben-Herzberg lens underlies the coastal region of western Hawaii from Keahole northward to beyond Kawaihae and southward to beyond Keauhou. In the Keahole vicinity, the lens is brackish, probably less than 125 feet thick and discharges freely along the coast in a narrow band a few feet wide in the intertidal zone (WRRC, 1980). The basal lens water does not meet the U.S. Drinking Water Standards even at the top of the lens and at a distance about 3 miles from the shoreline. Chloride, for example, was measured to be about 5,000 milligrams per liter (mg/l) to 520 mg/l, and total dissolved solids (TDS) to be about 10,000 to 1,200 mg/l over this distance (Ibid.).

The brackish water of the lens flows toward the coast along a regional gradient of about 1 foot per mile. The head in well 4360-1 (Kalaoa), 3 miles inland of Wawaloli Beach, was 3.2 feet when drilled, implying an average gradient of 1.1 feet per mile. Kanehiro and Peterson (1977) gave an average gradient of 1-to 2-feet per mile north of Keahole for the reach between Kiholo and Puako. The brackish water discharges preferentially at indentations in the coast. Groundwater flow lines converge toward these indentations while diverging at headlands (Ibid.). The coastal part of the lens experiences appreciable ocean tidal influence. At distances of up to 336 feet inland, tidal efficiencies range from 69% to 100%. Further inland, at 600 feet, the efficiencies decrease from 43 to 68% (WRRC, 1980).

4.0 Hazards

Keahole Point is sheltered from the major tsunami generation centers for the Pacific (the Aleutians and Chile); however, the effects of local quakes such as the one occurring in Ka'u in 1868, reported to have been 7.5 on the Richter scale and to have generated a wave as high as 45 feet, are more severe. Earthquakes are frequent in the Kona area; a quake of magnitude 5 was recorded west of Kona in 1972.

As shown by Cox (1982), the near-shore 100-year tsunami runup height in the Keahole area is estimated to be approximately 9.3 feet; the Corps of Engineers estimate is 8.7 feet. Examination of flood insurance rate maps for the area indicates shoreline areas in zones V15 (areas of 100 year coastal flood with wave action; base flood elevations and flood hazard factors determined) and A4 (areas of 100 year flood; base flood elevations and flood hazards determined) (HTDC, 1985).

5.0 Vegetation and Fauna

5.1 Vegetation

The strand or beach zone vegetation forms a narrow to somewhat wide (up to 300 ft. in width) belt along the coast. Clusters of naupaka (<u>Scaevola taccada</u>) shrubs are frequently encountered. A few scattered, windswept thickets of kiawe

(Prosopis pallida) are occasionally found along the landward edge of the strand. Other species found along the shore include hi'aloa (Waltheria indica var. americana), beach morning glory, Bermuda grass or manienie, and tree heliotrope. No rare, threatened or endangered plant species have been recorded in the project area. The native species that are found on the NELH site also occur in similar habitats throughout the West Hawaii area.

5.2 Avian fauna

Two species of endemic Hawaiian birds are known to exist in the Keahole region: the endangered Hawaiian stilt, known to be present in pond areas several miles to the north and south of the site, may fly over the area and the Hawaiian Owl (Pueo) may feed on rodents in the area. The Hawaiian stilt prefers the pond areas north and south of the project site and the Hawaiian owl has a large home range over which it forages for rats and mice. Other common, indigenous birds which have been observed in the area are the golden plover, wandering tattler and ruddy turnstone, which are all found elsewhere in the world. Introduced species known to be present in the area include the Indian grey francolin, barred dove, common mynah, Japanese white-eye, house finch, house sparrow, cardinal and Brazilian cardinal, among other species.

5.3 Land mammals

The Indian mongoose, the common house mouse, roof rat, Polynesian rat, and feral cats are known to inhabit the undeveloped portions of the NELH site.

5.4 Endangered and threatened species

The Hawaiian Hoary Bat, Hawaii's only endangered land mammal, is found from sea level to the 13,200-foot elevation and is known to occur in Kona. The bat probably feeds on insects along the coastal area of the project site during the evenings and night. No endemic birds are known to nest in the area, although the endangered Hawaiian stilt may fly over or occasionally feed there.

6.0 Historical/Archaeological Resources

A total of 10 archaeological studies have taken place in the NELH parcel. A Bishop Museum study (Clark, 1984) summarized much of this work and concluded that all historic sites had been found--a total of 24. The State Historic Sites Section has recently conducted field-checks of many of these sites (Cordy, Appendix D). The majority of sites are concentrated along the coast. The sites are composed of more than 60 individual features. Table 3-1 lists the sites and briefly describes them; Figure III-7 shows their location on the NELH property.

Table 3-1
List of Sites in the NELH Parcel

Site	Function	Nature
Kalaoa 4 -- North of NELH Lab (13 sites)		
D16-5	Permanent Dwelling	Enclosure with papamu
D16-6	Permanent Dwelling	Enclosure with internal enclosure & external platform
D16-7	Permanent Dwelling	Long, narrow enclosure & 2 platforms
D16-8	Permanent Dwelling	2-sided enclosure with cement foundation
D16-9	Permanent Dwelling	Long, narrow enclosure, C-shaped enclosure, modified anchialine pond
D16-10	Unknown	Enclosure
D16-11	Permanent Dwelling	Enclosure
D16-12	Permanent Dwelling	Enclosure, terrace
D16-13	Short-term occupa.	Cave
D16-14	Trail	Opihi-shell lined
D16-15	Trail	Opihi-shell lined
D16-16	Trail	Stepping stone
D16-17	Trail	Opihi-shell lined
Kalaoa 5 -- South of the NELH Lab (11 sites)		
D15-11	Permanent Dwelling	4 enclosures
D15-12	Permanent Dwelling	Enclosure, 2 platforms
D15-13	Permanent Dwelling	Platform
D15-14	Permanent Dwelling	Platform, 2 enclosures
D15-15	Permanent Dwelling	10 features = 2 enclosures, platform, 2 caves, 2 pools, etc.
D15-21	Unknown	8+ filled crevices*
D15-22	Unknown	Filled crevice*
D15-23	Unknown	Small platform, enclosure
D15-24	Short-term occupa.	Cave, C-shaped enclosure
D15-25	Short-term occupa.	Cave, platform
D15-26	Unknown	Stone cairn

*A 1986 fieldcheck indicates that these may not be historic sites (Cordy 1986). This is being further evaluated.

Source: Cordy, Appendix D

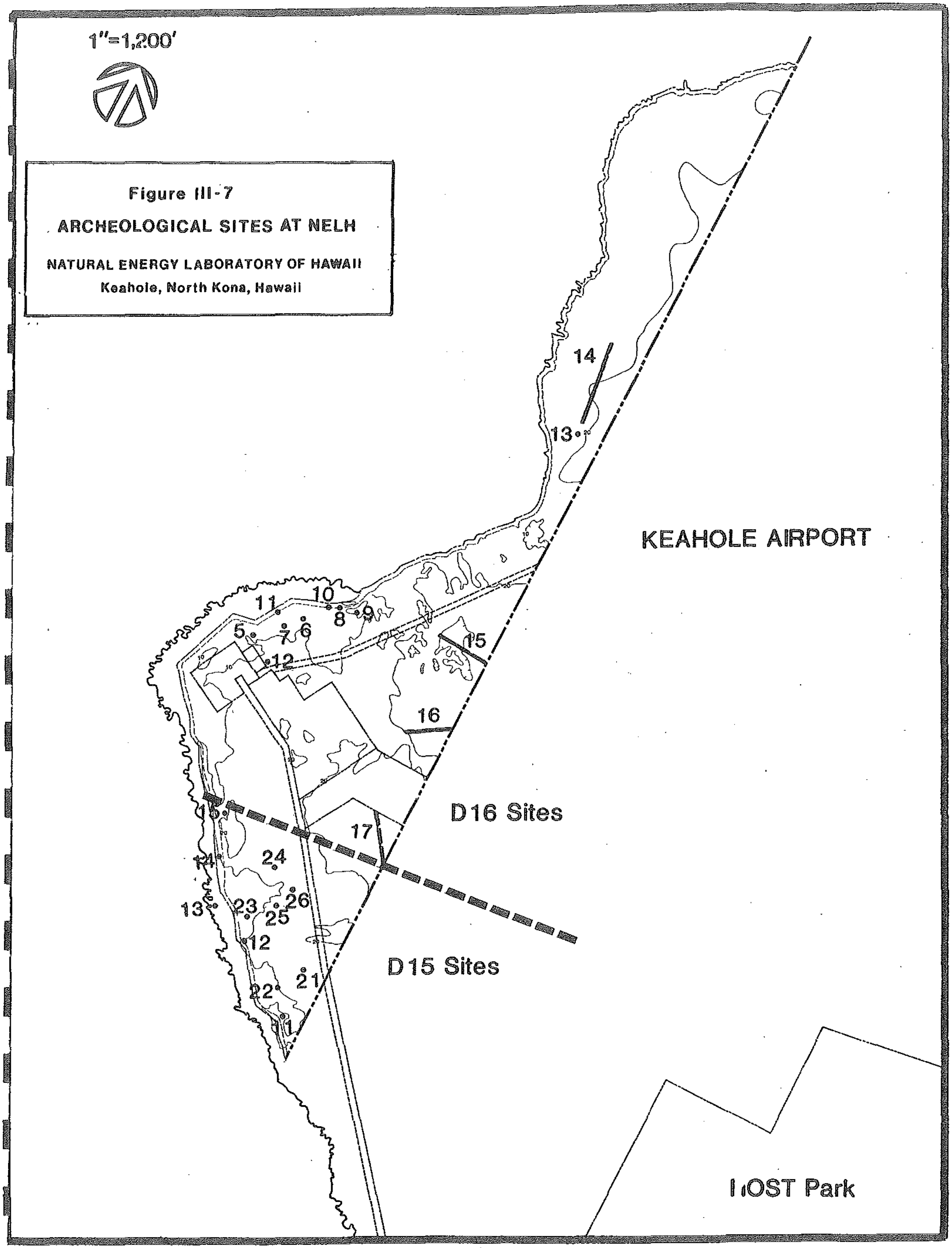


Figure III-7
ARCHEOLOGICAL SITES AT NELH
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

All of the sites still contain significant information on the prehistory of this area which must be recovered. NELH and the State Historic Sites Section have agreed that one site and a set of six sites are also significant as excellent examples of types of sites within the North Kona region and should be preserved. These are: (1) Site D15-12, a prehistoric permanent dwelling site which includes a walled enclosure with an internal house platform and external work structures, at least one petroglyph and salt pans; and (2) Sites D16-6 through -11, a complex of historic period (mid-1800s to early 1900s) dwellings and larger structures including two canoe-houses (Cordy, Appendix D).

C. THE MARINE ENVIRONMENT

1.0 Geology/Bathymetry

Figure III-8 shows the bathymetry off Keahole Point. Water depth increases rapidly with distance from the shore, with depths of 2,500 feet found within a mile of the coast. The rocky basalt shoreline drops abruptly to water depths of about 15 to 20 feet, then the ocean bottom slopes gradually to a shelf break at about 40 to 50 foot depths. The shoreline and nearshore foundation material is primarily basalt. The nearshore bottom is virtually bare of sand at depths less than 25 feet.

Surveys of the seafloor by submersibles show that the bottom consists of basaltic lava flow, coral and volcanic rubble and thin sediment. Lava flows from Hualalai form ridges and channels trending perpendicular to the slope. Calcareous sand occurs in the channels and in patches where the slope is gentle.

2.0 Physical and Chemical Oceanography

Currents offshore Keahole Point are dominated by two processes. Tidal oscillations drive reversing currents with diurnal and semi-diurnal periods. Typical maximal tidal current speeds are 3/4 to 1 knot. Tidal currents may be obscured for extended time periods by large-scale eddies propagated from the Alenuihaha Channel. An eddy off leeward Hawaii persisted and was tracked for 2 months (Lobel and Robinson, 1984).

Offshore surface currents range in speed from 10-37 cm/sec or, on average, less than half a knot (Bathen, 1975). Deep currents have been measured in the range 1-10 cm/sec (Bretschneider, 1978).

At Keahole Point, the westernmost point on the island of Hawaii, significant currents are dominated by large eddies (approximately 100 km in diameter) that reverse from time-to-time. These eddies have a tendency to take nearshore water away from, rather than along, the coastline. In general, waters entering the nearshore marine environment around Keahole Point are not expected to remain in the nearshore area for very long (Noda, 1986).

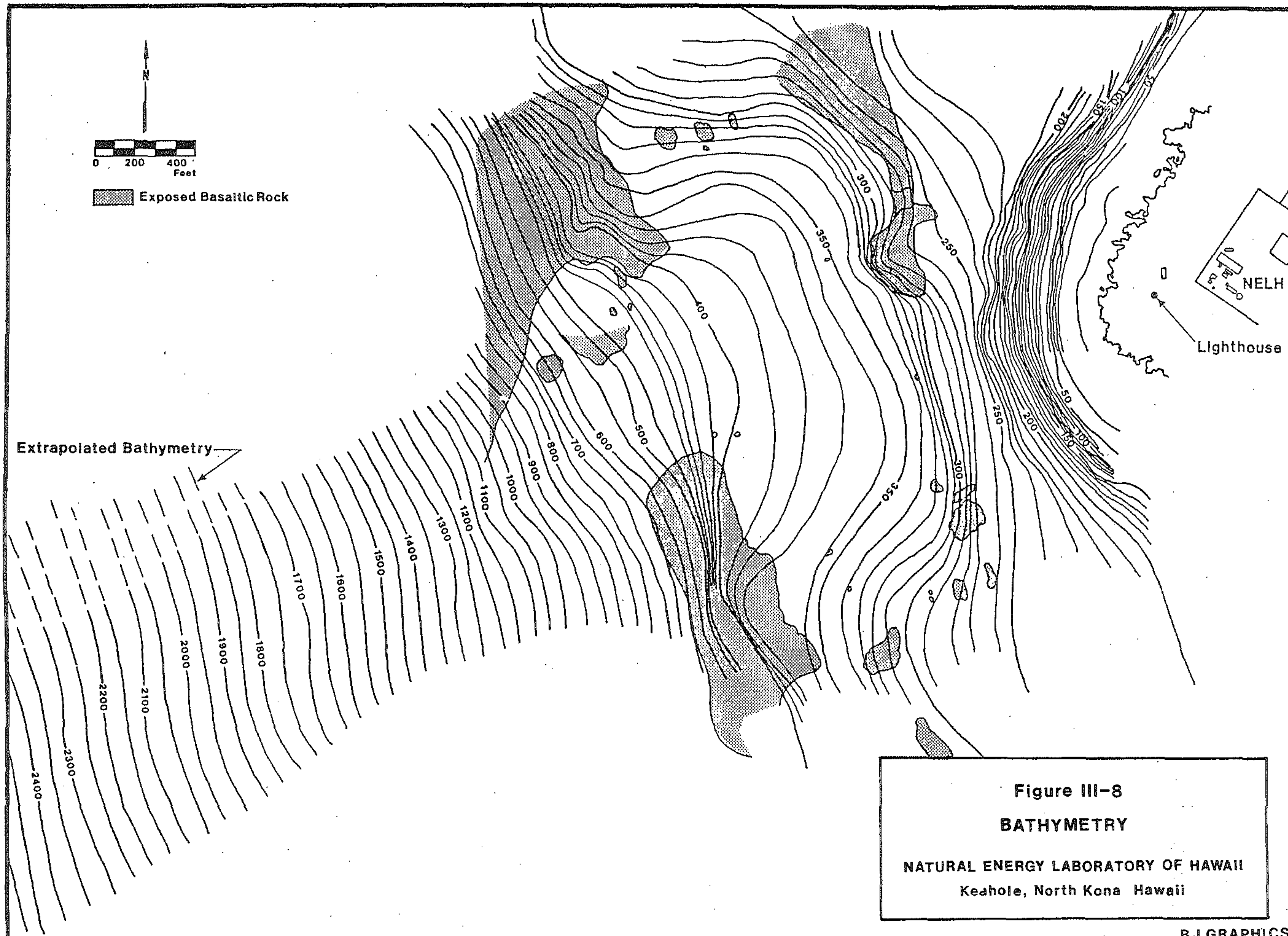


Figure III-8
BATHYMETRY
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona Hawaii

The wave climate of the Kona coast is typically characterized by two to four-foot waves with periods of 9 to 15 seconds. Wave heights rarely exceed seven feet, except during the winter months. Larger waves are generated by local "kona" storms and distant storms in the north Pacific. The highest recorded wave along the west coast of Hawaii over the past 20-year period was 25.5 feet (R.M. Towill, 1976).

Sea surface temperatures in Hawaii vary relatively little annually or diurnally, ranging between 23-28.5°C (Gundersen, 1974). The wind-mixed surface layer extends 50 to 100 meters deep; the bottom of the thermocline may extend to 150 meters.

Scalar (nondirectional) irradiance in the photosynthetically active wavelengths (400-700 nm) has been measured through the water column offshore NELH (Noda, et al., 1980). The photic zone extends to about 125 meters.

The results of water chemistry analyses on samples collected offshore of the NELH facility indicate that salinity always increases with depth in nearshore waters. Offshore there is a peak concentration at 30-150 meters with low surface values and even lower concentrations at 150-200 meters. Salinity values are highly variable spatially and temporally, indicating large scale, rapid water mass mixing or movement (Walsh, 1985).

Ocean water pH is maximal at the surface due to the combined effects of carbon dioxide uptake and oxygen evolution in the photosynthetic process. Decomposition and respiration increase with depth, consuming oxygen and depressing pH. A pH minimum generally coincides with the oxygen minimum.

Oxygen concentrations range between 4.8 and 6.3 ml/l in a mixed layer extending to about 90 meters below the ocean surface. Surface layer concentrations are at or above saturation values. A broad oxygen minima (1.0 ml/l) occurs between 450 and 900 meters (Noda, et al., 1980).

Three distinct nutrient layers have been identified in offshore depth profiles (Noda, et al., 1980). In the mixed layer, concentrations are low and uniform, the result of uptake by phytoplankton. In the aphotic waters between about 150 and 400 meters there is a rapid increase in nutrient values caused by dissolution of particulate material from above and vertical diffusion. Maximal values are found below 600 meters.

In general, inshore nutrient concentrations are low, but consistently higher than in offshore waters (Walsh, 1985). Offshore transects show that when nearshore salinities are lowest, nutrients are highest, clearly reflecting shoreline seepage of nutrient-rich, brackish basal water.

Coastal waters near Keahole are classified AA by the Department of Health (Chapter 54, Water Quality Standards). Waters classified AA are intended to remain as nearly as possible in their natural pristine state with a minimum alteration of water quality from any human-caused source or action. Offshore waters, beyond 100-fathom depths, are "oceanic," all Class A. The 1801 lava flow is a Class I, "protected reef community," sanctioned only for passive, non-consumptive uses. Other bottom areas, to 100-fathom depths, are Class II, "lava rock shorelines and solution benches."

Several studies (WRRC, 1980; R.M. Towill, 1982) have reported that coastal water quality standards are exceeded near the shore. This is not unusual as nutrient concentrations are generally elevated as a consequence of a high proportion of groundwater in very nearshore surface samples.

The quality of the surge channel water near Wawaloli Beach is influenced by the basal lens discharge to the extent that the coastal water quality standards are exceeded in terms of nitrogen and phosphorus (WRRC, 1980). The principal sources of the nutrients in the basal lens are, however, believed natural rather than man-made. The ocean water also exceeds the same nutrient standards (Dames & Moore, Appendix C).

3.0 Marine Biological Environment

(See GK & Associates, Appendix B, and HTDC, 1985, for a complete description of the marine biological environment)

The marine biological environment offshore of NELH/HOST Park was described in the HOST/NELH FEIS (HTDC, 1985). Since then additional surveys in the area have been completed for neighboring projects. Dollar (1986) carried out a qualitative marine biological reconnaissance survey of the area fronting the proposed 'O'oma II resort development immediately adjacent to and bounded on two sides by the HOST Park. His description of the area conforms with those previously summarized. Briefly, the following species were observed:

The seaweeds Ahnfeltia concinna and Ulva fasciata, encrusting red algae, sea urchins and juvenile fish are visible within tidepools along the intertidal platform. Pocillopora meandrina, a sturdy coral able to rapidly colonize new surfaces, is dominant along a shallow, basaltic terrace extending from the shoreline to about 25 m offshore. Porites lobata, found primarily as thick-lobed colonies, is the dominant coral seaward of the terrace in a zone that extends offshore about 55m into waters about 10m deep. Beyond this the dominant "finger coral," Porites compressa, forms dense thickets. In addition to the corals, sea urchins and sea cucumbers are common on the reefs.

Six categories of reef fish were found, including juveniles, planktivorous damselfishes, herbivores, rubble-dwelling fishes, swarming tetrodonts, and surge-zone fishes. The deep zone of finger coral harbors a high concentration of juvenile fishes. "Food fishes" are not abundant, but parrotfishes, goatfishes, taape (Lutjanus kasmira - an introduced snapper), jacks and groupers were observed.

4.0 Endangered and Threatened Species

Endangered Humpback Whales are often observed nearshore off the northwestern coast of the island of Hawaii during winter months. The threatened green sea turtle is also occasionally observed in the area (HTDC, 1985).

5.0 Anchialine Ponds

The first inventory of Kona coast ponds by Maciolek and Brock (1974) noted the presence of nine anchialine ponds in the boundaries of the combined NELH/HOST Park project area. Three of these ponds are situated north of the NELH facility and six were located to the south, along Wawaloli Beach. The latter have not been located in recent surveys.

In their study, Maciolek and Brock (1974) found one of the three NELH ponds to be less than 10 square meters in surface area while the two adjacent pools were between 10 and 100 square meters. Depths were shallow (0.5 m), pond bottoms rocky with some sand and sediment, and salinities ranged between 7 and 8 ppt. Algae and plants present included the encrusting carbonate alga, Schizothrix coricola; the alga, Rhizoclonium sp.; and the aquatic flowering plant, Ruppia maritima. In the vicinity of the ponds were kiawe (Prosopis pallida), naupaka (Scaevola taccada), fountain grass (Pennisetum setaceum), pohuehue (Ipomoea pes-caprae) and pickleweed (Bacopa sp.). Fauna inventoried in these ponds included an unidentified oligochaete, the snails Assiminea sp. and Melania sp., the limpet Theodoxus cariosa in one pond, opaeula (Halocaridina rubra) in one pond, and opae'o'haa (Macrobrachium grandimanus) present in two of the three ponds.

Ziemann (1985) examined ponds in the vicinity of NELH and noted five bodies of water. It is suspected that coralline rubble washed ashore and into these ponds by storm surf may have subdivided them temporarily creating additional pools. These rubble barriers have subsequently broken down leaving a three pool complex at high tide. In any case, Ziemann (1985) found higher salinities ranging from 10 to 11 ppt. Shoreline vegetation present included the sedge Cladium sp., fountain grass, pickleweed, pohuehue, Indian pluchea (Pluchea indica), naupaka, akulikuli (Sesuvium portulacastrum), and kiawe. In the ponds, Ziemann (1985) noted the alga Enteromorpha sp., the snail Melania sp., opaeula in two ponds only and opae'o'haa in one pond. All species were noted as being abundant.

In September, 1986, GK & Associates examined the NELH ponds (Appendix E). Three ponds were located, suggesting that rubble seen by Ziemann in 1985 had broken down. Further evidence for this was seen at high tide on 27 September, 1986, when a very shallow surface interconnection between two of the ponds was observed. The more northerly situated pond of the pair presently has a surface area of about 20 square meters and is about 38 meters inland of the ocean. The basin is rocky, attaining a maximum depth of about 46 cm. Salinity in this pool was 8 ppt. Deeper portions of this pond harbor growths of the green filamentous alga Cladophora sp. and a large snail population (Melania sp.). Neither fish nor shrimp were observed in this pond.

The more southerly adjoining pond is slightly deeper (about 75 cm). A single fish, possibly an aholehole (Kuhlia sandvicensis) and the crab Metopograpsus thunkar were observed. This pond has a surface area of about 11 square meters at high tide. Opaeula (H. rubra) were seen in one partially isolated portion of this pond. A third area of this pond is a nearly isolated circular depression about 1.2 m in diameter and 0.75 m deep which also harbors opaeula. In the two depressions where H. rubra are present, the flora is dominated by the typical anchialine pond cyanophyte (Schizothrix and Lyngbya) community.

The third pond is located approximately 30 m south of the above ponds. This pool has a surface area of about 70 square meters at high tide and a maximum depth of one meter (high tide on 27 September 1986 was about +73 cm). This pond is situated beneath a fringing canopy of kiawe and around it are naupaka and pickleweed. This pond is slightly seaward of the two open ponds; as a consequence surface salinity was slightly higher (10 ppt). No fish or shrimp were observed in this pond.

Photographs of the anchialine ponds at NELH are included in Appendix E.

PART IV: POTENTIAL ENVIRONMENTAL IMPACTS AND MITIGATING MEASURES

A. INTRODUCTION

The primary objective of this environmental impact analysis is to assess the effects of alternative methods of on-land disposal of seawater return flows that will be generated by proposed open-cycle (OC) OTEC experiments at NELH and evaluate the impacts of these effects on the terrestrial and marine resources on and offshore the Keahole facility. In addition, because the success of OTEC experiments is dependent upon the continued high quality of the ocean water resource, impacts on existing operations at NELH and cumulative impacts of combined OTEC and mariculture seawater return flow disposal are also addressed.

In many cases, the long-term environmental impacts of particular actions are unknown. Therefore, mathematical models are used to identify the degree of risk involved in undertaking a particular type of action. Modeling the effects of an action where the actual effects are unknown, although theoretical and based on stated assumptions of the behavior of a particular system, allow criteria to be developed that will enable the effects of the action to be monitored as development progresses. It also facilitates the formulation of recommendations for mitigating measures to minimize risks.

The environmental impact analysis of seawater return flow disposal will be based on the following discharge scenarios:

16,100 gpm of OC OTEC water discharged into a canal;

16,100 gpm of OC OTEC water discharged into injection wells;

16,100 gpm of OC OTEC water discharged into a trench within the NELH compound (two alternative locations); and

25,900 gpm of mariculture water discharged into a trench makai of the NELH access road (two alternative locations).

In addition, the following cumulative scenarios are assessed:

42,000 gpm mixed OC OTEC and mariculture discharge into a trench at location M1 makai of the NELH access road.

16,100 gpm of OC OTEC discharge into a trench at location O-2 within the NELH compound, plus 25,900 gpm of mariculture discharge into a trench at location M2 along the NELH access road.

Figure IV-1 shows the discharge facility locations analyzed in each of the above scenarios.

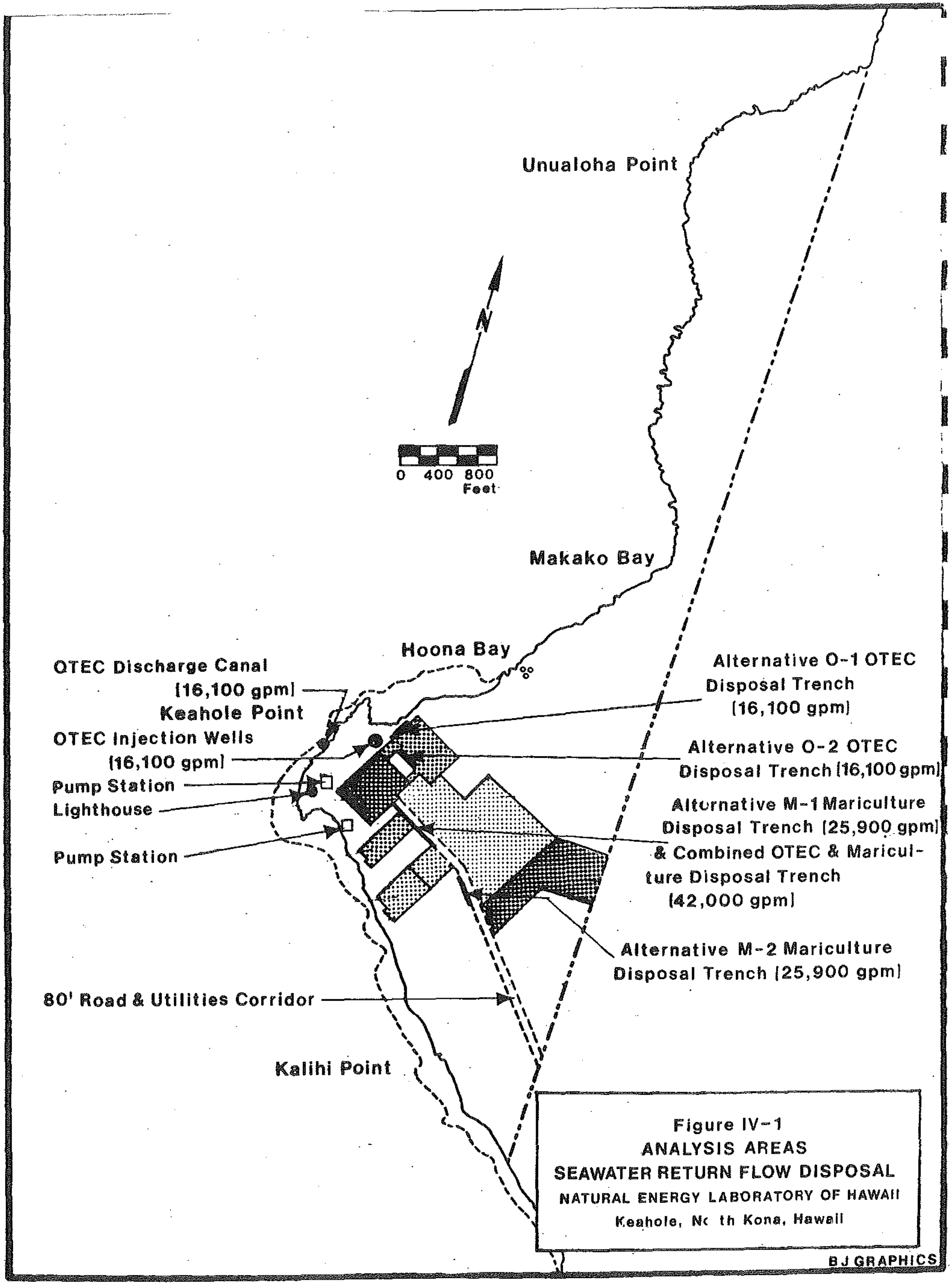


Figure IV-1
ANALYSIS AREAS
SEAWATER RETURN FLOW DISPOSAL
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

The reviewer is directed to the following appendices for complete discussions of the assumptions, methodologies and models used in evaluating specific actions, technical analyses, impact assessments and related recommendations:

Appendix A: Disposal of Open Cycle Ocean Thermal Energy Conversion Water "Via Canal" - Oceanit Laboratories, Inc.

Appendix B: Impacts of OC OTEC and Mariculture Discharges from the Natural Energy Laboratory of Hawaii on the Nearby Marine Environment - GK & Associates

Appendix C: Technical Evaluation of Seawater Return Flow Disposal by Deep Injection Wells and Shallow Trench - Dames & Moore

Appendix D: Historic Preservation Concerns At NELH - Dr. Ross Cordy, Department of Land and Natural Resources, Historic Sites Section.

Appendix E: Impacts of Open Cycle OTEC and Mariculture Discharges from the Natural Energy Laboratory of Hawaii on Nearby Anchialine Ponds - GK & Associates

Appendix F: Cost Estimate Data - Proposed Disposal Facilities Expansion at NELH - Dames & Moore

B. OC OTEC SEAWATER RETURN FLOWS

1.0 Characteristics of the Discharge Water

1.1 Overview

As stated in Part I of this SEIS, in OC OTEC warm seawater is used as the working fluid. Prior to evaporation the water is degassed, removing dissolved oxygen, nitrogen, carbon dioxide, and trace gases from the water. Steam is produced after a partial vacuum is created over the warm seawater. The steam, after passing through a turbine, is condensed either by direct contact with cold seawater or by surface contact with cold water heat exchangers. In the OC OTEC process both warm and cold seawater are exposed to low pressure environments to accomplish degassification. The water quality of OC OTEC mixed seawater discharge is expected to be low in oxygen and high in nutrients (Table 4-1).

Hybrid-cycle OTEC is a variation of OC OTEC. As in OC OTEC, seawater is evaporated under vacuum conditions to produce steam. In this case, however, heat in the water vapor is transferred to a closed-cycle heat exchanger system via a working fluid such as ammonia. The major advantages of hybrid-cycle OTEC are the production of fresh water (using steam produced through the evaporation of warm seawater) and the lack of warm water heat exchanger corrosion. Steam is condensed on the warm heat exchanger side of the closed-cycle subsystem. This effectively eliminates seawater contact on the warm heat exchanger; thereby eliminating corrosion. In this process only the warm seawater is degassed.

It is expected that nitrogen in the discharge from mixed cold:warm hybrid-cycle OTEC discharge would be higher than that found in OC OTEC. This is because the cold seawater from greater depths contains a significantly greater amount of nitrogen than warm seawater from shallow depths. In addition, degassing the warm seawater would reduce the oxygen in the water used in the hybrid-cycle process. The mixed discharge from the hybrid-cycle OTEC process, as in OC OTEC, is expected to be low in oxygen and high in nutrients (Table 4-1).

With the exception of oxygen, water quality characteristics of the discharge from both open and hybrid-cycle OTEC would be approximately the same. Because both cold and warm seawater are degassed in the OC process, the oxygen level of the OC OTEC discharge would be approximately 30% less than the discharge from the hybrid-cycle.

Both cycles would cause lysing of microogranisms in seawater. The effect of lysing in the hybrid-cycle would be less than in the open-cycle because in the hybrid process only the warm seawater is subjected to a low pressure environment. Because warm seawater contains more microorganisms, lysing effects of the two types of cycles are not expected to differ significantly.

The OC OTEC process does not produce dissolved metal ions and would very likely not utilize chlorination because direct contact heat exchangers would be used (L. Lewis, 1986). Although some hybrid-cycle research may be undertaken at NELH, the environmental impact analysis which follows is based on the characteristics of the discharge water from OC OTEC experiments.

Table 4-1: Characteristics of Mixed Seawater Discharge from OC OTEC and Hybrid-Cycle OTEC

	Cold Seawater	Warm Seawater	1:1.5 mix
D.O. (ppm)*	1.0	1.2	1.1
D.O. (ppm)**	0.2	1.2	0.8
NO_2+NO_3 (ug/NL)	554.0	2.4	223.0
PO_4 (ug/PL)	93.0	4.7	40.0
pH***	7.6	8.3	8.0
Temp (C)	8.3	26.1	19.0
TN (ug/NL)	590.0	57.6	270.6
TP (ug/PL)	94.0	10.9	44.1
Si (ug/L)	2180.0	97.0	930.2

D.O.=dissolved oxygen; NO_2+NO_3=nitrate+nitrite; PO_4=orthophosphate; TN=total nitrogen; TP=total phosphorus; Si=silicon

*Hybrid-cycle - after 80% of gas is removed from warm seawater only
**OC OTEC - after 80% of gas is removed from both warm and cold seawater
***Not including pH changes from removal of gasses, eg., CO_2

Source: Penney and Althof, 1985; Krock, 1986; Larsen-Basse, 1985b; Daniel, 1985.

1.2 Lysing Constituents

Due to the pressure decrease in the evaporator, lysing (disintegration or dissolution of tissues) of microoganisms in the OC OTEC water would occur because of internal boiling due to the drop in pressure. This would change the available nutrients in the water into more easily assimilated forms. Table 4-2 illustrates the percent weight composition of the most prevalent elements found in microorganisms (Gaudy & Gaudy, 1980).

Assuming that the organic content of warm seawater at NELH would be approximately 100 ug/l, and that most of these materials would be from living animals and plants, the increase in available nutrients in the mixed discharge water would be 14 ug/l of additional nitrogen or approximately 0.014 ppm. An increase to 1,000 ug/l of organic matter, would result in an increase of 0.14 ppm in the discharge plume -- an increase in nitrogen by up to 50% above that previously calculated using a 1:1.5 mixture of warm and cold seawater. Total nitrogen content would not change, lysing only changes the molecular state of the available nitrogen not the total nitrogen. Similarly, available phosphorus could increase by 0.003 to 0.03 ppm -- an increase of 5 to 60%, although the total phosphorus would remain constant.

Table 4-2: Elemental Cell Composition (16)

Element	Percent Dry Weight
Carbon	50
Oxygen	20
Nitrogen	14
Hydrogen	8
Phosphorus	3
Sulfur	1
Potassium	1
Sodium	1
Calcium	0.5
Magnesium	0.5
Chlorine	0.5
Iron	0.2
All Others	0.3

Source: Gaudy & Gaudy, 1980.

1.3 Dissolved Gases Removed During OC OTEC

Degassing OC OTEC water prior to evaporation removes dissolved oxygen, nitrogen, carbon dioxide, and trace gases such as Ar, He, and Xe from seawater. Initial results indicate that about half of the nitrogen and oxygen normally found in cold deep seawater would be removed under conditions that simulate OC OTEC degassification (Sansone, 1985). Later research done at NELH using warm and cold seawater indicates that up to 95% of the dissolved gases could be removed under OC OTEC conditions (Krock, 1986). The majority of the gases removed would be oxygen and nitrogen. Because most usable nitrogen in the seawater is in the form of nitrate, nitrite, ammonia and kjeldahl nitrogen, the nitrogen gas removed during degassification could be considered inert for most biological purposes and would not be expected to impact on the environment. Removal of dissolved oxygen would change the dissolved oxygen levels of the discharge water to values significantly below those found in the ambient seawater -- the discharge plume would be oxygen poor compared to surrounding waters.

From an OTEC system viewpoint, there are two considerations regarding the discharge of degassified seawater: the first is environmental, the second is related to the efficiency of the system. Due to the parasitic power losses that result from removing gases and pumping them to atmospheric pressure for disposal, there is interest in reinjecting the gasses back into the seawater prior to disposal. This could have a two-fold benefit; it could discharge much more environmentally-acceptable seawater and could decrease parasitic power losses associated with pumping the gases. According to Oceanit Laboratories (Appendix A), regassification of the discharge plume is of interest and concern to all parties that were interviewed in preparing this study; it will be the subject of future OC OTEC research efforts.

1.4 Trace Metals

Trace metals released in seawater from corrosion and erosion of metallic members within an OTEC facility could increase metallic ion concentrations in receiving waters. Based on calculations shown in Appendix A, if aluminum is the primary source of metallic ions, concentrations would be less than concentrations found in the ambient seawater.

1.5 Chlorine

Very little chlorine will be used in an OC OTEC operation because there are no warm seawater heat exchangers in the evaporator and, depending on the specific OC OTEC design, there may be no cold seawater heat exchangers in the condenser. In the event that heat exchangers are employed in the condenser, very little chlorine, if any, will be used to control biofouling because of the very low rate of biofouling found in cold seawater.

1.6 Nutrients From Mixing Warm and Cold Water

Nutrient levels in the discharge plume would change as a function of the cold:warm seawater ratio in the mixture. Table II-3 in Appendix A summarizes the nutrient content of OC OTEC discharge water if 1.5 parts of warm seawater is mixed with 1.0 part cold seawater.

2.0 Alternative Methods of Disposal

2.1 Disposal Via "Canal"

2.1.1 Analysis

Increasing the flow of the existing direct discharge of OTEC water via canal was analyzed. The model, which was developed to estimate the concentrations of conservative materials that are discharged in the seawater outfall and track the paths of water particles as they leave the shore and enter the ocean, is presented in Appendix A.

The advection process in a coastal area is controlled by longshore currents that are produced from wave action, ocean currents, wind stresses, etc. The resulting currents change their magnitude and direction as a result of prevailing conditions. A second type of current is due to the tides. Usually the flood and ebb tides are in opposite directions.

Ocean mixing begins to occur immediately after used seawater is discharged. The seawater is discharged with a particular injection velocity that ultimately decays. The nearfield is the region where the plume velocity is depreciated to no less than 10% of the injection velocity. Dimensions and behavior of the nearfield plume depend on the density difference between the discharged waters and the receiving waters, the velocities of discharge and receiving water, and the characteristics of the diffuser and its alignment.

After initial dilution, the discharged water particles are moved mainly by random motions due to turbulent diffusion and advection. The turbulent diffusion occurs in such a way that the standard deviation of the concentration of any effluent patch increases with the square root of elapsed time.

In order to simulate advection the longshore mean current was estimated at 0.33 feet/sec and the amplitude of the semidiurnal tidal currents at 0.44 feet/sec (Bathen, 1975). Results from work done by Noda (1986a) indicate that the currents at Keahole Point generally flow in the northern or southern direction.

A simulation model was run for the following test cases:

a) sinusoidal tidal current with period 12.5 hours and amplitude 0.44 feet/sec superimposed on a longshore current of 0.33 feet/sec flowing away from the OTEC warm water intake;

b) similar combination as in case a), except with the longshore current moving towards the OTEC warm water intake;

c) sinusoidal tidal current in the absence of any longshore current.

Calculations indicate that the concentrations of OC OTEC discharge water constitutents at the intake under conditions a and b are extremely low, on the order of $1X10^{-10}$ times concentrations in the discharged seawater (Appendix A). However, in the absence of a longshore current, the discharge plume could potentially cross directly over the warm water intake. The resulting concentration of the seawater plume at the warm water intake, under the worst condition of coastal currents, is estimated to be $6X10^{-3}$ of the concentration at the discharge outlet for a flow of 16,100 gpm. The worst conditions were found to occur only when ebb tidal currents were present (condition c). Under these conditions the highest concentrations occur 6 to 9 hours after the ebb tide begins.

In general, concentrations at the warm seawater intake were found to be sufficiently diluted during most tidal and current conditions so that water quality would not be affected. During an ebb tide, however, without external currents, constituent concentrations of the discharged water at the warm seawater intake would be diluted by approximately one part in 200. A 1 : 1.5 mixture of cold and warm seawater coupled with a dilution of one part in 200 would result in levels of dissolved oxygen slightly below the ambient and total nitrogen levels slightly above the ambient.

2.1.2 Disposal Facility Requirements

The size of the "canal" with ponding area would increase as discharge volumes increase. If constructed, this type of facility should be shallow enough to allow shortwave radiation to penetrate and warm the discharge --as is currently the case with the discharge flow of 1,000 gpm. If we assume a shallow basin that is 1.5 feet deep and we assume the discharge velocity in the existing canal is approximately 1.4 f/m, the width of the canal at various discharge rates is as follows:

Discharge Flow (gpm)	Width of Canal (ft)
1,000	60
3,000	180
5,000	300
16,000	960

The analysis in Appendix A assumes that the disposal facility would be in approximately the same location as the existing discharge point (Figure IV-1). As shown in the preceding table, the canal and ponding area required for disposing of 16,100 gpm of discharge would require a very large land area. Before considering this disposal option for such a large volume of discharge, a site study should be undertaken to determine whether or not this method of disposal is even possible, considering the implications of committing such an extensive area of shorefront land to this purpose.

2.2 Disposal Via Deep Injection Wells

2.2.1 Analysis

Disposal by deep injection wells would take advantage of the storage capacity, porosity, and the filtration effect of the lava formation to provide dispersion, diffusion and residence time before the water is discharged to the ocean. An analysis of discharge of OC OTEC water via deep injection wells, assumed to be located immediately seaward of the NELH laboratory, is presented in Appendix C. The location analyzed is indicated on Figure IV-1.

The disposal of OC OTEC discharges by deep wells was modeled using an analytical computer model based on the Theis non-equilibrium equation. Because of temperature considerations, and relatively close proximity to the shoreline, the injected seawater was modeled based on the flow being confined to a zone from elevation -300 to -400 feet. Injection below -300 feet was selected based on keeping the emergent plume below the ocean thermocline.

It is anticipated that the discharge might not be confined to the -300 to -400-foot zone, but may go deeper due to lower temperatures and consequent higher densities relative to the ambient groundwater. There may also be a tendency for the seawater return to rise because of hydraulic head increases caused by injection. This tendency would, however, be somewhat counteracted by the density (temperature) gradients and by the constant head condition imposed by the ocean when the seawater return water reaches areas overlain by the ocean.

Upon emergence, it is calculated that 85% of the discharge would occur over a horizontal distance of 30,000 feet along the -300 foot bathymetric contour, an average of 660 gpd/foot (Figure IV-2). Assuming that the flow was distributed evenly between the -300 and -400 foot contours, the discharge flow would average 1.2 gpd/ft^2 of ocean bottom in this zone. Discharge would actually be greater in offshore areas in near proximity to the injection point. At these locations, the flow would be approximately 2.9 gpd/ft^2 between the -300 and -400 bathymetric contours. A minimum residence time of approximately three months is estimated.

2.2.2 Disposal Facility Requirements

For a disposal requirement of 23 mgd (16,100 gpm), it is estimated that 4 wells (2 primary and 2 backup) would be needed. The wells would be approximately 2 feet in diameter, 400 feet deep and spaced at least 100 feet apart.

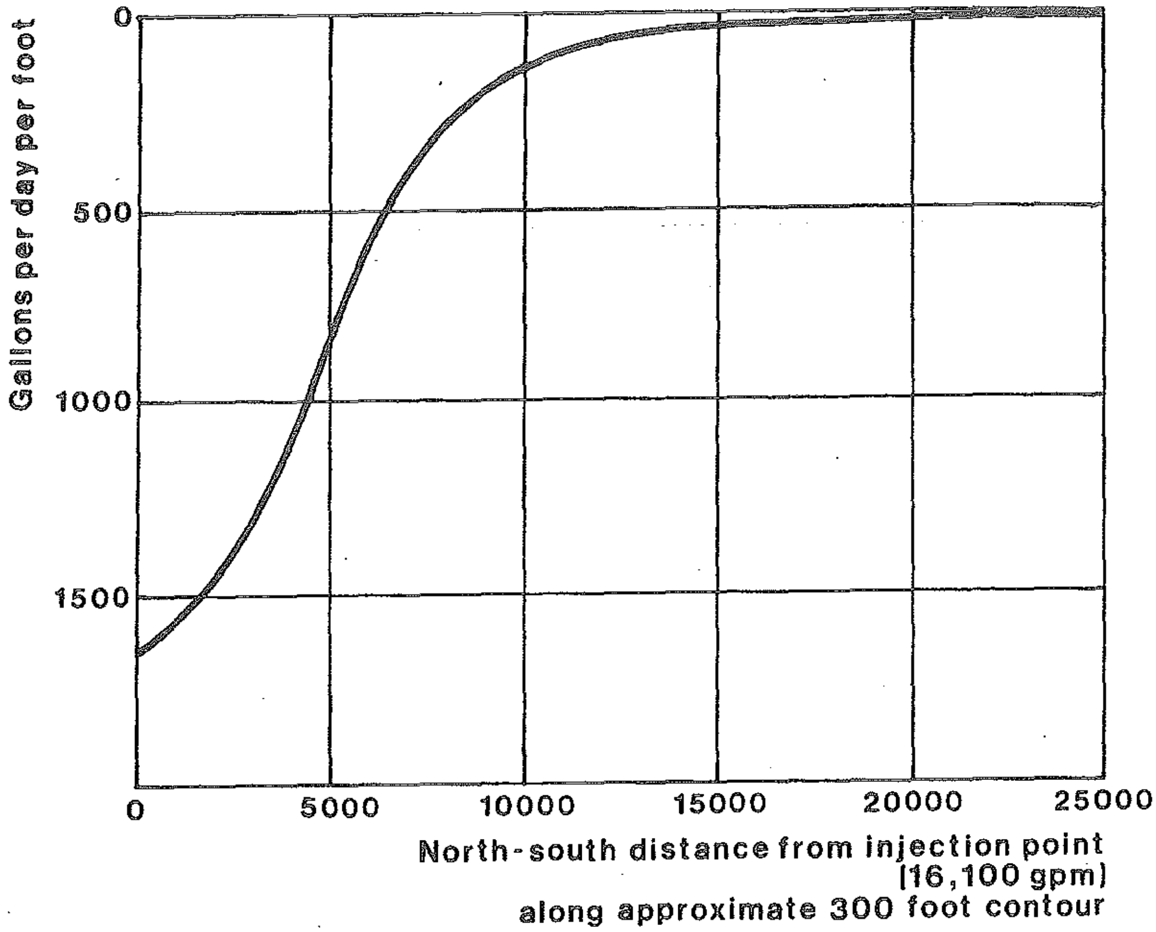


Figure IV-2
DISTRIBUTION OF DEEP WELL
INJECTION DISCHARGE
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

Dames & Moore

They would be cased with solid casing from 0 to -300 feet to limit discharge to a depth below -300 feet and with either open hole or slotted casings from -300 to -400 feet. The wells may need to be deepened if low permeability zones which reduce capacity are encountered. The wells would utilize gravity as the prime moving force and thus conserve energy.

It is estimated that each well could handle about 11.5 mgd (8,000 gpm). Therefore, for 16,100 gpm, only 2 of the 4 wells would be operating. The extra wells would be standby capacity for planned maintenance or in case of one or more wells becoming inoperative due to clogging. The piping system and well head design would require careful engineering for smooth operation and ease of maintenance.

2.3 Disposal Via Shallow Trench Within the NELH Facility

2.3.1 Analysis

The disposal of OTEC discharges in a shallow trench was modeled for two alternative locations within NELH (Figure IV-1) using an analytical computer model based on the Theis non-equilibrium equation. For alternative location 0-1, parallel to and approximately 100 feet from the shoreline, the results of the model indicate that 67% of the discharge would occur over a distance of 600 feet along the shoreline, an average of 26,000 gpd/ft. Assuming that the flow was distributed evenly between the 0 to -50-foot bathymetric contour, discharge seepage would average 26 gpd/ft^2 of ocean bottom in this zone. Discharge would be greater in offshore areas closest to the discharge trench. At these locations, the flow would be approximately 72 gpd/ft^2. Because of the proximity of the shoreline, minimum residence times would be less than one day.

For alternative location 0-2, perpendicular to and approximately 250 feet from the shoreline at the closest point, the model calculates that 80% of the discharge would occur over a horizontal distance of 4,100 feet along the shoreline, an average of 4,500 gpd/foot. Again, assuming that the flow was distributed evenly between the 0 and -50-foot bathymetric contours, discharge seepage would average 4.5 gpd/ft^2 of ocean bottom in this zone. Discharge would be greater in offshore areas closest to the discharge trench. At these locations, seepage would be approximately 6.6 gpd/ft^2. Minimum residence time before emergence at the shoreline would be between one and two days.

The proximity of each alternative trench location to the shoreline and the location on a point (Keahole) limits effects on the groundwater table. The land configuration results in much less groundwater flow occurring under the site (due to the groundwater divergence caused by the presence of a point of land), and the presence of two ocean boundaries in near proximity to the discharge locations results in relatively rapid migration of discharges to the coastlines.

In each case, the disposal plume would displace the existing groundwater flow in the immediate vicinity of Keahole Point. The area of displacement would vary with the amount of discharge and location of the trench. Flow nets showing flow patterns for 16,100 gpm of discharge into trenches at two alternative locations within the NELH compound are schematically depicted in Figures IV-3 and IV-4. Location 0-2 is recommended because discharge there would result in lower concentrations at the shoreline and greater minimum residence time than at location 0-1.

The advection of the plume in coastal waters would depend on the waves and currents present at the time of discharge. During the advection process, the discharge plume would be expected to remain relatively low because of its greater density. As the plume moves from the immediate nearshore marine environment it would become more dispersed as more turbulent mixing occurs.

The concentrations from the trench disposal scheme would be expected to be more diluted at the warm water intake than they would be if discharged into the canal.

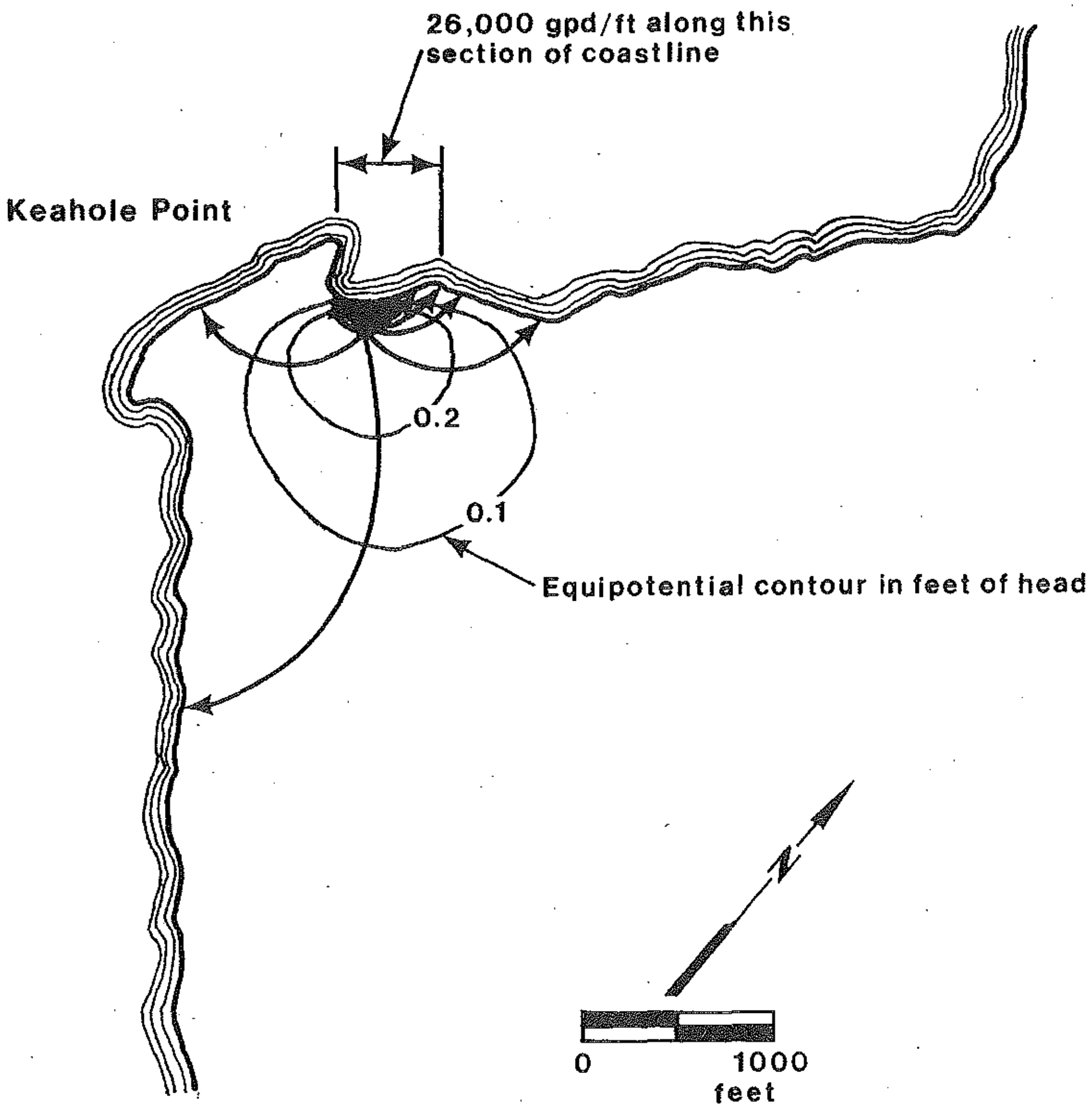
2.3.2 Disposal Facility

The disposal trench would utilize gravity as the prime moving force in order to conserve energy. In order to dispose of 23 mgd (16,100 gpm) of ocean water from OC OTEC experiments, the required trench size for recommended location 0-2 would be 5 feet wide by 5 feet deep by 193 feet long. To be conservative, the design length should be extended by a factor of two. The trench could be filled with crushed lava or gravel to increase the filtration effect of the lava formation and to provide greater dispersion and diffusion before the water is discharged to the ocean as underwater seepage flow along the coast.

3.0 Environmental Impact Analysis

3.1 Impacts on the Nearshore Marine Environment

Of potential concern to the nearshore marine environment ecosystem are altered oxygen and nutrient concentrations and lowered temperatures. The dissolved oxygen concentration in the mixed discharge could be as low as 3.98 ppm without degassing.



OTEC discharge to disposal trench within NELH
16,100 gpm
(alternative location O-1)

Figure IV-3

FLOW NET

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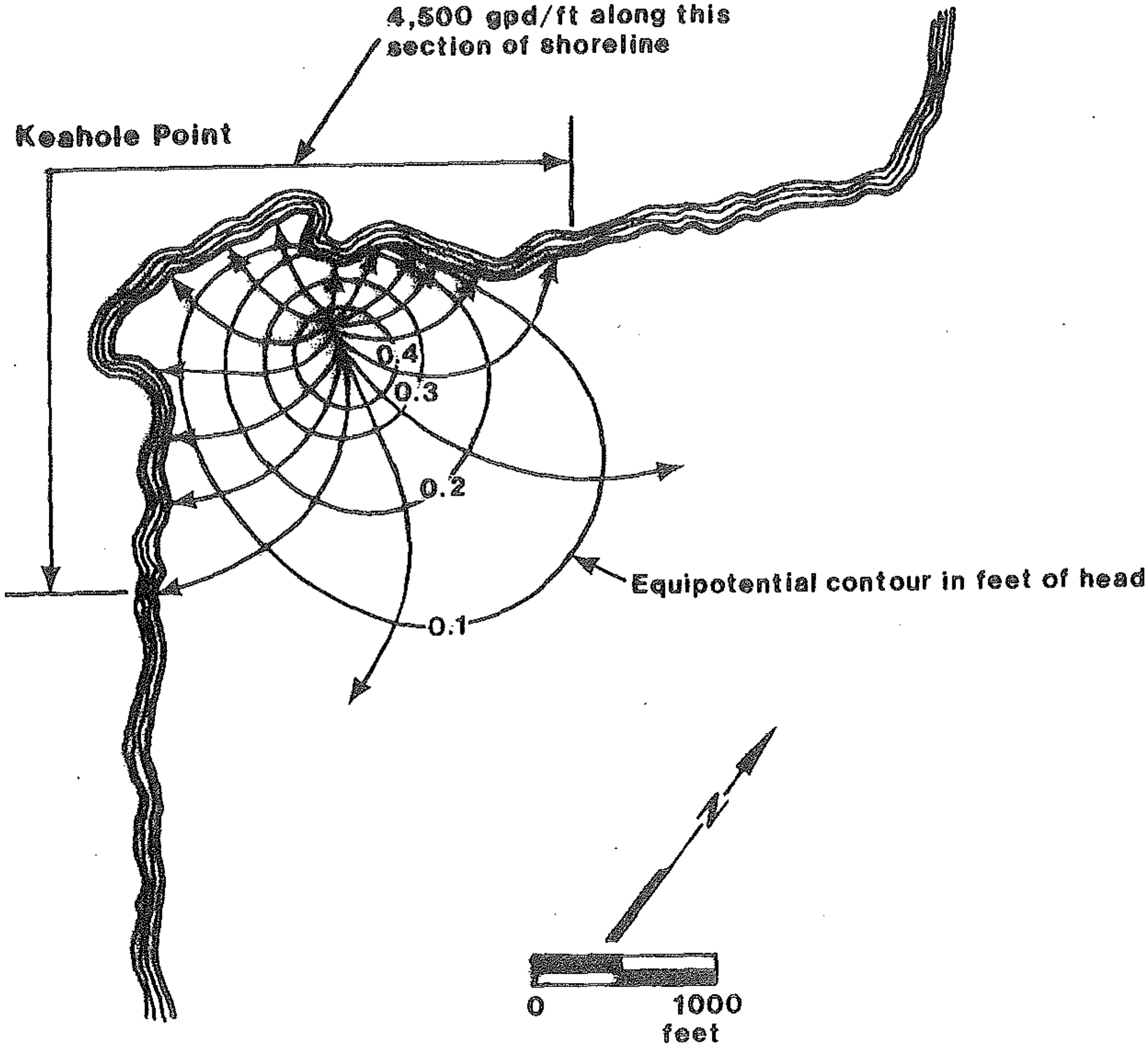

OTEC discharge to disposal trench within NELH
16,100 gpm
(alternative location O-2)

Figure IV-4

FLOW NET

NATURAL ENERGY LABORATORY OF HAWAII

Keahole, North Kona, Hawaii

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Recent research indicates that as much as 80% of the oxygen could be degassed (Penney and Althof, 1985). The impact of reduced oxygen concentrations on the marine biota in areas affected by the discharge would depend on the disposal method and location chosen and whether or not reaeration was employed. If reaeration is employed, the method would affect discharge concentrations. Direct replacement of gasses removed in the OC OTEC process would result in a discharge water oxygen level close to that calculated for the raw non-degassed seawater mix, about 4 ppm. This would be about two-thirds the ambient warm water concentration and about 60% saturation. Physical reaeration could produce essentially saturated oxygen concentrations. Most marine organisms are physiologically adapted to tolerate wide variations in oxygen concentration and generally respiratory consumption of oxygen is independent of oxygen concentration down to very low levels (Richards, 1957). Sixty percent saturation would not impose undue stress on offshore populations, even in the absence of the dilution with more oxygenated waters which would occur at entry to the ocean.

In the absence of reaeration, discharge concentrations would depend on the efficiency of the degassification process. If both seawater streams were 80% degassed then discharge concentrations would be about 0.8 ppm, or about 12% of the ambient warm water saturation value. This could cause severe stress on benthic populations, especially at night when respiration proceeds in the absence of photosynthesis. The location and magnitude of potential impacts would vary with disposal methods.

Due to turbulence and exposure to the atmosphere, canal discharge of OTEC waters would have the effect of aerating the discharge stream, probably to values near saturation. Photosynthesis in the canal would add oxygen during daylight hours; respiration would decrease oxygen during the night.

Oxygen in waters disposed of into injection wells would remain at much the same concentration through the substratum which could potentially impact resident marine communities near seepage areas. Seepage from injection wells would enter the sea at depths between -300 and -400 feet. These depths are generally above or near the top of the thermocline, and dissolved oxygen concentrations are near saturation. At these depths biomass is lower than in shallower waters, photosynthesis and diurnal variability in oxygen concentrations are negligible and turbulent mixing from wave energy is minimal. Again, it would appear that reaerated OTEC waters would not significantly impact biota, but degassed discharges could have severe impacts. Although discharges from injection wells would be diffused over land areas, poor mixing at these depths could result in a near-bottom boundary layer which would essentially bathe infaunal and epifaunal organisms in the discharge for extended periods, or perhaps indefinitely at steady-state. Significant mortalities could result.

OC OTEC waters disposed of into a trench at NELH would not benefit from the turbulence and photosynthesis which would characterize passage through a canal and ponding area. Oxygen concentrations would likely further decrease somewhat due to bacterial activity in the trench. Seepage from a trench would enter the sea at depths between 0 and -50 feet. Turbulent mixing by waves is significant in this range. Formation of a near-bottom boundary layer is less likely, but at steady-state, sessile biota near seepage points could still be affected if OC OTEC discharges are not reaerated. These depths harbor relatively high densities of coral which in turn provide habitat for communities of reef organisms, particularly juvenile fish. Sustained exposure to very low oxygen concentrations could severely impact these communities.

OC OTEC discharge water temperatures would be above 19°C, and lethal impacts are not expected on any affected populations. Impacts would be greatest on the sessile biota; these components may experience physiological and metabolic alterations due to the lowered ambient temperatures. These changes may include reduced spawning periods and lowered metabolic rates. The growth of major space occupiers such as corals may decline retarding overall reef growth (carbonate accretion) and in the long-term altering community structure by changing the competitive balance among species. Species dominance in the benthos would probably change and macrothalloid algae (particulary crustose forms) may become more evident. The physical and biological alteration could lead to avoidance by some motile forms such as fishes but many herbivorous fish and invertebrate species could locally become more abundant due to increased food resources (fleshy algae and detritus).

On the other hand, it should be noted that many of the nearshore species found along the Kona coast occur in the northwestern Hawaiian Islands (Grigg and Tanoue, 1984) where winter sea surface temperatures dip to 19.2°C (Dana, 1971).

Canal discharge of OTEC waters would provide considerable warming, especially during the day. Thermal impacts from this discharge method would be very minimal.

OTEC waters disposed of via injection wells would not receive an appreciable amount of warming in disposal, but would receive high dilution prior to entry into receiving waters and would enter waters of low ambient temperature. At -300 to -400 feet, ambient temperatures vary between about 20° and 25°C depending on depth and season. Impacts of adding water of 19°C or greater would be very slight.

Trench disposal would afford some warming and would greatly diffuse the flux and allow for high initial dilution in the receiving waters.

Nutrient concentrations in OC OTEC discharges would be elevated over those of receiving waters. Nutrient subsidies could increase algal uptake rates, growth rates and standing crops. Fleshy macroalgae are notably sparse off the coast except in the surge zone where grazing is inhibited, so impacts of stimulation of the benthic algal community beyond the surge zone might be expressed as increased population sizes of herbivores and higher trophic levels rather than elevated algal standing crops. Offshore phytoplankton densities are very low in these clear, oceanic waters. Nutrient subsidies may increase uptake and growth rates, but the time lag between uptake and growth responses (on the order of a day), advection by offshore currents and grazing by herbivorous zooplankton would all act to minimize elevations of phytoplankton concentrations.

Complete nitrogen removal is not necessary. The offshore ecosystem is adapted to a constant influx of nutrient-rich brackish groundwater. Walsh (1984) found an inverse relationship between nitrogen and salinity in nearshore surface seawater samples off Keahole Point which indicates that groundwater of about 8 ppt would be expected to have a nitrogen concentration very similar to that of the mixed OC OTEC discharge. Groundwater seepage along this coast has been estimated a 2-5 mgd/mile.

The offshore benthic algal community is maintained at a very low standing crop by grazing and physical stresses. Nutrient subsidies would be expected to increase macroalgal standing crop only in the surge zone where grazing is inhibited. Even there, however, pounding by waves would reduce this build-up. The impact would primarily be aesthetic and its significance would depend on individual perceptions of the degree of visual degradation caused by its presence.

Disposal via canal of 16,100 gpm of OC OTEC discharge would require a very large ponding area ($\pm$ 900 ft) for complete nitrogen removal. About 920 pounds dry weight of algae would be produced daily in this situation. Without significant nutrient removal, the impact of canal discharge would likely be localized visible stimulation of the algal turf in the surge zone.

Disposal of OC OTEC waters via injection well would result in high nutrient concentrations at the point of entry into the marine environment because of the lack of opportunities for biological treatment within the disposal system. According to modeling done by Noda and Associates (1985) for the deep-ocean outfall concept, the density of the OC OTEC discharge plume would match ambient densities at -250 feet in summer and -380 feet in winter. The former is at the lower limit of the mixed layer, but above the top of the nutricline. Some stimulation of phytoplankton production is possible but mixing and advection would likely obscure these impacts. Entrainment of these waters in an eddy system could have the indirect impact of raising the bottom of the photic zone and the nutricline depth range.

The deep injection wells would provide a residence time of about three months, and would create seepage through the bottom between -300 and -400 feet depths. While this would avoid potential biostimulation of the algal turf at the shoreline, it would come at substantial additional cost.

Algal nutrient uptake in trench disposal would be minimal. Bacterial action would serve to reduce nitrogen concentrations somewhat and flux into the receiving waters would be more diffused than from a canal. As it appears that this water would be similar in nutrient content to existing groundwater flux, impacts would result not from concentrations themselves but from elevated flux rates. Where grazers have access to algal growth, it is likely that the same processes now acting to remove fleshy algae from the benthos would mitigate impacts. Some localized increase in herbivore population sizes could be expected.

Phytoplankton growth responses would lag nutrient uptake by a day or more, during which time advection would carry the cells away from the area and mixing would dilute cell concentrations.

In summary, in comparison to ambient waters, OC OTEC discharges would be altered in some physicochemical parameters and would contain elevated concentrations of inorganic nutrients. OC OTEC would not introduce supplemental concentrations of heavy metals, and chlorine additions are unlikely. With appropriate mitigation, impacts of on-land disposal on the marine environment are anticipated to be low. Because of the relatively short time frame anticipated for the programmed OC OTEC experiments, it is expected that any adverse impacts would also be reversible. Because of unknowns associated with OTEC discharge, however, a monitoring program should be a condition of any discharge method chosen.

3.2 Impacts on Anchialine Ponds

Of the optional methods of disposal of waters from NELH, injection wells or a canal would not be expected to impact the ponds. Disposal of the waste waters of NELH into trenches would, however, displace the groundwater beneath the existing anchialine ponds on the property. The natural groundwater lens beneath Keahole Point occurs as an unconsolidated lens of mixohaline (5 ppt) water approximately 38 m thick and has a flow rate averaging 2-5 mgd/mile. At maximum development, the volume of water disposed of via trench would be 60 mgd. Dilution of the discharge by groundwater would be insignificant. During the OC OTEC experimental program, and for an indeterminate time after, the aquifer surrounding Keahole Point would be expected to experience reduced temperatures, increased salinity, increased solute concentrations, and greater localized groundwater head.

Because of the extent of the resultant altered groundwater plume, it does not appear to be possible to mitigate this impact by changing the locations of trenches; rather, if mitigation is necessary, either an alternative to the disposal trenches could be implemented or new habitat could be created outside of the zone of impact. Alternatives to the trench disposal method are more expensive, however, and may have greater overall negative impacts on nearby marine communities and/or NELH operations.

There is very little credible biological information on anchialine flora and fauna. What is known has been summarized by Brock (1985). Hence, with little "hard" data conclusions regarding significance of impacts are "best guesses" based on qualitative and observational (field) information. The expected impacts on the anchialine biota with the implementation of the project are discussed below.

Salinity

With trench disposal, groundwater salinities in the areas of anchialine ponds are expected to rise from the present condition (6-12 ppt) to something close to normal seawater (i.e., 35-36 ppt). Little is known about the salinity tolerances of anchialine species, however, many of the common epigeal forms are invaders from marine or estuarine habitats (e.g., Theodoxus cariosa, Metopograpsus thunkar, Palaemon debilis, Kuhlia sandvicensis and probably the cyanophyte mat--Schizothrix-Lyngbya). Other epigeal species are usually freshwater forms; these include Cladophora sp., Melania sp., Macrobrachium grandimanus (adults only--larvae enter the sea), and pond insect larvae (midges, dragonfly nymphs and mosquito larvae, etc.). It is expected that those forms derived from freshwater habitats would be unable to cope with high salinities and would disappear from ponds in the project area. These species include M. grandimanus, Melania sp. and Cladophora sp.; none of these species are restricted to the anchialine habitat.

Obligate anchialine species (hypogeal species) that have been seen in the NELH ponds include H. rubra and Metabetaeus lohena. M. lohena has been found in salinities from 2 to 36 ppt; most commonly, however, this species and H. rubra are found in waters with salinities between 2 and 30 ppt. However, Brock (unpublished) has maintained H. rubra in the laboratory in seawater (36 ppt) for several months with no noticable negative effects. In the field in deeper water exposures or when wind stress and mixing are low, vertical stratification of temperature and salinity will frequently occur. Both M. lohena and H. rubra move through these gradients with impunity, implying euryhalinity. Taken together, these observations suggest that negative impacts due to salinity increases may be non-existent for adults of the known obligate anchialine species present in the NELH ponds. Nothing may be said about potential impacts associated with increased salinity on the fecundity or survival of juvenile stages of these species.

Temperature

With the proposed trench disposal operation, the temperature of the groundwater could decrease to 19°C. Ziemann (1985) reported temperatures in nearby ponds to be between 21 and 31°C. Brock (1985) noted that M. lohena and H. rubra are usually found in waters with temperatures between 22 and 30°C.

Lower temperatures will reduce physiological and metabolic rates and processes. The long-term impacts of a thermal alteration to anchialine organisms are unknown, but colder water could affect reproductive success. The altered thermal regime resulting from trench disposal would probably be near the lower thermal limits of many species. The lowest temperature recorded in an anchialine pond was 19°C (Maciolek and Brock, 1974); fauna present in this pond included H. rubra, M. grandimanus and M. thunkar. Thus, the most common and characteristic anchialine species can live at the lowest anticipated discharge water temperature. In most cases discharge temperatures would be higher than 19°C due to higher than minimal warm water temperatures and warming subsequent to passage through the OC OTEC experimental module.

Oxygen

Discharges from OC OTEC experiments may be degassed. If the discharge is not reoxygenated, many of the anchialine species in the ponds situated on the project site may disappear. The ponds would be expected to recolonize, however, once oxygen levels return to normal.

There is some evidence to suggest that some of the rare hypogeal shrimp species are able to live in very low (about 0.3 ppm) oxygenated waters (Kensley and Williams, 1986). These rare hypogeal forms are known from only one water exposure on Hawaii Island more than 80 km away. None of the anchialine species present in the NELH ponds are known to co-occur with the above rare forms.

Reoxygenation of the disposal waters is strongly recommended.

Nutrients

The concentrations of inorganic plant nutrients (e.g., nitrate, nitrite, phosphate, ammonium, silicate) are expected to increase in the groundwaters due to high cold water concentrations, cell lysis and mariculture discharges. Nutrient loading may stimulate benthic algal and phytoplankton communities. Brock and Norris (1986) found no detectable biological response by anchialine pond organisms to significant man-induced nutrient loading in a large system of ponds over a nine-year period. In their study, nutrient levels increased by 360% for nitrates (to 65 μM/l), 320% for phosphates (to 3.71 μM/l) and 100% for ammonium (to 1.01 μM/l). Algae and shoreline plants with roots reaching the watertable strip the nutrients as the water passes seaward through the anchialine system. Uptake by algae is not however manifested by large increases in algal standing crops; rather these authors attribute the lack of response by benthic algae or phytoplankton to be related to the grazing pressure exerted by herbivores (H. rubra and Melania sp.), thus maintaining the dominant cyanophyte mat community. Additionally, they suggest that phytoplankton response could be limited by short water residence times.

Nutrient concentrations in insular groundwaters are quite variable and frequently high, particularly for nitrates. Johannes (1980) reported groundwater nitrate levels between 115 and 380 μM/l from Perth, Australia. Marsh (1977) noted nitrate levels in Agana, Guam groundwater at 178 μM/l and Kay et al. (1977) found Kona groundwater nitrate levels to range between 29 and 91 μM/l.

Anchialine ponds appear to naturally exist under a highly variable nutrient regime imposed by groundwater. This suggests that if the anchialine community is intact, it can function normally under some level of loading.

Groundwater Head

The disposal of large volumes of water into a trench would create a localized elevation (or head) of the groundwater. These changes in groundwater head are given on equipotential contour charts in Appendix C; they show a maximal local elevation greater than 30 cm. This localized rise in the groundwater could lead to the creation of new water exposures at any location where depressions in the lava field are deep enough to intersect the elevated watertable. If environmental conditions permit the existence of anchialine biota in the altered watertable, the newly created ponds should be rapidly colonized.

3.3 Impacts on Existing Operations at NELH

Of the discharged nutrients, nitrite + nitrate could increase to levels significantly above the ambient. In OC OTEC research where lysing occurs, the usability of nutrients in the discharge would be expected to increase. In addition, dissolved oxygen would be expected to decrease. An increase in organic material would result in increased rates of biofouling in closed-cycle heat exchangers and low dissolved oxygen levels could adversely affect heat exchanger corrosion rates.

Impacts on OTEC experiments dependent on consistently high quality of warm intake water (such as materials testing) could be adverse if degassed cold seawater is discharged via canal without reoxygenation. Under ebb tide conditions and in the absence of other currents, the resulting plume would pass over the warm water intake. Because of the dilution that occurs at the intake when other currents are active impacts would be insignificant. Impacts on OTEC research not affected by nutrient loading and oxygen depletion would be minimal.

Existing operations at NELH, particularly those using the warm ocean water, would not be adversely affected if OC OTEC seawater return flows are discharged into deep injection wells. The discharge plume would not be expected to affect either the warm or cold water intakes.

Nutrients from a trench discharge might also affect the warm water intake during ebb tide conditions. It might be desirable to reduce nutrients in the discharge to protect the warm water source and minimize biofouling of various experiments.

Existing and future mariculture activities at NELH could be negatively impacted by OC OTEC discharges if these discharges were recycled through either the warm or cold water supply systems, and if the OC OTEC discharges were less suitable for mariculture than the unaffected water suppplies. In Appendix A, Oceanit Laboratories analyzes the potential for contamination of the ocean water supply systems. Disposal into injection wells would not affect either water supply. Disposal of OC OTEC waters via canal has the potential under certain current regimes to contaminate the warm water supply. Under these same conditions, disposal into a trench could also affect the warm water supply by slightly elevating nutrient concentrations, decreasing temperatures and possibly reducing oxygen. Effects, if any, would be slight. The cold water supply would not be affected. The ratio of warm to cold water expected to be used for NELH mariculture is 1:4. Therefore, any effects on the warm water supply would only involve 20% of the mariculture source water.

Elevated nutrient concentrations would benefit mariculture. Reduced temperature would be a negative impact, but, in any event, the mixture of source waters requires warming prior to use in mariculture. Reduced oxygen content of the warm water supply would be of most concern, but mixing and aeration during transit from seepage points to the intake would minimize this reduction. Most culture systems would require supplemental aeration to elevate oxygen concentrations in the cold water and replace that used by respiration of the culture organisms so that a slightly reduced oxygen concentration in the raw warm water would not be of concern.

3.4 Impacts on the Terrestrial and Human Environment

Discharge of OC OTEC waters via canal would not impact the flora, fauna or archaeological sites on the NELH property. The land (or rock) area required as a ponding area at 16,100 gpm of discharge would be very large (960 feet wide). Finding a suitable site of sufficient size may not be possible without seriously restricting the public shoreline area.

Discharge of OC OTEC waters via deep injection wells would not impact the flora, fauna or archaeological sites on the NELH property.

The primary effect caused by disposal of OC OTEC waters in shallow trenches would be the disruption and displacement of the existing brackish water lens. The lens is unsuitable for groundwater development, but is probably the source of water for some small stands of kiawe trees located about 1/4 mile north of Keahole Point. Trees that have deep root systems that reach the groundwater level may not survive the displacement of the brackish water lens by the saline ocean water plume. If this should occur, they could be replaced with trees with a greater tolerance to salinity such as coconut palm (cocos nucifera), heliotrope (messershmidia argenta), or milo (phesbesia populnea) (Char, 1986).

The on-site anchialine ponds are not a habitat for sea birds, therefore, there would be no impact on avifauna; in addition, no impacts from trench disposal on archaeological sites would be expected to occur. A trench would have minimal impact on recreational uses of the coastal area.

3.5 Mitigating Measures

3.5.1 Canal Disposal

Canal disposal of OC OTEC discharges would provide considerable in situ treatment which could mitigate some possible impacts. As discussed previously, due to turbulence and exposure to the atmosphere, canal discharge of OTEC waters would have the effect of aerating the discharge stream, probably to values near saturation. Additionally, photosynthesis in the canal would add oxygen during daylight hours, and supersaturation would be likely; but respiration would decrease oxygen during the night. Even without supplementary reaeration, impacts would likely be restricted to canal areas nearest the discharge point and would not extend to the sea.

Canal discharge would also provide the opportunity for solar warming of the discharge stream. Monitoring of the present NELH canal discharge shows temperatures at the seaward end of the canal at and above ambient receiving water temperatures.

In canal disposal of OC OTEC water, uptake of solutes by aquatic vegetation could be important in the waste treatment process. Approximately five species of marine algae dominate effluent streams now existing at Keahole Point. These communities are capable of removing inorganic nitrogen and phosphorus at rates of 1.2 $g/m^2/day$ and 0.67 $g/m^2/day$ respectively (Robichaux, 1986). In addition, they are effective in removing CO_2 at rates of over 26 $g/m^2/day$. Trace metals such as iron, copper and zinc are absorbed at rates in the range of 1-10 $micrograms/m^2/day$, when concentrations are non-toxic.

The only potential reason for reducing nutrient content in the discharge would be because stimulation of the nearshore algal turf is aesthetically unacceptable. In this case, nutrient stripping using intensive algal culture or nitrifying bacteria on a "rotating biological contactor" (RBC) might be possible. Either method would require disposal of biomass generated in the process. If a commercially valuable seaweed could be utilized in a canal system and sufficient land area could be made available then this might be a technically and economically viable treatment system. It appears, however, that the amount of land required would be prohibitive and a more intensive nutrient stripping process would be required.

If there are longshore currents present in addition to purely tidal currents, discharge flows of 16,100 gpm via canal would not impact existing operations at NELH by affecting the warm water source. Results of modeling indicate that the quality of the water at the warm seawater intake could be compromised if OC OTEC water is discharged into a canal during ebb tide conditions (Oceanit Laboratories, Appendix A). Therefore, an alternative disposal method should probably be chosen as a means to mitigate this impact.

3.5.2 Disposal Via Injection Wells

Disposal of the OC OTEC discharges via injection wells would require reoxygenation to avoid damage to sessile biota in the area of seepage.

3.5.3 Disposal Via Trench

Trench disposal of OC OTEC waters could stress nearshore marine benthic communities due to low oxygen concentrations. Seepage into shallow waters would be rapidly diluted, but deeper areas (-25 to -50 feet) might not receive adequate mixing under some conditions, and a relatively stagnant boundary layer could develop which would jeopardize benthic communities. To mitigate this impact, some form of reaeration would be necessary, either reinjection of gasses removed from source waters or mechanical aeration.

Filling the trench with crushed lava or gravel would be expected to increase the filtration effect of the lava formation and to provide greater dispersion and diffusion before the water is discharged to the ocean as underwater seepage flow along the coast. This would not enable maintenance of the trench, but the end of the trench would be designed to enable extension should clogging occur or if additional capacity is required.

C. MARICULTURE SEAWATER RETURN FLOWS

1.0 Characteristics of the Discharge Water

At full development, it is estimated that approximately 25,900 gpm of mixed warm and cold seawater would be discharged by mariculture operations at NELH. Cold, nutrient-rich and pathogen-free ocean water would be pumped to the operations from pipelines deployed in waters off Keahole with intakes at approximately the -2100-feet depth. Warm ocean water would be provided either by pumping it ashore from approximately the -60-feet depth, warming the cold water on-site, or by re-using water from OTEC or other mariculture operations. The overall ratio of cold to warm water resulting from all mariculture operations is estimated to be 4:1.

Constituents of discharges derived from mariculture operations could be characterized by examination of solute levels resulting from continuous operation and from periodic manipulations to the system such as harvesting, cleaning or feeding which typically would result in brief, low-volume, but concentrated, pulses of waste material. Sparrow (1979) found that up to 25% of the wastes from typical salmonid hatcheries were generated in cleaning the tanks. Waste products of mariculture could be characterized as: (a) organic wastes from crop metabolism and unused feeds; (b) inorganic fertilizers; (c) antibiotics and other disease treatments; (d) chemicals used for maintenance of water quality or facility disinfection, and (e) larvae or other propagules (G.K. & Associates, Appendix B).

The following is a partial list of chemicals in popular use among mariculturists. It is by no means comprehensive; however, many of the chemicals not found in the following list are similar or identical to those presented below. Microalgal culture media that were described previously are not repeated here.

Aquatic Herbicides/Selective Toxicants

Aquathol-K (oxabicycloheptane-dicarboxylic acid): A contact weed killer for use on submerged aquatic vegetation along pond margins, also toxic to phytoplankton. Used in concentrations around 100 ppm. Probably would not be used at NELH because weeds would not be a problem on lava. Large ponds there require impervious liners.

Copper Control/Cutrine-Plus (Copper-triethanolamine-diethanolamine complex): Control of filamentous and planktonic algae. Chelated copper used in concentrations of up to 1.0 ppm. Periodicity ranges from several times per year in stagnant ponds to daily in high intensity raceways. Average concentration in current high-tech shrimp culture is slightly over 1 ppm on an annual basis. Potential use in crustacean and finfish culture at NELH.

Copper sulfate: Traditionally used as an algecide in fresh water and to a limited extent in marine waters in concentrations up to 10 ppm. Limited application at NELH because of its limited effectiveness in seawater.

Diquat (1,1-ethylene-2,2-bipyridylium dibromide cation): A commonly used herbicide lethal to most vascular aquatic plants such as duckweed, hydrilla and water hyacinth. Probably would not be used at NELH because vascular aquatic plants would not be a problem.

Rotenone: Toxic to fish at concentrations of 0.2-20 ppm. Is used for nonselective irradication of fish from ponds and lakes. Limited application at NELH, except perhaps as part of an anchialine pond restoration program.

Disinfectants

Argentyne (Polyvinylpyrrolidone-iodine, 10%): Time release iodine for disinfection of eggs suspended in hatchery tanks. Used as a 100 ppm solution for short periods during hatchery operations. Total amounts depend on hatchery size and frequency of the hatchery cycles. Very small quantities might be used. Maximum strength before dilution in the discharge would be non-toxic to eggs.

Benzalkonium Chloride (N-alkyl quaternary amines): Disinfectant for tanks and other hard surfaces. Used as a 1-2% solution as necessary for cleaning equipment.

Chlorine (Sodium or calcium hypochlorite): The most widely used disinfectant for hard surfaces, equipment and tanks. Used as 200-1000 ppm solutions as necessary.

Antibiotics/Antiparasitics

Antibiotics: Many of the traditional antibiotics (Erythromycin, Neomycin, Penicillin, Sulfamerazine) are used to reduce bacterial contamination in phytoplankton stock cultures or as treatment for culture animals. Due to the expense, these chemicals are not generally used in large quantities. One popular antibiotic, Chloramphenicol, has been restricted, and is no longer sold over the counter in the United States.

Chloramine-T (Sodium para-toluene-sulfonchloramide): Chlorine-based treatment for bacterial gill disease in salmonids and other finfish. Concentrations of 6-10 ppm not more than 1/day.

Formaldehyde: The universal bacteriocide. Used for in situ disinfection of fish and shrimp, and preservation of specimens. Concentrations of 5-50 ppm are used for short intervals in culture water. Average additions for operational shrimp culture facilities are 2 ppm in the effluent stream on an annual basis.

Malachite Green: Traditionally used in conjunction with formalin as antiparasitic, antibacterial, and antifungal agent. Concentrations of 0.05-0.1 ppm are effective. Regulations restrict its use in the United States due to its resistance to natural degradation.

Potassium Permanganate: Used in concentrations of 1-5 ppm to relieve oxygen shortage, rotenone detoxification, removal of organic contaminants, and bacterial/parasitic control.

Prefuran/Furance/P 7138 (Nifurpirinol): A general treatment for bacterial, fungal and parasitic infections. Used either as treatment of known infections (1-2 ppm), or as a prophylactic (0.05-0.1 ppm).

Trichlorfon/Masoten/Dylox/Dipterex/Chlorofos/Metrifonate/Neguvon (Dime-thyl-trichloro-hydroxyethyl) phosphonate: Used commonly for treatment of ectoparasites such as anchorworm, flukes or isopods. Concentration is roughly 0.25 ppm; treatment no more frequently than once per week.

New chemicals will undoubtedly be added to this list in the future. Each of these chemicals is toxic to some organisms at some concentrations, and each mariculture operation should be required to demonstrate that its chemical additives and patterns of usage would not detrimentally effect other mariculturists, OTEC experiments, the treatment system, the anchialine ponds or offshore ecosystems. Surveilance and monitoring are recommended.

2.0 Seawater Return Flow Disposal

2.1 Analysis

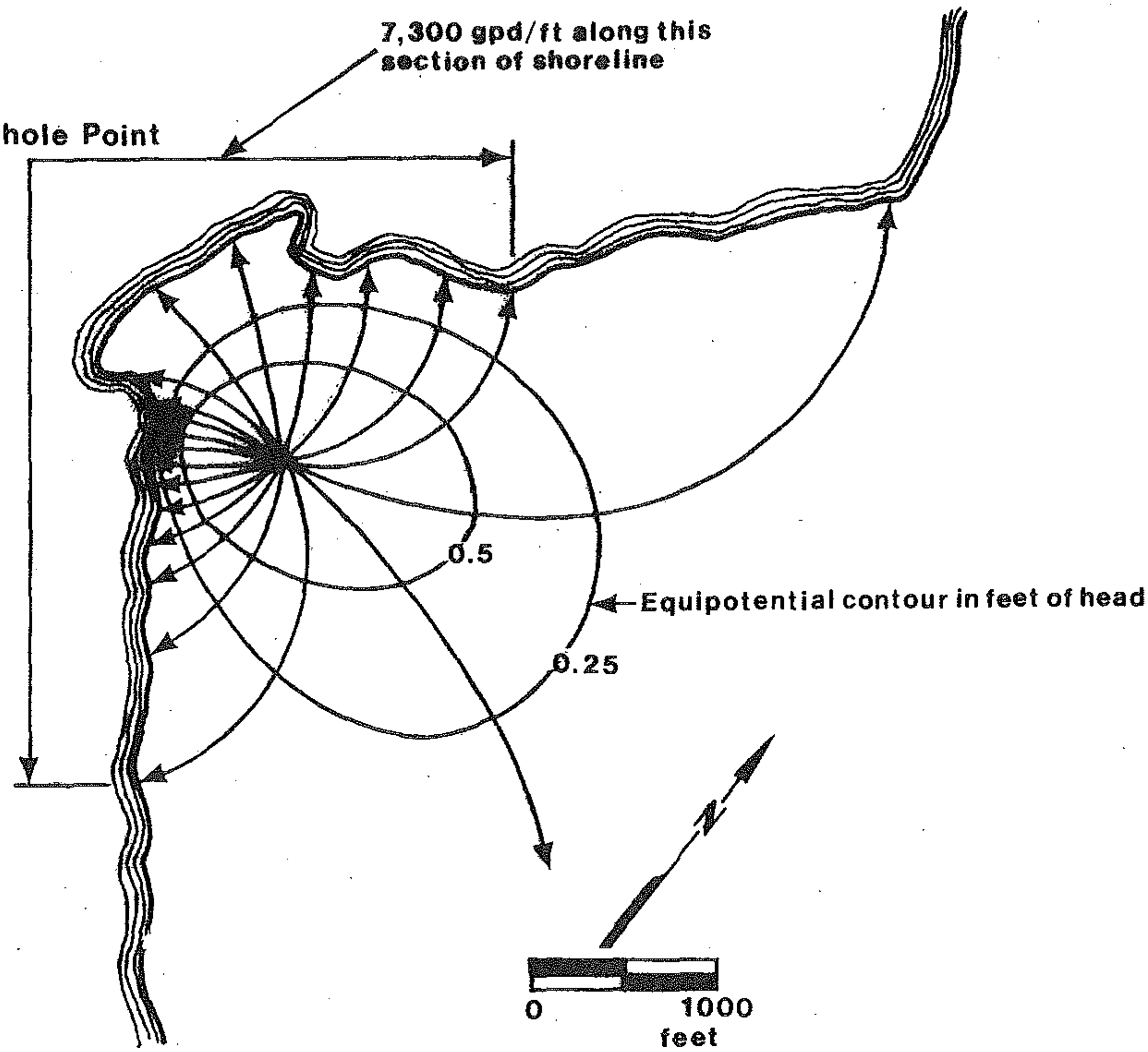
The proposed disposal method for mariculture discharges analyzed in this SEIS is via a trench located along the makai side of the NELH access road towards HOST Park. Two locations along this road were analyzed: location M-1, which is roughly parallel to and approximately 750 feet from the shoreline at a ground elevation of approximately 10 feet above sea level; and location M-2, which is southward of location M-1 along the NELH access road approximately 900 feet from the shoreline at its closest point (Figure IV-1).

Disposal of mariculture discharges into shallow trenches at two alternative locations was modeled using analytical computer models based on the Theis non-equilibrium equation (Dames & Moore, Appendix C). Based on results of the model, it is estimated that 85% of the discharge from a trench at location M-1 would occur over a distance of 4,300 feet along the shoreline, an average of 7,300 gpd/ft (Figure IV-5). If the flow is assumed to be distributed evenly between the 0 to -200-foot bathymetric contour, it would average 1.9 gpd/ft^2 of ocean bottom in this zone. Discharge would be greater in offshore areas closest to the discharge trench. At these locations, the flow would be approximately 4.2 gpd/ft^2. A minimum residence time of 5 to 35 days was calculated for this location (see Appendix C).

The model predicts that 76% of the discharge from a trench at location M-2 would occur over a distance of 6,200 feet along the shoreline, an average of 4,600 gpd/ft (Figure IV-6). If the flow is assumed to be distributed evenly between the 0 and -200-foot bathymetric contour, it would average 1.2 gpd/ft^2 of ocean bottom in this zone. For a distance of 1200 feet along the shoreline, approximately parallel to the proposed trench, the flow would be approximately 2.6 gpd/ft^2 of ocean bottom in this zone. Minimum residence times would average from 9 to 61 days (Appendix C).

Location M-2 is the recommended location for the mariculture disposal trench because the concentrations at the shoreline would be less than at location M-1. In addition, location M-2 is also the preferred location based on operational considerations at NELH.

Waste water discharged from mariculture facilities would be subjected to a variety of processes or treatment mechanisms as it (1) flows through trenches enroute to the disposal trench, (2) infiltrates into the aquifer system, and (3) mixes with the ground water underlying Keahole Point. The principal mechanisms include biological absorption, physical filtering, precipitation reactions, and dilution.



Mariculture discharge to disposal trench along roadway to NELH
25,900 gpm
(alternative location M-1)

Figure IV-5

FLOW NET

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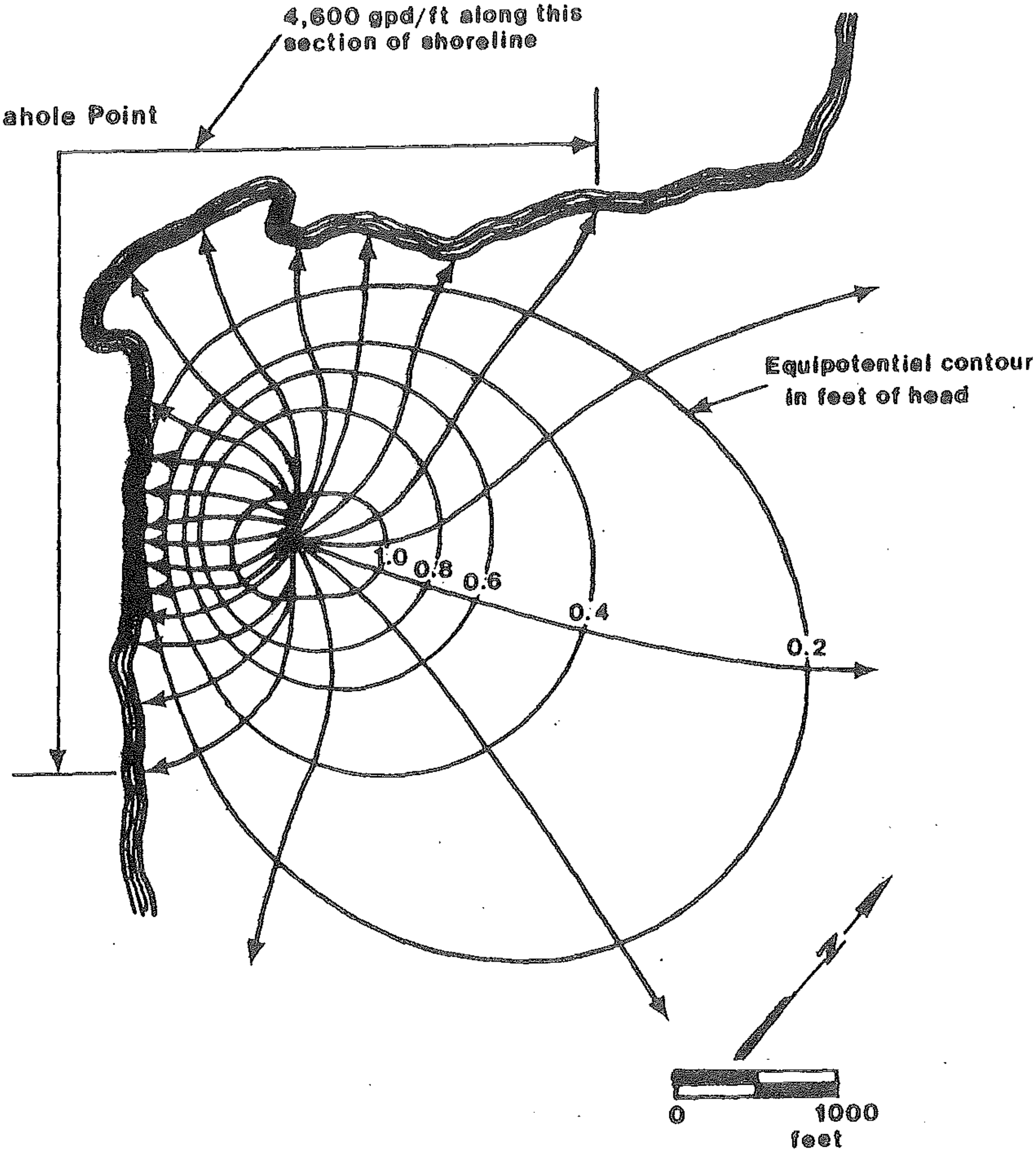
Keahole, North Kona, Hawaii

Dames & Moore



Mariculture discharge to disposal trench along roadway to NELH
25,900 gpm
(alternative location M-2)

Figure IV-6

FLOW NET

NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

Dames & Moore

Trench disposal would serve to remove solids, precipitate some of the phosphorus and metals, allow decomposition to break down some of the organic material, and provide a matrix for nitrifying bacteria. After entering the aquifer, the rate of adsorption and oxidation of organic chemicals and metabolites is considerably slowed. Inorganic ions in the effluent, including ammonia, will pass through the ground relatively unaffected due to the short residence time (less than 61 days) and lack of soils or clays in the Keahole Point region.

Organic material entering the disposal trench system would be remineralized to end products which would depend largely on the amount of available oxygen. Under aerobic conditions, carbohydrates and proteins are oxidized to CO_2, H_2O, NO_3, SO_4, and microbial cell tissue. In the absence of oxygen, the same inputs become reduced end products such as methane, hydrogen, ammonium, hydrogen sulfide, and a variety of intermediate products such as organic acids, alcohols, amines and mercaptans. It is likely that the proposed disposal trench would be predominantly aerobic; however, pockets of particulate accumulation may provide reducing environments which would allow denitrification of nitrates and nitrites to ammonia, nitrogen gas or nitrous oxide.

2.2 Disposal Facility Requirements

Trench dimensions for disposal of 37 mgd (25,900 gpm) would be approximately 5-feet wide by 5-feet deep by 362-feet long at location M-1 and 5-feet wide by 5-feet deep by 374-feet long at location M-2. Although the available length of the disposal area is more than 2,000 feet, the length of the trench could be shortened by digging a deeper trench. In order to allow for non-homogeneity of the hydrogeologic characteristics of the proposed disposal area, subsurface materials and to mitigate silting and clogging problems that may occur in the initial start-up stage, the actual excavation should probably be twice the theoretical trench length.

As for the OC OTEC trench, the preferred construction method is excavation, placement of a perforated discharge pipe, and backfilling with crushed lava or gravel. As mariculture discharge volumes gradually increase, the operation of the trench should be monitored to collect operation and maintenance data for subsequent phases of the expansion program. Assuming that the technical parameters used in the theoretical computations can be validated by the actual performance, the disposal trench could then be incrementally extended to handle more disposal quantity as mariculture facilities expand.

3.0 Environmental Impact Analysis

3.1 Impacts on the marine environment

Mariculture operations at NELH would result in discharges with the following components and characteristics of most concern:

- o elevated concentrations of plant nutrients;
- o increased concentrations of dissolved and particulate organic matter;
- o pulses of chemicals used to treat culture organisms, clean facilities or maintain water quality in culture containers (especially chlorine compounds); and
- o exotic species or other propagules.

Nutrient concentrations in mariculture discharges would be quite variable depending on specific source water mix ratio, fertilization, culture organisms, stage of life cycle, intensity of culture, efficiency of culture operations and other variables. In general, these discharges will contain levels of nutrients higher than those expected from OC OTEC discharges, although this may not be the case for some macroalgal culture systems.

Seepage from either alternative mariculture trench location would enter the sea at depths between the surface and -200 feet. Nutrient subsidies could increase algal uptake rates, growth rates and standing crops. Fleshy macroalgae are notably sparse off the coast except in the surge zone where grazing is inhibited, so impacts of stimulation of the benthic algal community beyond the surge zone might be expressed as increased population sizes of herbivores and higher trophic levels rather than elevated algal standing crops. Offshore phytoplankton densities are very low in these clear, oceanic waters. Nutrient subsidies may increase uptake and growth rates, but the time lag between uptake and growth responses (on the order of a day), advection by offshore currents and grazing by herbivorous zooplankton would all act to minimize elevations of phytoplankton concentrations.

Dissolved organic matter present in the mariculture discharges would also provide a nutrient subsidy to nearshore marine communities. Particulate organic matter would be filtered out in the trench and perhaps the aquifer, eventually decomposing and entering the sea as dissolved organic and inorganic material.

Of the compounds identified as having potential uses in NELH mariculture operations, most are added to cultures of living organisms, some at very fragile stages of their life cycles. At the maximum dosages they are intended to kill or inhibit bacteria, fungi or small parasites. Deactivation in culture systems, and dilution in the disposal system, would render them completely innocuous to anchialine pond or marine biota.

Of more concern are those compounds, essentially all chlorine-based, used in higher concentrations when living culture organisms are not present. There is the potential for excessive use of chlorine compounds by technicians in washdown operations, although in a practical sense, the very high cost of these compounds will induce management oversight and use restrictions. It is likely that dilution in washdown and comingling with other discharges in the waste stream will provide adequate mitigation of potential impacts.

Formalin (dilute formaldehyde) is used in mariculture operations to reduce bacterial, fungal and parasitic infections. Biological degradation of formalin occurs with or without oxygen to end products of CO_2 and H_2O. This breakdown, measured as standard BOD, shows only 40% activity after 5 days. Residence in the substratum should be sufficiently long to insure its complete oxidation prior to reentering the source waters. Wastewater treatment methods for formalin include adsorption on activated charcoal (adsorbability: 0.018 g/g-Carbon, 9.2% reduction at 1 g/l influent concentration); absorption in trickling filters (up to 3.45 lbs/cubic yd.) or in activated sludge filters (G.K. & Associates, Appendix B).

The probable concentrations of formalin appearing in effluent from mariculture operations would be absorbed by bacteria and algae in the supply and disposal trenches. Assuming the average residence time in the ground is greater than 30 days, it is doubtful that any formalin will reach the receiving waters. Preliminary treatment in the disposal trench is dependent on the standing crop of bacteria which is susceptible to poisoning by infrequent pulses of formalin above concentrations of 20 ppm in the discharge. It is recommended that any formalin used as a disinfectant be diluted out into the discharge stream as necessary to prevent high concentrations from appearing in the disposal trench.

Cutrine-plus and copper control are used to reduce phytoplankton populations in ponds or biofouling in tanks. Cutrine-plus and copper control are more effective than copper sulfate in marine systems because of the chelating agent triethanolamine which oxidizes very slowly. After 20-day BOD tests only 6.2% of the theoretical oxygen demand was met. As a result, the copper triethanolamine complex is likely to remain active through all of the treatment processes described above. Both copper and triethanolamine can be removed by activated charcoal (0.067 g/g-carbon). Triethanolamine is toxic to algae and bacteria in concentrations in the range of 2-60 ppm (Appendix B), but the copper complex would not be expected to appear in the discharge in concentrations higher than 1 ppm. **(Federal regulations restrict the discharge of copper from power plants and other point sources to concentrations less than 1 ppm.)** Further dilution by mixing of the various waste streams in the disposal system will preclude negative impacts on anchialine pond and marine biota.

Certain chemical additives, unknown at the present time, could potentially impact the marine environment. For example, isopods and other parasites have been reported to infest oysters grown in dense cultures and natural waters. At the present time, there is no effective chemical for treatment of these endoparasites; however, if some treatment is developed, the nature of the chemical should be investigated prior to its introduction into the discharge system, as it may significantly impact the resident epifauna.

Importation of exotic species to Hawaii is controlled by a multi-tiered review and permit system administered by the Plant Quarantine Branch of the Hawaii Department of Agriculture. All potential imports and the facilities for holding them must undergo a thorough review prior to approval. Disposal of mariculture effluents into a trench would effectively preclude escape of exotic species under normal operating conditions.

3.2 Anchialine Ponds

Potential impacts on anchialine pond systems of disposal of mariculture waters via trench are discussed here, but a major qualification is necessary. In the case of simultaneous discharge, a dedicated trench is used to dispose of OC OTEC waters, and the flow net analyses that follow in Section E-1.0 show that these waters, not waters of mariculture origin, would displace groundwaters in and beneath the anchialine ponds. Impacts of the OC OTEC discharge on anchialine ponds were previously described.

Components of the mariculture discharge of concern to the anchialine pond system are the same as those of concern to the nearshore marine environment, i.e., nutrients, organics, chemical additives and exotic species.

Anchialine ponds appear to naturally exist under a highly variable nutrient regime imposed by groundwater. This suggests that if the anchialine community is intact, it can function normally under some level of loading.

The potential impacts of aquaculture additives and release of exotic species would be as described in Section 3.1 above.

3.3 Impacts on Existing Operations at NELH

Mariculture operations could impact other NELH uses if the source waters are affected. Seepage from a mariculture trench is expected to emerge at depths between the surface and -200 feet. The cold water intake would not be affected. There is a possibility that the warm water intake could receive very diluted amounts of mariculture discharges. Components of interest would include nutrients and additives, the respective effects of which would be opposite. That is, increased nutrient levels would encourage biofouling, but the additives likely to be present would tend to inhibit fouling organisms. It is likely, however, that dilution of the additives in the discharge trench and receiving waters would render them undetectable at the warm water intake.

3.4 Impacts on the Terrestrial and Human Environment

Impacts on the terrestrial and human environment would be similar to those discribed in Part IV, Section B 3.4.

3.5 Mitigating Measures

Using mariculture for treatment of wastes has been suggested. The primary purpose of a mariculture waste treatment facility at NELH would be to reduce the nutrient content of the discharge. Algal uptake experiments at NELH indicate that only a small percentage of the nutrients in the discharge would be removed in an open trench or canal system. To significantly reduce nutrient loading would require a very large land area, probably more land than would be feasible to commit to this use. Some treatment, however, would occur incidental to mariculture operations at NELH. Algae culture would serve to reduce nutrient loading; but culture of higher organisms would increase loading.

In a treatment system, accumulation of algal biomass beyond the densities which may be supported in non-limited growth would hinder biological absorption of pollutants. Consequently, regular removal of the algae produced in the treatment system would be required.

A more fundamental question than whether mariculture waste treatment is appropriate is whether nutrient removal is necessary. Although it may be desirable to reduce nutrients in the discharge to protect the warm water source and minimize biofouling of various experiments, nutrient enrichment of the waters offshore Keahole Point could be beneficial to the local fishing industry.

Chlorine-based compounds, used in higher concentrations when living culture organisms are not present, could be of concern. Although dilution in washdown and comingling with other discharges in the waste stream would probably provide adequate mitigation of potential impacts, monitoring of residual oxidants in the disposal trench is recommended. If excessive concentrations occur, a policy of neutralization of washdown waters with sodium bisulfate could be instituted.

D. COMBINED SEAWATER RETURN FLOWS GENERATED BY OTEC AND MARICULTURE OPERATIONS

1.0 Characteristics of the Discharge Water

At full development, it is estimated that approximately 42,000 gpm (60 mgd) of mixed warm and cold water discharge will be generated by OTEC and mariculture operations at NELH. Maximum volumes of water projected to be disposed of at NELH (by use) are as follows:

> OTEC--23 mgd (16,100 gpm--6,500 gpm cold, 9600 gpm warm)
> Mariculture Uses--37mgd (25,900 gpm--20,720 gpm cold, 5,180 gpm warm).

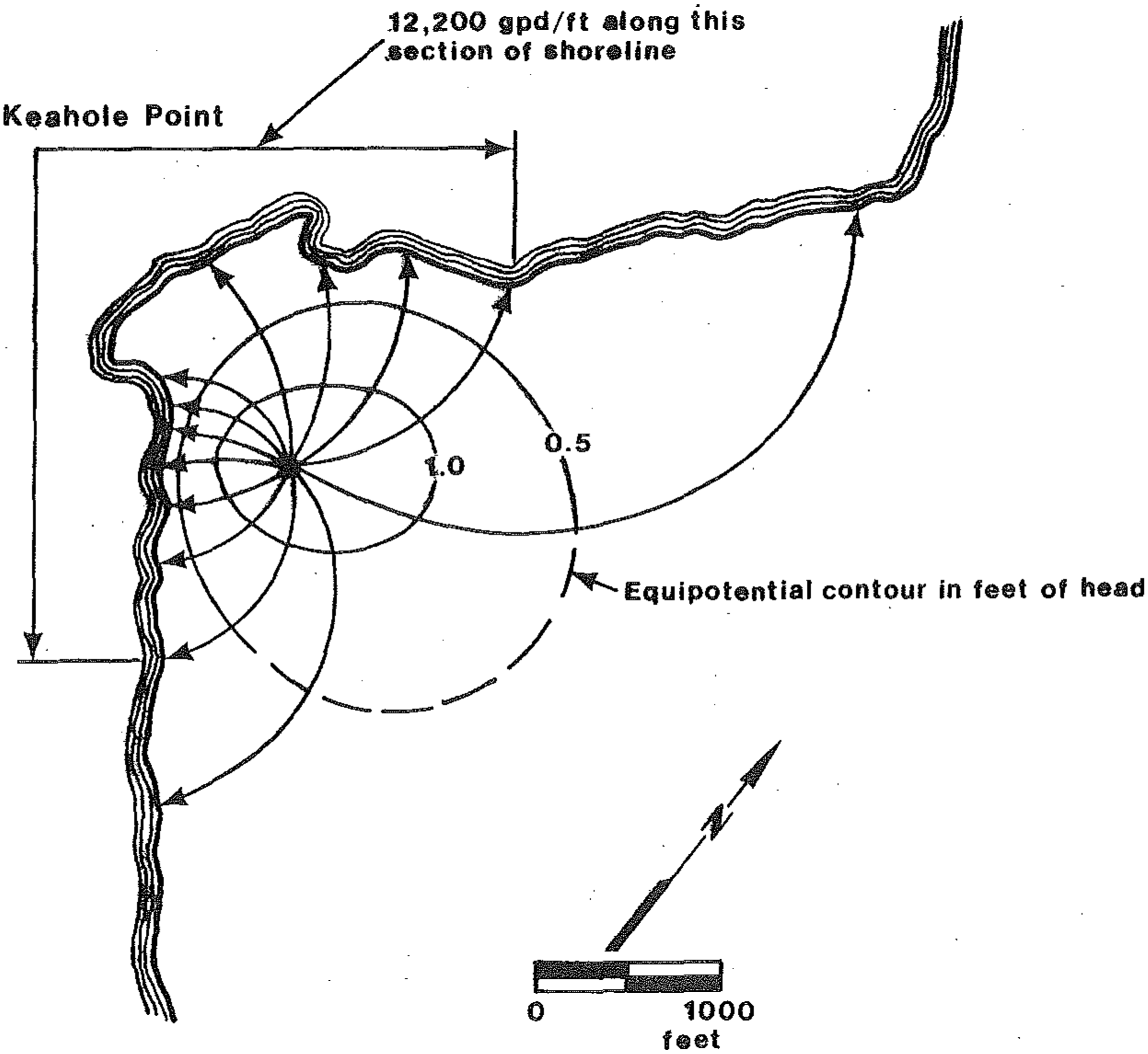
2.0 Combined Disposal Via Trench Along the NELH Access Road

2.1 Analysis

The disposal of combined OTEC and mariculture discharges of 42,000 gpm in a shallow trench was modeled using an analytical computer model based on the Theis non-equilibrium equation (Dames & Moore, Appendix C). The modeling indicates that 77% of the discharge would occur over a shoreline distance of 3,800 feet, an average of 12,200 gpd/foot. If the flow is assumed to be distributed evenly between the 0 and -200 feet bathymetric contours, it would average of 3.2 gpd/ft^2 of ocean bottom in this zone. Discharge would be greater in offshore areas closest to the discharge trench. At these locations, the flow would be approximately 5.9 gpd/ft^2. Minimum residence times of from 3 to 23 days were calculated using expanding sphere and expanding cylinder models (Appendix C).

The disposal by trenches would displace the existing groundwater flow in the immediate vicinity of Keahole Pt. A flow net showing flow patterns for the combined discharge is presented in Figure IV-7.

Dames and Moore (Appendix C) noted the probable occurrence of lava tubes and other zones of high permeability in the subsurface geology. If lava tubes are present in close proximity to the diffusion trench, discharges may have a hydrologic residence time considerably less than expected, and suspended solids passing into the receiving water may be higher than expected. If no direct channels are encountered, the lava



Combined mariculture & OTEC discharge to disposal trench along roadway to NELH
42,000 gpm

Figure IV-7
FLOW NET

NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

Dames & Moore

structure is expected to provide a matrix for accumulation of bacterial biomass which allows limited biological treatment.

2.2 Disposal Facility

The disposal trench analyzed in Appendix C (location M-1, Figure IV-1) is located along the makai side of the NELH access road towards HOST Park roughly parallel to and approximately 750 feet from the shoreline. The ground elevation in the area is approximately 10 feet above sea level.

Trench dimensions for a disposal quantity of 60 mgd (42,000 gpm), would be approximately 5-feet wide, 5-feet deep, and 587-feet long. Although the available length of the disposal area is more than 2,000 feet, the length of the trench could be shortened by digging a deeper trench.

3.0 Environmental Impact Analysis

3.1 Impacts on the Marine Environment

Comingling of OC OTEC and mariculture discharges in a single disposal trench would produce a hybrid water type. If the OTEC discharge consisted of 6,500 gpm cold and 9,600 gpm warm and the mariculture discharge was derived from source waters in a ratio of four cold to one warm (20,720 gpm cold, 5,180 gpm warm), then the mixed water would be about two-thirds of cold origin. The dominant component, nearly half the total, would be cold water used for mariculture. Anticipating the impacts of this discharge suffers the same uncertainty as for an isolated mariculture discharge, i.e., the mariculture crops and processes are presently undefined. In general, however, in comparison with the OC OTEC discharge, the mixed discharge would be considerably warmer due to warming in the culture systems and higher in oxygen content due to aeration in the cultures. Two of the major concerns with the OC OTEC discharge would be mitigated somewhat by mixing these waste streams.

Nutrient concentrations would still be high, as they would be high in each of the discharge streams. Biostimulation of algae in nearshore wates could result but, as explained previously, accumulations of algal biomass are unlikely except in the surge zone. Even there, wave action would tend to break up algal accumulations. Any additives in the mariculture discharge would be diluted to a greater extent than they would in an isolated mariculture disposal trench and impacts would be even less likely.

3.2 Impacts on Anchialine Ponds

The flow net analysis done by Dames and Moore (Appendix C) for this scenario again shows that the groundwater in and beneath the NELH anchialine ponds would be replaced by the discharge plume. The impacts of this mixed discharge plume would be moderated over those of the pure OC OTEC plume in the same manner as discussed above for impacts on the marine environment. Water temperature would be warmer and oxygen content higher than of the pure OC OTEC discharge. The anchialine system appears well adapted to high nutrient influx so minimal impacts would be expected from this source. Mariculture additives would receive greater dilution than in a dedicated mariculture disposal trench so impacts from this source are even less likely.

3.3 Impacts on Existing Operations at NELH

Seepage from a combined discharge would enter the sea at depths between the surface and -200 feet. The plume would be considerably more dilute and generally deeper than that from a dedicated OC OTEC discharge trench and would thus provide mitigation of potential impacts on the warm water intake. Again, the main potential problem would be enhancement of biofouling due to elevated nutrient concentrations

3.4 Impacts on the Terrestrial and Human Environment

Impacts would be similar to those described in Part IV, Section B. 3.4.

3.5 Mitigating Measures

Mitigating measures would be similar to those described previously for trench disposal, and could include procedures for reduction of nutrient and mariculture additives concentrations.

E. CUMULATIVE IMPACTS

1.0 Simultaneous Disposal of OC OTEC and Mariculture Discharges into Two Dedicated Trenches

1.1 Analysis

Modeling was conducted to analyze the effects of simultaneous discharge of OC OTEC return flows of 16,100 gpm into a trench within NELH (Figure IV-1, location O-2) and mariculture return flows of 25,900 gpm into a trench along the NELH access road (Figure IV-1, location M-2). Results of this modeling indicate that 76% of the discharge would occur over a horizontal distance of 5,900 feet along the shoreline, an average of 7,800 gpd/ft. Assuming that the flow was distributed evenly between the 0 to -150 -foot bathymetric contour, discharge seepage would average 2.8 gpd/ft^2 of ocean bottom in this zone. Minimum residence times would be between one to two days for OC OTEC discharge and from 9 to 61 days for mariculture discharge.

Please refer to Appendix C, Addendum II, for more detailed explanations of these calculations.

After reaching its equilibrium configuration, the water from the two disposal trenches would remain relatively separate except at the interfaces between the two plumes and the existing ground water. In simple terms, water introduced into the OTEC trench could be identified as water "X" and the water entering the mariculture trench could be identified as water "Y". After the waters are introduced, except for interaction with tidal motions and the interfaces between the two plumes, the water would remain as X and Y (Appendix A).

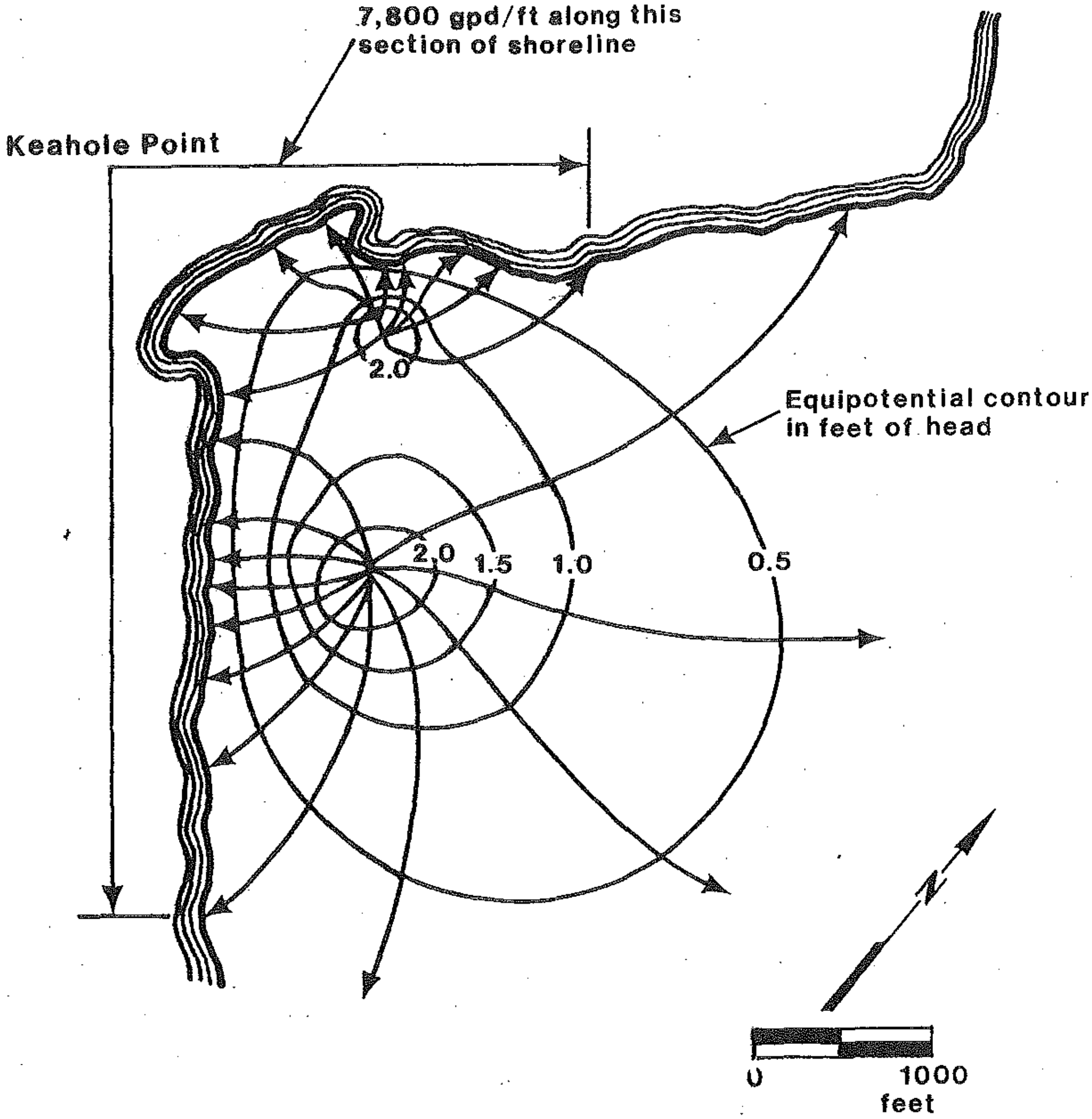
Flow nets illustrating simultaneous discharge from the two aforementioned locations are presented in Figure IV-8. The mixing and/or the specific displacement of the ground water by these seawater return flows would be very site-specific. Theoretically, the streamlines resulting from steady discharge from the two locations would not cross; there would be no mixing. Due to unpredictable inconsistencies in the geology, however, such as lava tubes, discharge via trench might not always behave in this simple manner. Site testing and monitoring would be required to validate the model results.

Although simultaneous discharge into the two trenches would be expected to result in the return seawater entering the marine environment at average depths of from 0 to -150 feet, because of the differences in density and volume between the types of discharge and differences in location of the respective trenches, it is expected that the distribution of OC OTEC discharge would be weighted toward the upper levels of the 0 to -150-foot region, i.e., 0 to -50 feet; and that the discharge from the mariculture trench would be distributed at the lower depths of this range (Oceanit Laboratories, Appendix A).

1.2 Environmental Impacts Analysis

1.2.1 Impacts on the Marine Environment

Disposal of OC OTEC and mariculture discharges into two separate dedicated trenches would have much the same impacts as described previously for each disposal trench separately. As stated previously, the OC OTEC discharge seepage would enter the ocean between 0 and -50 feet, while the mariculture discharge would seep through the bottom from the surface to -200 feet. Cumulative impacts could occur in the 0 to -50 feet range, however, the only cumulative agent would be nutrient concentrations. Potential biostimulation under the dual disposal scenario would be greater than for either scenario separately, at least in the 0 to -50 feet layer. In addition, the affected area along the shoreline would be greater than for either disposal trench considered



Combined discharge to recommended disposal trench locations
42,000 gpm
Figure IV-4 + Figure IV-6

Figure IV-8

FLOW NET

NATURAL ENERGY LABORATORY OF HAWAII
Keahole North Kona, Hawaii

Dames & Moore

separately. Nevertheless, the analysis above would still apply and accumulations of algal biomass would not be expected, except perhaps very near to shore, in the surge zone where grazing is inhibited.

1.2.2 Impacts on the Anchialine Ponds

The flow net analysis produced by Dames and Moore for the simultaneous discharge scenario indicates that the subsurface area of the NELH anchialine ponds would only be affected by the OC OTEC discharge plume. Impacts would therefore be as described previously for the OC OTEC discharge plume alone.

1.2.3 Impacts on Existing Operations at NELH

The primary potential impact would be increased biofouling potential if nutrient concentations in the warm water intake are increased. The likelihood of this occurring would be greater with two operating disposal trenches situated as planned because their areas of maximum flux would straddle Keahole Point and alongshore currents in either direction would move high nutrient water toward the intake. Mixing and advection would provide the primary means of mitigation.

1.2.4 Impacts on the Terrestrial and Human Environment

Impacts on the terrestrial and human environment would be the same as for each disposal trench separately.

1.3 Mitigating Measures

Mitigating measures would be as described for each disposal trench separately.

2.0 NELH and HOST Park

At maximum development, the adjacent HOST Park anticipates an eventual discharge of 100,000 gpm into a trench. This discharge would be increased gradually from an initial flow of 6,800 gpm in 1987 to full development of the park in approximately 10 years.

HOST Park discharges would reflect the mixture of park uses as it develops. The area of influence of the combined NELH and HOST Park plumes would be dominated primarily by the HOST Park mariculture plume and secondarily by the NELH mariculture plume. The combined area influenced would include waters along the coast fronting the NELH, the HOST Park and adjacent properties from the shoreline out to bottom depths of at least -200 feet. Concentrations of discharge waters would be highest directly offshore of the respective disposal trenches and less at increasing distances. Concentrations of plume tracer parameters could be expected to exhibit a relative minimum offshore between the two mariculture plumes.

The offshore bathymetry of the area of concern indicates that the -200 feet contour lies at only about 600-800 feet offshore. Beyond this, the bottom slopes more gently to depths of -400 feet at about 2,000 feet offshore. The benthic community out to depths of approximately -200 feet is dominated by several species of coral, encrusting algae and sea urchins. Beyond this the rocky slope grades into a sandy plain harboring large aggregations of taape (Lutjanus kasmira).

In the water column above the benthos are populations of phytoplankton, zooplankton (including fish eggs and larvae), micronekton and nekton. Marine mammals and threatened or endangered species may also pass through these waters.

Degradation of water quality parameters is a negative impact to the extent that biota are affected or that human use and enjoyment of the environment is compromised. Present plans for both facilities include a gradual increase in volumes of water to be used. This would allow a monitoring program to provide early detection and quantification of any impacts. In addition, the potential impacts are reversible. That is, if discharges of toxic substances harmful to the environment (as evidenced by results of the monitoring program) are halted or mitigated, the affected ecosystems could be expected to revert to baseline conditions.

Disposal of the seawater return flows from NELH and HOST Park into trenches would displace the groundwaters beneath the existing anchaline ponds at NELH. Because of the extent of the resultant subsurface plume, it does not appear to be possible to mitigate this impact by altering the locations of the trenches. As stated in Part IV, Sections B and C, the anchialine ecosystem is expected to adapt to increased salinities and nutrient loading, and impacts are anticipated to be minimal.

OI Consultants, Inc. (1985, 1986) examined the anchialine ponds at Kohanaiki, a land parcel immediately south of 'O'oma II which is slated for resort development. The comprehensive baseline survey of anchialine ponds of the Kona coast by Maciolek and Brock (1974) identified the Kohanaiki ponds as having exceptional value, and potential impacts on these ponds were addressed in the modeling and analysis done for the HOST/NELH FEIS (HTDC, 1985). The OI surveys found a number of ponds not previously mentioned in the literature, bringing the total number known from that area to about 60. However, the biota of many of the ponds originally surveyed in 1972 by Maciolek and Brock (those in the northern half of the parcel, closest to the HOST Park/NELH site) has changed appreciably. Topminnows (family Poeciliidae) are now present in these ponds, evidently at the expense of crustaceans and many algal species. The ponds in the southern half of the parcel remain of exceptional value in that they evidence the rich algal diversity and endemic crustacean fauna formerly found in the northern ponds. If the subsurface plume should reach these ponds, (estimated to require 10-30 years (HTDC, 1985)), the adverse impacts on the anchialine ecosystems would be similar to those described for the NELH ponds. The proposed monitoring program, however, would identify any adverse impacts long before they would occur, thus allowing appropriate mitigation in a timely manner.

3.0 West Hawaii Development

The recent surge of resort development planning for West Hawaii has implications for operations at NELH. Adjacent to and south of the HOST Park site are the proposed 'O'oma II and Kohanaiki developments, respectively. Each is anticipated to include golf courses and substantial other landscaped areas. Domestic wastes are projected to be disposed of into or onto the ground. Coastal waters nearby may receive additional nutrient subsidies as well as rations of various pesticides and other pollutants typical of urban runoff. Although it is anticipated that these could be quickly diluted and advected out to sea, there is a potential long-term impact to the warm water intakes at NELH and HOST Park. This situation should be carefully monitored and appropriate mitigating measures taken if adverse impacts occur.

F. OVERALL MITIGATING MEASURES

1.0 Water Quality Monitoring Program

The HOST/NELH FEIS (HTDC, 1985) and the Master CDUP for pipelines off NELH and HOST Park (CDUA HA-1962) specify development of monitoring programs for offshore waters and anchialine ponds. It is recommended that monitoring of appropriate water quality and biological parameters be done. The goals of the monitoring program should be to protect the natural ecosystems present in the anchialine ponds and coastal waters and to maintain the quality of the warm and cold source waters for NELH and HOST Park. Because of past and ongoing OTEC research at NELH, water quality parameters off Keahole Point are well-studied; considerable baseline data are available for the monitoring program (see HTDC, 1985; Marine Sciences Group, 1986). Although baseline data are available, implementation of at least portions of the monitoring program should take place as soon as possible to supplement existing data for selected parameters.

The monitoring program, which is outlined in Appendix B, has been designed to detect the effects of all major anticipated environmental perturbations by using sampling stations offshore, in the anchialine ponds, at shoreline seepage points (e.g., the springs at Wawaioli), and at inshore wells. Offshore sampling locations and depths have been suggested in the plan (Figure 3, Appendix B).

Parameters to be monitored should be varied depending on the impacts which are possible at a given state of development. For example, during construction turbidity, habitat loss and protected species activities should be documented. Baseline and operational monitoring should include both biological and water quality parameters. Water quality parameters should include temperature, salinity, dissolved oxygen, turbidity, nutrients, indicators of fecal contamination, chlorophyll, chlorine residuals and copper. Biological monitoring should include documentation of faunal assemblages offshore and in the anchialine ponds, as well as human activities in the area. Measures of variability should include species present, biomass, density, diversity, frequency of occurence and others if appropriate. Along the shoreline of NELH/HOST Park, the distribution and abundance of fleshy macroalgae should be closely monitored. Recreational fishing effort and catch composition should also be monitored.

To understand the offshore dynamics of the system, ongoing current measurements should be continued. Data on disposal rates, tidal state and basic climatology are also necessary to evaluate results of the monitoring program.

The suggested frequency of monitoring has been designed to allow early detection of potential impacts. Frequency should be greatest during construction and start-up and later be reduced when consistent patterns are established with confidence. Whenever possible, monitoring should also be done when special situations, such as washing down of tanks, occur. The monitoring plans should be frequently reevaluated to provide for modifications based on new results as they become available.

2.0 Reoxygenation Through Aeration

Dissolved oxygen could be substantially lowered if one or both of the source water streams are degassed prior to use in OC OTEC experiments. If degassing of the OC OTEC waters does take place, then an aeration pretreatment may be beneficial prior to discharge in order to minimize metabolic stress to communities resident in the ponds and nearshore.

Relatively little information is available on the aeration of seawater. However, if conventional wastewater procedures are followed we can estimate the cost and volumetric requirements for the aeration of 16,100 gpm of OC OTEC discharge. Results indicate that costs will range from $34-57 per day with volumes of 43,000 cubic feet (10' X 65' X 65'). Initial investigations on the aeration of seawater indicate that costs could be reduced.

According to some scientists contacted by Oceanit Laboratories (Appendix A), it would be environmentally and economically beneficial to reinject the removed gases into the water prior to discharge. Research at U.H. indicates that this is very possible. One scientist says that his research will include effects of degassification. Reinjection studies will be part of his research effort at NELH.

Another scientist says that the U.S. DOE will be looking at degassification and regassification problems associated with OC OTEC. The impact on the environment from discharging oxygen-poor water is a concern. One possibility would be to aerate by using a spout. Another possibility is with a hydraulic pump that could recombine the gases removed in an earlier state of the OC OTEC operation.

In any event, monitoring will be an important consideration of any research done on this problem as the degree of environmental impact of discharging oxygen-poor water is unknown. The proposed monitoring program should provide early detection of any adverse impacts so that, if required, alternative disposal methods can be instituted. As stated previously and in Appendix B, any adverse impacts on the environment are reversible and can be mitigated by ceasing to discharge oxygen-poor water in a manner that affects the nearshore environment.

G. COMPARISONS AND RECOMMENDATIONS

1.0 Comparative Analysis of Disposal Alternatives

Based on existing research, it is assumed that OC OTEC return waters will be characterized by low dissolved oxygen, low temperature, high nutrient concentrations and possibly a very small amount of chlorine, but no additional heavy metals. The low dissolved oxygen concentration could cause some reductions of metabolic rates of nearshore communities and reaeration may be required. This mitigation would be required for trench or well disposal.

Discharges via either canal or very nearshore shallow trench (such as optional location O-1 for NELH OC OTEC disposal trench) have the most potential to elevate nearshore nutrient concentrations, and some effects may be experienced at the warm water intake. It should be noted, however, that several studies (WRRC, 1980; R. M. Towill, 1982) have reported that coastal water quality standards are exceeded near the shore. This is not unusual as shoreline nutrient concentrations are generally elevated as a consequence of a higher proportion of groundwater in very nearshore samples. Elevated nutrient concentrations could be beneficial to commercial and recreation fishing activities that take place in the area.

As proposed, the deep injection wells would provide the greatest residence time for discharge waters, about three months, and would create seepage through the bottom between -300 and -400 feet depths. While this would avoid potential biostimulation of the algal turf at the shoreline, it would come at substantial additional cost.

Theoretically, discharge into a canal and ponding area appears to be an environmentally acceptable method of disposing of OC OTEC return flows. The 1,000 gpm of seawater currently discharged by this means does not produce a nutrient-rich plume or any measureable adverse environmental impact with mixtures of 1:1 to 1:6 cold to warm seawater. This is because significant nutrient stripping by macroalgae takes place in the inter-tidal ponding area. However, before the same type of ponding area can be used for larger discharge volumes, additional investigations would be required to determine the physical characteristics that cause the pond to act as a "reactor vessel" that adds oxygen, removes nutrients and increases the discharge water temperature to approximately that of the ambient seawater. For this reason, and the fact that the land area required for this disposal method might be prohibitively large in relation to the area available to NELH, discharge of 16,100 gpm of OC OTEC waters via canal was determined to be unfeasible at the present time. It is strongly recommended, however, that additional research be undertaken before this method is completely rejected for lower volumes of discharge.

Trench disposal would serve to remove solids, precipitate some of the phosphorus and metals, allow decomposition to break down some of the organic material, and provide a matrix for nitrifying bacteria. Pretreatment requirements would primarily be for reoxygenation through aeration. Although the rate of discharge to the sea per unit bottom area is greater for the trench discharge within NELH than for deep injection wells rapid dilution, advection, low toxics concentrations, algal uptake capacity, warming in process systems, and reaeration, if necessary, would act to mitigate most impacts.

Assuming a homogeneous subterranean environment (i.e., no lava tubes, etc.), disposal of the waste waters into trenches would displace the groundwaters beneath the existing anchialine ponds at NELH. The area of displacement would vary with the amount of discharge and location of the trench. Disposal via deep injection wells would not affect this system. The anchialine pond ecosystems which may be affected by this plume are expected to adapt to the change in salinity of the water (G.K. & Associates, Appendix E).

A cost comparison between trenches and deep injection wells is presented in Appendix F. In general, deep injection wells are approximately 15 times more costly to construct and operate than disposal by trench within NELH. Without empirical data from monitoring a trench system, the theoretical minimal improvement in avoiding impacts to the environment by disposing via injection wells does not appear to warrant the additional cost.

2.0 Recommendations

Based on current assumptions concerning OC OTEC discharge water, and the relatively short time frame within which the OC OTEC experiments will be conducted, the analysis shows that adverse environmental impacts resulting from each of the three methods of disposal are reversible and/or can be mitigated. There are still many unknowns, however, associated with the processes involved. It is therefore recommended that initially OC OTEC discharges (up to a maximum 5,000 gpm) be disposed of into a research trench within the NELH compound. A trench for volumes up to 5,000 gpm would be approximately 5 feet by 5 feet by 45 feet long. It has been suggested that a full-sized trench with a capacity of 16,100 gpm is required for initial testing of the full ocean water system. Although this would be more costly if research and monitoring indicate that an alternative disposal method should be used during the 16,100 gpm 165 kW experiment, it is still in keeping with this recommendation.

During the 3 to 4 year period of heat and mass transfer experiments, an intensive water quality monitoring program should be conducted in order to determine the actual impacts associated with the discharge flows. Various mitigating measures, such as filling the trench with crushed lava or gravel to increase filtration, and various reaeration pretreatment techniques could be tested at the same time. The research would generate valuable information on discharge water constituents and their environmental impact that could possibly be transferred to larger-scale experiments or operating plants.

It appears from the analysis that a combination of existing and trench methods would be acceptable for mariculture discharges, depending upon the flows involved. It would be valuable, however, to initially construct a mariculture research trench along the NELH access road. Various hypotheses concerning temperature, filtration and nutrient stripping could be tested at relatively low volumes of discharge so that any undesirable effects could be identified and mitigation measures could be developed. Monitoring would also be an important requirement for mariculture discharge, for both environmental and economic reasons.

H. OTHER ALTERNATIVES

Disposal of OC OTEC water via a mixed-water deep ocean discharge pipe was assessed in the HOST/NELH FEIS (HTDC, 1985). Impacts of outfall disposal would be similar to those of injection wells, however, a pipe would produce a point source of concentrated discharge water rather than the diffuse flow through the bottom produced by on-land disposal methods. Impacts on water column organisms would be greater than other methods due to the more concentrated discharge and possible entrainment in the plume.

As the plume density from the outfall would exceed ambient seawater density at the anticipated discharge depth, it would sink and flow downslope along the bottom. This would expose benthic communities in the plume path to more concentrated discharges than would result from on-land disposal.

In general, outfall discharge impacts would be more intense over smaller areas than injection well disposal impacts. Mitigation of the impacts of the low oxygen content of OC OTEC discharge would be more critical for the case of the more concentrated outfall discharge plume.

I. NO PROJECT

In terms of this SEIS, the project is defined as on-land disposal of OC OTEC seawater return flows. No project would mean no further funding by the U.S. DOE for both the proposed ocean water supply system and future research programs for OC OTEC at NELH until such a time as funds became available and a mixed-water discharge pipe could be designed and constructed. U.S. DOE OC OTEC research at NELH could be delayed for several years. HOST Park, however, would proceed to obtain its final permits to construct the 28-inch cold water pipe and pumping system that they originally planned before joint funding with the U.S. DOE for a larger system became a possibility.

No project would also mean that research opportunities to monitor low-cost disposal methods would be lost. This could be significant in that a potential opportunity to transfer cost-effective, reliable disposal technology to other countries would be lost. In addition, the State of Hawaii is actively seeking high-tech mariculture enterprises to diversify the economy of the State. A cost-effective disposal technique might make the difference between success and failure for "state-of-the-art" fledgling businesses.

J. IMPACTS OF LAND DEVELOPMENT AND CHANGES IN LAND USE

The proposed NELH Land Use and Ocean Water Plan is presented in Figure II-3. Figure II-5 illustrates proposed improvements and expansion of the NELH laboratory compound (also known as the Seacoast Test Facility (STF)).

Certain aspects of the NELH land use plan have changed since the previous EIS. This section will assess the environmental impacts of these changes on various aspects of the environment.

1.0 Construction Impacts

1.1 Anticipated construction activities.

Construction of on-land seawater return flow disposal facilities would involve drilling, ripping, blasting and/or grading. Construction of public parking areas and restrooms, future road extensions to tenants' parcels and research areas would require ripping, grading and surfacing.

1.2 Impacts and Mitigating Measures

Temporary construction related impacts include noise, increased dust and particulate matter in the air, and increased vehicular traffic along the NELH access road. Construction of a trench makai of the NELH compound may affect the nearshore area of the facility. These impacts would be mitigated by existing governmental regulations which control noise, air quality and water quality.

Construction of improvements would destroy vegetation on the site. Vegetation in the area is generally sparse and scattered. No rare, threatened or endangered plant species have been recorded from the project area. Because the native species that are found on the project sites also occur in similar habitats throughout the West Hawaii area, the proposed developments would have minimal impact on the total island populations of the native components (HTDC,1985).

Construction of the proposed improvements would lead to the loss of habitat on land cleared of vegetation; however, the project area provides only a marginal habitat for birds and animals and the impact would be insignificant (HTDC, 1985).

Shoreline recreation may be impacted during construction activities as the contractor would most likely close off construction areas because of safety considerations.

Construction impacts on historical/archaeological sites are addressed in a following section (L-1.0) of this part.

2.0 Subdivision

2.1 Anticipated Activities

The mariculture areas of NELH are planned to be subdivided into individual parcels of minimum one-acre size. Approximately 60 acres would consist of one to seven-acre lots for research and development activities. Land to be utilized for commercial demonstration parcels would consist of larger lots, minimum 5-10 acres in size. These lots will be offered to tenants via facilities use agreements and/or 35-year leases with the State of Hawaii.

Each lessee would construct access roads and utility connections to his own lot and construct on-site facilities, including buildings, ponds, raceways, etc. Each user would also provide individual sewage disposal systems meeting State Department of Health requirements. Local drainage from each lot would be the responsibility of the lessee.

The increased number of people on-site and increased industrial activity would generate a demand for additional potable water supply. NELH would provide water, at a cost, for each tenant's use.

2.2 Impacts and Mitigating Measures

Subdivision of land would involve the surveying and staking out of boundary pins so that land parcels can be readily located, identified, and verified. Subdivision would provide conveyable real estate property title and rights for individual or collective development of NELH Board approved projects. Development of the parcels would result in added jobs, more people and associated people oriented impacts. The vacant areas on the site would become available for higher and more beneficial uses. The lessee would be bound by covenants in his lease and by rules and regulations governing NELH.

Roadways would be located, graded, paved, and marked to permit access to each parcel. Because the lava flow is geologically recent, little flora, fauna, or environmentally sensitive areas would be disturbed. Roadways would permit access to each property and would facilitate economical and efficient movement of people and products to their desired destinations.

All plans for tenant improvements would be subject to approval by the NELH Board of Directors as well as appropriate State and County agencies. Right of approval of improvement plans will insure that the improvements enhance the aesthetics of the property.

At a minimum, septic tanks and seepage fields would be constructed for domestic sewage treatment and disposal. No hazardous wastes or process waters would be allowed to be disposed of in the septic tanks. Planting of grass and shrubs above the leaching fields could enhance the beauty of the area and reduce the amount of sewage effluent that could reach the ocean.

Drainage could be handled with swales, ponding areas, seepage pits and other on-site drainage improvements. Drainage improvements are necessary to protect people and property from flooding, and to assure that storm runoff will be handled in an environmentally safe manner. NELH will also monitor fresh water usage by its tenants in order to insure that appropriate conservation measures are being undertaken.

K. SOCIO-ECONOMIC IMPACTS

Socio-economic impacts were addressed in the HOST/NELH FEIS (HTDC, 1985) and are incorporated by reference.

L. SOCIO-CULTURAL ATTRIBUTES AND RECREATIONAL RESOURCES

1.0 Historic/Archaeological Sites

Actions described in this SEIS have the potential of disturbing and/or destroying historic/archaeological sites. Please refer to Appendix D, which was prepared by Dr. Ross Cordy of the State Historic Sites Section, for an evaluation of the sites at NELH, and assessment of potential impacts and a proposed archaeological preservation/mitigation plan.

Briefly, as discussed in Appendix D, adverse impacts to all of NELH's sites could occur as a result of land alteration, pipeline expansion and increased public access to the site. Mitigation plans have therefore been developed by NELH in consultation with the state's Historic Sites Section (DLNR HSS); some have already been put into effect.

Seven sites in the two site groupings that are significant as examples of types have been set aside for preservation. These are sites D15-12 and D16-6 though D16-11 (Figure III-7). These sites are in "no build" areas, and buffers to prevent direct and indirect damage have been determined in consultation with the DLNR HSS. The remaining 17 sites, those signficiant solely for their information content, will be protected until archaeological data recovery occurs. To ensure protection, the borders of the accessible sites have been marked in company with DLNR HSS staff and will be located on base maps, so their locations will be known to present and future users at NELH.

Archaeological data recovery plans have been prepared in detail by the DLNR HSS. These plans are summarized in Appendix D, Table 4. To ensure that data recovery work is done correctly, the DLNR HSS and the County of Hawaii Planning Department will review and approve each detailed scope of work, verify the satisfactory conclusion of fieldwork, and review and approve the final archaeological report.

2.0 Recreational Resources

Impacts on recreational resources were addressed in HOST/NELH FEIS and are incorporated by reference. Of the alternative methods of disposal, only direct discharge by canal has the potential of affecting recreational resources.

M. PROBABLE ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED

1.0 Construction Impacts

1.1 Traffic:

There would be an unavoidable increase in traffic during the construction period in order to bring construction equipment and materials to the site. This impact would be intermittent but it would continue for some time into the future as various projects come on-line.

1.2 Air Quality:

Increased traffic and the use of heavy construction equipment would lead to the temporary generation of emissions from internal combustion engines. Construction activities would lead to increased dust and particulate matter in the air. These impacts would be mitigated by existing governmental regulations concerning air quality.

1.3 Vegetation:

Construction of portions of the disposal systems and future land development activities at NELH may destroy some vegetation. Vegetation in the area is generally sparse and scattered. Native species that are found in the project area also occur in similar habitats throughout the West Hawaii area so there would be minimal impact on the total island populations of the native components.

1.4 Terrestrial Fauna:

Resident fauna in the areas directly disturbed by construction would be affected. Other fauna inhabiting the site may be temporarily frightened away. The area has a low concentration of wildlife because of its sparse vegetation. There are no known officially designated endangered or threatened terrestrial species that inhabit the project site.

1.5 Archaeological Sites:

Archaeological sites directly affected by construction activities would be destroyed. Archaeological data recovery plans have been prepared in detail by the DLNR Historics Sites Section. To ensure that data recovery work is done correctly, the Historic Sites Section and the County of Hawaii Planning Department would review and approve each detailed scope of work, verify the satisfactory conclusion of fieldwork, and review and approve the final archaeological report.

1.6 Recreation Activities:

Some disruption of beach recreation can be expected during the construction period due to concerns for public safety.

2.0 Operations

2.1 Water Quality

Potential degradation of water quality parameters is a negative impact to the extent that biota are affected or that human use and enjoyment of the environment is compromised. A proposed water quality monitoring program has been designed to provide insights to an understanding of these impacts. Present plans for NELH include a gradual increase in volumes of water to be used. This would allow the monitoring program to provide early detection of any impacts. In addition, the potential impacts are reversible. That is, when OC OTEC experiments are terminated and/or an alternative method of disposal is instituted, the ecosystems affected by OC OTEC discharge could be expected to revert to baseline conditions. The same situation would hold true for mariculture discharge.

2.2 Seawater Return Disposal Effects

2.2.1 Vegetation

The on-land disposal of ocean water into a shallow trench could disrupt and displace the existing brackish water lens for some distance inland and along the coast. In the long-term, trees with deep root systems that reach groundwater level may not be able to survive the change in salinity caused by the ocean water plume. This impact can be mitigated by planting trees with a greater tolerance to salinity.

2.2.2 Anchialine Ponds

The aquifer surrounding Keahole Point is expected to experience reduced temperatures, increased salinity, increased solute concentrations, and greater localized groundwater. Groundwater salinities in the areas of anchialine ponds are expected to rise from present condition (6-12 ppt) to something close to normal seawater (i.e., 35-36 ppt).

Anchialine species observed in the NELH ponds include *H. rubra* and *M. lohena*. *M. lohena* has been found in salinities from 2 to 36 ppt; most commonly, however, this species and *H. rubra* are found in waters with salinities between 2 and 30 ppt. In the field, in deeper water exposures or when wind stress and mixing are low, vertical stratification of temperature and salinity will frequently occur. Both species move through these gradients with impunity, implying euryhalinity. Negative impacts due to salinity increases may be non-existent for adults of the known obligate anchialine species present in the NELH ponds. The potential impacts associated with increased salinity on the fecundity of survival of juvenile stages of these species is unknown.

Discharges from OC OTEC experiments may be degassed. If the discharge is not reoxygenated, many of the anchialine species in the ponds situated on the project site may disappear, at least temporarily. Reoxygenation of the disposal waters is strongly recommended.

The concentrations of inorganic plant nutrients (e.g., nitrate, nitrite, phosphate, ammonium, silicate) are expected to increase in the groundwaters due high cold water concentrations, cell lysis and mariculture discharges.

Nutrient concentrations in insular groundwaters are quite variable and frequently high, particularly for nitrates. Anchialine ponds appear to naturally exist under a highly variable nutrient regime imposed by groundwater. This suggests that if the anchialine community is intact, it can function normally under some level of loading.

Chemicals and waste products from mariculture operations in concentrations that would be harmful to nearshore marine organisms would also probably have negative impacts on the anchialine biota. Discharges of known toxic materials would be prohibited and regulations enforced. In addition, discharges should be monitored in order to ensure that toxic concentrations of substances are not present in the discharge waters.

2.2.3 Marine Environment

OC OTEC discharges containing reduced concentrations of oxygen would tend to depress metabolic activity of the coastal community, but trench disposal would considerably diffuse entry of these waters to the sea and rapid mixing at entry would tend to minimize this impact. Reoxygenation by aeration would be beneficial in mitigating this potential impact.

Potential impacts from discharging seawater at temperatures cooler than the ambient water temperature of the receiving waters could include reduced metabolic rates, especially of corals. This could retard reef growth and in the very long-term alter community structure by changing the competitive balance among species. Trench disposal would afford some warming and would greatly diffuse the flux and allow for high initial dilution in the receiving waters. If permit conditions requiring a minimum discharge temperature of 19°C are adhered to, it does not appear that the magnitude of the potential temperature depression would cause mortalities in the benthic community, but monitoring of community structure should be required to provide quantitative estimates of this impact.

Nutrient concentrations in OTEC discharges would be elevated over those of receiving waters. The offshore benthic algal community is maintained at a very low standing crop by grazing and physical stresses. Nutrient subsidies would be expected to increase macroalgal biomass in the surge zone where grazing is inhibited and increase herbivorous fish biomass elsewhere.

In OC OTEC research where lysing occurs, the usability of nutrients in the discharge would be expected to increase. In addition, dissolved oxygen would be expected to decrease. An increase in organic material could result in increased rates of biofouling in closed-cycle heat exchangers and low dissolved oxygen levels could adversely affect heat exchanger corrosion rates. The situation should be monitored in order to determine the significance of this impact, if it should occur.

Certain chemical additives used in mariculture operations, unknown at the present time, could potentially impact the marine environment. The nature of all new chemicals should be reported and investigated prior to their introduction into the discharge system as they may significantly impact the resident biota.

N. THE RELATIONSHIP BETWEEN SHORT TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The energy research activities at NELH would benefit society by developing renewable energy resources. The knowledge gained would be disseminated throughout the scientific community and effects would be felt worldwide. In addition, as techniques for cold water mariculture are continually refined, new industries may develop which would utilize the techniques being developed in Hawaii and many would choose Hawaii as the location of their production facilities. This could further enhance the opportunities for economic diversification in the state.

The major tradeoff of disposal of OC OTEC and mariculture discharges into shallow trenches rather than injection wells or outfalls would be between potential sub-lethal impacts to some nearshore biota and the extremely high cost of avoiding these impacts completely. The State of Hawaii is actively seeking high-tech mariculture and energy enterprises to diversify the economy of the state. An environmentally acceptable, cost-effective disposal technique might make the difference between success and failure of these businesses.

The proposed water-quality monitoring activities at NELH would enhance knowledge of coastal and ocean processes and facilitate the development of standards for OTEC, mariculture and other ocean-related research and development activities throughout the state and the world. This item is top priority because preservation of the integrity of the cold and warm ocean water resources is fundamental for the continued growth and success of the proposed projects.

The on-land disposal of seawater return flows and other activities would result in a commitment of land within and adjacent to the NELH site. If monitoring discloses that there are adverse effects, the trenches and canal could be filled and any injection wells could be plugged. Therefore the commitment only needs to be of a temporary nature.

This SEIS has been prepared to disclose the potential implications of proceeding with the alternative disposal methods. It will be the responsibility of various state, federal and county officials to evaluate the tradeoffs between research goals and effects on the natural environment and to make informed decisions based on knowledge of the potential consequences. Mitigating measures, as outlined in this report, should be incorporated into the design of the disposal facilities.

O. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

The construction and operation of the alternative disposal methods and other NLEH development activities discussed in this SEIS would involve the irretrievable commitment of certain natural and fiscal resources. Major resource commitments include land, money, construction materials, manpower and energy. The impacts of using these resources should be weighed against the economic and research benefits to the residents of the state and other countries.

Land committed to the projects is adjacent to airport industrial activities and thus would be a continuation of an existing land use pattern. The capital committed to the construction of the disposal facilities and other NELH improvements described in this SEIS would be irrevocably committed, although some may be recovered in the lease rents paid by future commercial tenants. The commitment of resources required to accomplish the project includes labor and materials, which are mostly unrenewable and irretrievable. Benefits would accrue to the County of Hawaii construction industry. The operation of the project would create new jobs for West Hawaii residents, but would also increase the consumption of potable water and petroleum-generated electricity which also represents the irretrievable commitment of resources.

If properly monitored, almost all of the potential negative environmental effects of the project on natural resources can be reversed and/or mitigated.

P. SUMMARY OF UNRESOLVED ISSUES

Various approaches to reoxygenation of degassed OC OTEC waters are being discussed. The process is in the research stage. Although reaeration could easily be accomplished by a fountain or any other turbulent motion in the air, it is believed that it would be environmentally and economically beneficial to reinject the removed gases into the water prior to discharge. This would remove the problem of discharging deoxygenated water. The specific process for this mitigating measure is unresolved and will be the subject of research. Monitoring of effects of degassed discharged water on nearby marine communities would serve both to identify adverse impacts and to test the effectiveness of various alternative processes during the research stage. If adverse impacts continue to occur, an alternative method of disposal would be instituted.

Future mariculture crops and processes are currently undefined, although most are anticipated to be similar to those described previously in this SEIS. The significance of impacts of mariculture discharge are, however, uncertain. Based on the analysis presented in this SEIS, with appropriate controls by NELH management (to insure that all chemicals to be used in various mariculture processes are fully disclosed and concentrations are within the limits set by federal and state agencies and the NELH Board of Directors) and a comprehensive monitoring program, adverse environmental impacts would be minimal. Various mitigating measures, as suggested in Part IV of this SEIS, could be instituted if adverse impacts should occur. Mitigation could include diverting discharge to an alternative disposal system.

There is very little credible biological information on anchialine flora and fauna. Therefore, conclusions regarding significance of impacts are "best guesses" based on qualitative and observational (field) information. The proposed monitoring program is intended to facilitate quantification of any adverse impacts that might occur so that appropriate mitigating measures can be instituted.

The monitoring program is intended to provide additional information to resolve the above issues. Because discharge quantities are expected to increase gradually, both for OC OTEC and mariculture, the trench disposal system is still recommended, even though some issues remain unresolved.

PART V: THE RELATIONSHIP OF THE PROPOSED ACTION TO LAND USE PLANS, POLICIES AND CONTROLS FOR THE AFFECTED AREA

A. STATE LAND USE LAW

The NELH site is in the Urban District, therefore there is no conflict.

B. HAWAII COASTAL ZONE MANAGEMENT OBJECTIVES AND POLICIES

The relationship of the proposed project to the objectives and policies of the Hawaii State Coastal Zone Management Program (HRS 205A-2) was discussed in the HTDC FEIS. Modification of the proposed action will not result in reduction of public access to the shoreline, destruction of historic sites or degradation of scenic and open space resources. The regional water quality monitoring program that has been recommended will "improve the technical basis for natural resource management."

The CZM objective relating to coastal ecosystems is to "protect valuable coastal ecosystems from disruption and minimize adverse impacts on all coastal ecosystems." The research trench, the NELH ponds and the nearshore area will be monitored for changes in these systems. Because the initial flows are anticipated to range between 3,000 and 5,000 gpm for three to four years, injection wells can be constructed if the results of the monitoring program indicate adverse environmental impacts. Any potential impacts are expected to be reversible.

The proposed modifications are also in conformance with CZM policies and objectives regarding economic uses, coastal hazards and managing development.

Coastal Zone Consistency Certification is being addressed through the U.S. Army Corps of Engineers permitting process.

C. CONSERVATION DISTRICT POLICIES AND REGULATIONS

The proposed disposal facilities will be constructed in the State Urban District, although waters from canal disposal will traverse Conservation District Lands. A Conservation District Use Permit (CDUP) for use of approximately 2940 acres of ocean waters and submerged lands for ocean research, alternative energy and mariculture research, and commercial mariculture and energy activities and facilities, including construction of up to 15 additional warm and cold water intake pipelines, was approved by the Board of Land and Natural Resources on July 23, 1986. Conditions on this permit require monitoring of anchialine ponds -- as described in this SEIS -- and approval of an acceptable seawater disposal system for OC OTEC water. This SEIS is directed towards fulfilling the latter condition.

D. HAWAII WATER QUALITY STANDARDS AND PERMITS

1.0 Ocean Discharge

Coastal water quality is protected by the federal Clean Water Act (33 USC 1251 et. seq.) and the State Environmental Quality Act (Chapter 342, HRS), administered by the Hawaii State Department of Health. The two applicable regulations are Water Quality Standards and Water Pollution Control, Chapters 54 and 55 of Title 11, Administrative Rules.

The waters off Keahole are classified as AA in the Water Quality Standards. The objective of this class is to keep these waters in their natural pristine state as nearly as possible with an absolute minimum of pollution. Uses to be protected in this classification include oceanographic research.

The Water Pollution Control rules define the requirements for National Pollution Discharge Elimination System (NPDES) permits. The NELH Seacoast Test Facility has a NPDES permit valid until March, 1991. If the canal discharge option is chosen, this permit may need to be modified.

2.0 Underground Injection Wells (UIC)

Groundwater quality is protected under the Hawaii Safe Drinking Water Act (Chapter 340E HRS). Under this Act, rules have been adopted to regulate injection wells (Chapter 23, Administrative Rules, Underground Injection Control). Even though the NELH site is in an exempted aquifer area, that is, designated as unsuitable as an underground source of drinking water, a permit is required from the Department of Health if injection wells are used.

3.0 Trench Discharge

Discharge into a trench is not covered by any specific environmental regulation. NPDES permits apply only to direct discharges to surface waters; a UIC permit is required only for a well, defined as "a bored, drilled or driven shaft, or a dug hole, whose depth is greater than its widest surface dimension."

However, Section 33 of Chapter 342 contains a general prohibition against the discharge of any pollutant into state waters, which by definition include ground water. Although a specific permit would not be required, the proposed trench disposal system would need review by and approval of the Department of Health before it is implemented.

E. HAWAII COUNTY SPECIAL MANAGEMENT AREA

In the Keahole area, the special management area runs from the ocean to Queen Kaahumanu Highway. A Special Management Area Use Permit (SMA 77) controls uses on NELH property. The County Planning Department has determined that an amendment to this permit is required in order to permit alternative methods of seawater return flow disposal at NELH.

F. POLICIES AND PLANS INCORPORATED IN THIS SEIS BY REFERENCE

The Hawaii State Plan: Objectives and policies (Part I) and priority guidelines (Part II) in relation to the economy, energy, etc., as described in the HTDC FEIS.

Environmental Policy: Chapter 344, HRS - State Environmental Policy Act - Conforms

Air Quality: Federal Clean Air Act, as amended (42 U.S.C. 1857h-7 et seq. and State Environmental Quality Act (Chapter 342 HRS) - No effect expected

Fish and Wildlife Habitat: Fish and Wildlife Coordination Act (16 U.S.C. Sec.661 et seq.) - Coordination is being accomplished through U.S. Army Corps of Engineers permit process.

Historic and Cultural Properties: National Historic Preservation Act of 1966, as amended (16 U.S.C. 1251 et seq.) - No historic sites will be disturbed by construction of disposal facilities.

Hawaii County General Plan: As discussed in the HTDC FEIS, the proposed action conforms to County of Hawaii economic and energy policies.

G. AN INDICATION OF WHAT OTHER INTERESTS AND CONSIDERATIONS OF GOVERNMENTAL POLICIES ARE THOUGHT TO OFFSET THE ADVERSE ENVIRONMENTAL EFFECTS OF THE PROPOSED ACTION

The various federal, state and county agencies which have issued or are processing permits for the implementation of the proposed projects at NELH and the adjacent HOST Park that were described in the HTDC FEIS, have imposed conditions and restrictions that will help insure that adverse environmental impacts are properly monitored and mitigated. The most significant consideration that will offset adverse effects is the importance of the pristine quality of the nearshore and offshore water resource to the success of OTEC and other activities at NELH. This will ensure that all activities, whether on land or in the water, will be monitored in order that the integrity of these waters is not compromised.

PART VI: LIST OF NECESSARY REVIEWS AND/OR APPROVALS

The following list of necessary reviews and/or approvals does not include compliance activities to be undertaken by the U.S. DOE.

Federal

Clean Water Act (33 USC 1251 et. seq.)
-Administered by the State. See Department of Health

Federal Aviation Agency (FAA)
-Notice of construction within 20,000 feet of airport runways (14 CFR 77)

U.S. Coast Guard
-If required, license to construct facilities on Coast Guard land.

State of Hawaii

Department of Agriculture
-Mariculture operations culturing exotic species: Permit to import non-indigenous species.

Department of Health
-Trench Disposal: Review and approval for compliance with Section 33, State Environmental Quality Act (Chapter 342, HRS)
-Disposal Via Canal: Existing National Pollution Discharge Elimination System (NPDES) Permit must be modified if discharge exceeds 1500 gpm.
-Underground Injection Wells (UIC): Permit required even though proposed site is in an exempted aquifer area.
-Mariculture operations involving shellfish: Shellfish Sanitation Certificate.
-Individual domestic wastewater disposal systems: Permit required.

Department of Land and Natural Resources
-Satisfaction of and request to remove condition #8 -- approval of an acceptable seawater disposal system for 16,100 gpm of OTEC water -- from CDUA HA-1862.
-Historic Sites review.
-Approval of plans for construction within the Conservation District.
-Approval of all NELH tenants' subleases.

Hawaii County

Special Management Area (SMA) Use Permit
-Amend existing SMA #77
Subdivision Application and Approval

Plan Approval and Various Construction Permits.

PART VII: AGENCIES, ORGANIZATIONS AND INDIVIDUALS CONSULTED IN THE PREPARATION OF THE DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT

A. AGENCIES, ORGANIZATIONS AND INDIVIDUALS CONTACTED

This SEIS was prepared under a contract with R.M. Towill Corporation, the prime contractor for planning and engineering of HOST Park and the HOST/DOE ocean water supply systems.

The following individuals and firms were contacted for professional services and/or specialized advice during the preparation of the SEIS. Sub-consultants in the preparation of this SEIS are indicated with an asterisk (*).

*Dames & Moore	Hydrology and Seawater Return Flow Disposal Via Deep Injection Wells and Shallow Surface Trenches
*GK & Associates	Water Quality, Mariculture Characteristics, Marine Impacts and Anchialine Ponds
*Oceanit Laboratories, Inc.	OTEC Characteristics and Discharge of OTEC Water Via Canal

Federal Agencies

U.S. Department of Commerce, National Marine Fisheries Service

Mr. John J. Naughton	Western Pacific Program Office

U.S. Department of Energy

Mr. Carmine Castellano	
Dr. Lloyd Lewis	Wind/Ocean Technologies Division
Dr. John W. Shupe	Director, Pacific Site Office, Honolulu

U.S. Department of the Interior, Fish & Wildlife Service

Mr. John Ford	Office of Environmental Services

State Agencies

Department of Accounting and General Services

Mr. Ralph Yukumoto	Planning Branch
Mr. Jerry Nishida	Project Management

Department of Health

Mr. Dayton Frain	Environmental Permits Branch
Mr. Steve Chang	
Mr. Brian Choy	Environmental Planning

Department of Land and Natural Resources

Mr. John Corbin Mr. William Brewer	Aquaculture Development Program
Mr. Dean Uchida	Planning Office
Dr. Ross Cordy	State Parks, Outdoor Recreation and Historic Sites

Department of Planning and Economic Development

Dr. Takeshi Yoshihara Mr. Gerald Lesperance	Energy Division

Natural Energy Laboratory of Hawaii

Dr. Thomas Daniel	Laboratory Director

High Technology Development Corporation

Mr. William Bass	Executive Director
Ms. Kay Yamada	
Mr. George Mead	HOST Park Manager

University of Hawaii

College of Engineering

Dr. Paul Yuen	Dean
Dr. Hans-Jurgen Krock	Chairman, Department of Ocean Engineering
Dr. John Craven	Prof. Em, Department of Ocean Engineering

College of Tropical Agriculture and Human Resources

Mr. David Robichaux Mr. Mark Underwood	Department of Agricultural Engineering

Hawaii Institute of Marine Biology

Dr. Richard E. Brock

Hawaii Natural Energy Institute

Mr. E. Chipman Higgins

County of Hawaii

Planning Department

Mr. Albert Lono Lyman	Director

Other Institutions, Private Businesses and Organizations

Mr. David K. Barclay	Argent Chemical Laboratory
Mr. Steven Katase	Hawaiian Nori Company
Mr. Richard Krauss	Aquaculture Research Corporation
Dr. Noam Lear	
Dr. Kelly Moorhead	Cyanotech, Inc.
Dr. C. B. Panchal	Argonne National Laboratory
Dr. Terrence Penney	Solar Energy Research Institute
Dr. David Johnson	
Mr. Garret Vuillemot	Oceanic Institute
Mr. Peter Steel	Hawaiian Abalone Farms
Mr. Bruce Tsuchida	R.M. Towill Corporation
Mr. Bud Vuillemot	R.M. Towill Corporation
Ms. Andrea Wangler	Hawaiian Electric Company

B. COMMENTS ON THE SEIS PREPARATION NOTICE (NOP)

The SEIS Preparation Notice (NOP) was officially filed with the State Office Of Environmental Quality Control on July 16, 1986. Comments on the NOP were requested on or before August 22, 1986. All comments received up to October 5, 1986 were acknowledged. A total of 20 letters were received; 9 expressed "no comment" and therefore did not require a response. No letters were received by individuals requesting to be consulted parties. The following agencies, organizations and individuals received copies of the NOP; those identified with asterisks (*) responded; respondents with substantive comments are identified by double asterisks (**) and their comments are included in this section of the draft SEIS.

Federal

Advisory Council on Historic Preservation

U.S. Department of the Army
* Army Engineer District
Army Engineer Operations Branch

U.S. Department of Commerce
National Oceanic & Atmospheric Administration
** National Marine Fisheries Service, Western Program Office

U.S. Department of Energy

U.S. Department of the Interior
Environmental Protection Agency, Region IX
Environmental Services
** Fish & Wildlife Sevice
* Geological Survey

U.S. Department of Transportation

United States Coast Guard

State

Board of Directors, High Technology Development Corporation
Board of Directors, Natural Energy Laboratory of Hawaii
Department of Accounting & General Services
* Department of Budget and Finance
** Department of Health
** Department of Land & Natural Resources
* Department of Planning and Economic Development
* Department of Transportation
Office of Environmental Quality Control
University of Hawaii
** Environmental Center
Hawaii Institute of Marine Biology
** Hawaii Natural Energy Institute
J. K. K. Look Laboratory of Oceanographic Engineering
Pacific International Center For High Technology Research
Sea Grant Marine Advisory Program
* Water Resources Research Center

State Legislature

Senate

President
Senators, Island of Hawaii
Senate Committees
Economic Development
Energy
Finance
Tourism and Recreation

House of Representatives

Speaker
** Representatives, Island of Hawaii
House Committees
Finance
** Ocean & Marine Resources
Planning, Energy, Ecology and Environmental Protection
Water, Land Use, Development & Hawaiian Affairs

County of Hawaii

Mayor's Office
** County Council
Housing and Community Development Office
* Parks and Recreation
** Planning Department
* Public Works Department
Research and Development

Organizations and Individuals

Conservation Council, Hawaii Island
Construction Industry Legislative Organization, CILO
Mr. Gerald Cysewski, Cyanotech
Hawaii Audubon Society
Hawaii Electric Light Company (HELCO)
Hawaii Leeward Planning Conference
* Hawaiian Telephone Company
Mr. George Lockwood, Hawaiian Abalone Farms
** Mrs. Mae Mull, Hawaii Island Chapter, Hawaii Audubon Society
Dr. Edward K. Noda, Oceanographic Consultant
Sierra Club, Hawaii Chapter

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region • Western Pacific Program Office
2570 Dole St. • Honolulu, Hawaii 96822-2396

August 20, 1986 F/SWR1:JJN

The Natural Energy Laboratory of Hawaii
220 S. King Street, Suite 1280
Honolulu, Hawaii 96813

RECEIVED
AUG 25 1986
NELH

ATTENTION: Mr. Jack P. Huizingh, Executive Director

Gentlemen:

Subject: Environmental Assessment (EA) and Supplemental Impact Statement Preparation Notice - Development Plan For The Hawaii Ocean Science and Technology (HOST) Park and Proposed Expansion of the Natural Energy Laboratory of Hawaii (NELH) at Keahole, North Kona, Hawaii: Modification of Proposed Action To Permit Alternative Methods of Seawater Return Flow Disposal At NELH.

The National Marine Fisheries Service (NMFS) has received the subject Supplemental Impact Statement Preparation Notice and EA for the modification to the proposed action. We offer the following comments for your consideration in preparing the Supplemental Environmental Impact Statement (SEIS).

NMFS was involved in the development of the original EIS for the subject project, the final of which was accepted by the Governor in September 1985. We understand that, subsequently, the U.S. Department of Energy (DOE) learned that because of Federal budget cuts it would be unable to fund the proposed expansion of OTEC facilities at NELH to the level they had originally proposed. The mixed-water discharge pipe that was to be used to dispose of the 16,100 gpm of seawater that will be used in forthcoming OTEC experiments will not be funded. Alternative disposal methods for this seawater, including direct disposal via canal, trenches and deep injection wells (and/or a combination thereof), are being investigated.

NMFS concurs with your conclusion that the on-land disposal of OTEC seawater flows may have different impacts than those described in the accepted Final EIS. We understand that NELH is presently preparing a supplemental EIS for the purpose of assessing the environmental impacts of alternative methods of seawater return flow disposal. In addition, the cumulative impacts that could occur as a result of on-land disposal of seawater return flows from both OTEC experiments and future research, development and mariculture operations at NELH are also being reevaluated.

In our original comments on the Draft EIS (report dated August 21, 1985) one of our major concerns dealt with the possibility of on-land disposal of seawater. NMFS continues to feel that potential impacts from on-land disposal, via canal, trenches or deep injection wells, could have major adverse impacts on anchialine pond and neashore marine biota.

In conclusion, NMFS considers the evaluation of on-land disposal of seawater from OTEC experiments to be critical. Please refer to our original report on the project Final EIS for a more detailed description of our concerns. For further assistance in preparation of the Supplemental EIS, please contact Mr. John J. Naughton of my staff.

Sincerely yours,

Doyle E. Gates

Doyle E. Gates
Administrator

cc: F/SWR, Terminal Is., CA
F/M4, Washington, D.C.
EPA, Region 9, (P-5)
FWS, Honolulu
Corps of Engineers, Honolulu
Hawaii State Div. of Aquatic Resources
MCM Planning (Ms. Marilynn Metz)

The Natural Energy Laboratory of Hawaii

October 14, 1986

Mr. Doyle E. Gates, Administrator
U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii 96822-2396

Subj: Environmental Assessment and Supplemental EIS Notice of Preparation - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Mr. Gates:

Thank you for commenting on the subject NOP. Your concerns will be addressed in the draft SEIS. Mr. George Krasnick, biological oceanography consultant to the project, will be contacting Mr. Naughton for assistance in preparing his draft SEIS report.

We look forward to your comments on the dEIS.

Best regards,

Jack P. Huizingh
Executive Director

cc: MCM Planning

☐ 220 South King Street, Suite 1280 * Honolulu, HI 96813 * (808) 548-7017
☐ P.O. Box 1749 * Kailua-Kona, HI 96745 * (808) 329-7341

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
Room 6307

RECEIVED
AUG 25 1986
NELH

AUG 2 8 1986

Mr. Jack P. Huizingh, Executive Director
The Natural Energy Laboratory of Hawaii
220 South King Street, Suite 1280
Honolulu, Hawaii 96813

Re: Environmental Assessment and Supplemental Impact Statement Preparation Notice, Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at the Natural Energy Laboratory of Hawaii (NELH)

Dear Mr. Huizingh:

We have reviewed the Environmental Assessment (EA) and notice of preparation for the Supplemental Environmental Impact Statement (SEIS) and offer the following comments for your consideration.

General Comments

The SEIS is being prepared because the mixed-water discharge pipe that was proposed as a means to dispose the seawater from Ocean Thermal Energy Conversion (OTEC) experiments will not be funded by the Department of Energy. The SEIS will discuss alternative methods to dispose the seawater including direct disposal via a canal, trenches, deep lined injection wells, and/or a combination of these techniques.

Our primary concerns with the alternative methods of disposal of seawater from the NELH are the potential long-term adverse impacts to anchialine ponds and nearshore marine water quality and fishery resources from altered nutrient and salinity levels, and reduced temperatures.

Specific Comments

a. Page 21. Anchialine Ponds. We disagree with the statement that the anchialine ponds on the NELH site "are not considered biologically significant." The proposed development of numerous luxury resorts along the West Hawaii coastline may affect a substantial number of anchialine ponds and the cumulative loss of anchialine ponds may be significant. We strongly urge that potential impacts to anchialine ponds be a factor in selecting the disposal method.

b. The discussion of the proposed disposal methods should discuss the effects of lava tubes intercepting the flow field.

c. We support the additional analyses to determine an appropriate disposal method.

We appreciate the opportunity to comment.

Sincerely,

William R. Kramer

for Ernest Kosaka
Project Leader
Office of Environmental Services

cc: MCM Planning
CE, Operations Branch
NMFS - WPPO
EPA, San Francisco
DLNR

The Natural Energy Laboratory of Hawaii

October 13, 1986

Mr. Ernest Kosaka, Project Leader
Office of Environmental Services
U.S. Department of the Interior
Fish and Wildlife Service
P.O. Box 50167
Honolulu, Hawaii 96850

Subj: Environmental Assessment and Supplemental EIS Notice of Preparation - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Mr. Kosaka:

Thank you for commenting on the subject NOP. Your concerns will be addressed in the draft SEIS.

In response to your specific comments:

a. The anchialine ponds at NELH have been surveyed again as part of the preparation of the draft SEIS. Two of the three ponds are very small (120 sq. ft. and 220 sq. ft.) and shallow (2 feet deep at the deepest point at high tide). The third pond is larger (750 sq. ft.) and deeper (3 feet deep at its deepest at high tide). Only one of the smaller ponds supports a typical anchialine pond community. The draft SEIS will address the significance of these small, shallow ponds in relation to the cumulative effect of losing larger, more significant ponds to resort development. The ponds will not be dredged or filled and they will be monitored for a minimum ten years under the conditions of the CDUA permit issued by the Board of Land and Natural Resources for construction of the proposed offshore pipelines.

b. The effects of lava tubes intercepting the flow field will be addressed to the extent possible in the dSEIS.

We look forward to your comments on the dSEIS.

Best regards,

Jack P. Huizingh
Executive Director

cc: MCM Planning

☐ 220 South King Street, Suite 1280 * Honolulu, HI 96813 * (808) 548-7017
☐ P.O. Box 1749 * Kailua-Kona, HI 96745 * (808) 329-7341

GEORGE R. ARIYOSHI
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF HEALTH
P. O. BOX 3378
HONOLULU, HAWAII 96801

RECEIVED
AUG 2 1986
NELH

LESLIE S. MATSUBARA
DIRECTOR OF HEALTH

In reply, please refer to:
EPHSD

August 18, 1986

Mr. Jack P. Huizingh, Executive Director
The Natural Energy Laboratory of Hawaii
220 S. King St., Suite 1280
Honolulu, Hawaii 96813

Dear Mr. Huizingh:

Subject: Environmental Assessment and Supplemental Impact Statement Preparation Notice - Development Plan for The Hawaii Ocean Science & Technology (HOST) Park and Proposed Expansion of the Natural Energy Laboratory of Hawaii (NELH) at Keahole, North Kona, Hawaii: Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH

Thank you for allowing us to review and comment on the subject preparation notice.

The comments in our letter and memorandums dated April 25, 1985, August 21, 1985 and March 4, 1986 (all attached), still apply.

Sincerely,

for JAMES K. IKEDA
Deputy Director for
Environmental Health

Attachments

cc: DHO, Hawaii

7-3-43:33 ; Fr
7-3-43: 3, 4, 5

FILE COPY

April 25, 1985

Mr. William M. Bass, Jr.
Executive Director
High Technology Development Corporation
Central Pacific Plaza, Suite 252
220 S. King St.
Honolulu, Hawaii 96813

Dear Mr. Bass:

Subject: Environmental Impact Statement Preparation Notice - Development Plan for the Hawaii Ocean Science & Technology Park and Proposed Expansion of the Natural Energy Laboratory of Hawaii at Keahole, N. Kona, Hawaii

Subsequent to our letter dated April 22, 1985, the following additional comments were generated by our staff.

Surface Disposal of Wastewater

Aquatic developments, proposed by the H.O.S.T. Park, may be subject to one of the following NPDES regulations:

A. Aquaculture Projects

The EPA defines an aquaculture project as a managed water area in which "discharged pollutants" are used for the maintenance or production of harvestable freshwater, estuarine, or marine plants and animals. The State does not have delegation to issue this type of NPDES permit. Therefore, aquatic projects involving the use of wastewater sources would be directed to EPA.

B. Concentrated Aquatic Animal Production Facilities

A hatchery, fish farm, or other facility is a concentrated aquatic animal production facility if it contains, grows, or holds fish species or aquatic animals in ponds, raceways, or other similar structure which discharge at least 30 days per year. These operations are point sources subject to the State NPDES Program. Facilities that may be exempted from permit requirements include the following:

1. Cold Water Aquatic Animals (i.e., Salmon and Abalone):

   a. Facilities which produce less than 20,000 pounds harvest weight of aquatic animals per year; and

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b. Facilities which feed less than 5,000 pounds of food during the calendar month of maximum feeding.

2. Warm Water Aquatic Animals (i.e., Prawn, Shrimp and Catfish):

a. Closed ponds which discharge only during periods of excess runoff; or

b. Facilities which produce less than 100,000 pounds harvest weight of aquatic animals per year.

Specific permit requirements or exemptions will be reviewed by the Department on a case-by-case basis with respect to the water quality standards of the receiving water.

Subsurface Disposal of Wastewater

Even though the subject site is located in an area which has been designated as an exempted area under the Underground Injection Control (UIC) Program, the permitting of the injection wells will depend upon the quality and content of the wastes. If the wastestream will contain industrial wastes, close scrutiny will be required to assure that the wastes are not hazardous in accordance with 40 CFR 261. The disposal of wastes of this nature would result in the classification of the injection wells as Class IV wells which are prohibited under the State UIC Program.

This condition is also applicable to any individual disposal systems which may be proposed by the tenants.

Sincerely,

Melvin K. Koizumi

MELVIN K. KOIZUMI
Deputy Director for
Environmental Health

cc: DHSA, Hawaii

FILE COPY

August 21, 1985

MEMORANDUM

To: Ms. Letitia N. Uyehara, Director
Office of Environmental Quality Control

From: Deputy Director for Environmental Health

Subject: Draft Environmental Impact Statement (EIS) - Development Plan for Hawaii Ocean Science & Technology Park and Proposed Expansion of Natural Energy Laboratory of Hawaii, Keahole, North Kona, Hawaii

Thank you for allowing us to review and comment on the subject draft EIS. We provide the following comments.

Shellfish Sanitation

Shellfish sanitation requirements need to be addressed for the applicable type of aquaculture projects. They should comply with Chapter 35 of Title 11, Administrative Rules, Department of Health.

Surface Disposal of Wastewater

Aquatic developments, proposed by the H.O.S.T. Park, may be subject to one of the following NPDES regulations:

A. Aquaculture Projects

The EPA defines an aquaculture project as a managed water area in which "discharged pollutants" are used for the maintenance or production of harvestable freshwater, estuarine, or marine plants and animals. The State does not have delegation to issue this type of NPDES permit. Therefore, aquatic projects involving the use of wastewater sources would be directed to EPA.

B. Concentrated Aquatic Animal Production Facilities

A hatchery, fish farm, or other facility is a concentrated aquatic animal production facility if it contains, grows, or holds fish species or aquatic animals in ponds, raceways, or other similar structure which discharge at least 30 days per year. These operations are point sources subject to the State NPDES Program. Facilities that may be exempted from permit requirements include the following:

1. Cold Water Aquatic Animals (i.e., Salmon and Abalone):

   a. Facilities which produce less than 20,000 pounds harvest weight of aquatic animals per year; and

   b. Facilities which feed less than 5,000 pounds of food during the calendar month of maximum feeding.

2. Warm Water Aquatic Animals (i.e., Prawn, Shrimp and Catfish):

   a. Closed ponds which discharge only during periods of excess runoff; or

   b. Facilities which produce less than 100,000 pounds harvest weight of aquatic animals per year.

Specific permit requirements or exemptions will be reviewed by the Department on a case-by-case basis with respect to the water quality standards of the receiving water.

Subsurface Disposal of Wastewater

Even though the subject site is located in an area which has been designated as an exempted area under the Underground Injection Control (UIC) Program, the permitting of the injection wells will depend upon the quality and content of the wastes. If the wastestream will contain industrial wastes, close scrutiny will be required to assure that the wastes are not hazardous in accordance with 40 CFR 261. The disposal of wastes of this nature would result in the classification of the injection wells as Class IV wells which are prohibited under the State UIC Program.

This condition is also applicable to any individual disposal systems which may be proposed by the tenants.

Proposed Ocean Outfall

The proposed mixed-seawater (wastewater) discharge of 16,000 gpm (23 MGD) for the forthcoming OTEC experiments at NELH is subject to the above-mentioned surface disposal requirements. If the ocean outfall disposal is selected over on-land disposal for the full development flow of 183 MGD (HOST Park 144 MGD and NELH 39 MGD), these will also be subjected to the surface disposal requirements.

In accordance with the Administrative Rules (AR), of the Department of Health, Title 11, Chapter 54, Water Quality Standards, the receiving water is classified as Class AA, which requires that these waters remain in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration by human activity. The beneficial uses shall be protected so in the strict interpretation and intent of the Ar, no construction activity and disposal are desirable in Class AA waters.

Proposed On-Land Disposal

The on-land disposal of shallow surface trench and deep injection wells are being considered. Either on-land disposal method will affect the existing nature of the anchialine ponds which will violate conformance to the basic water quality criteria applicable to all waters as contained in Section 11-54-04. According to the draft EIS, it was noted the anchialine ponds are "not of high natural value," which should be further addressed such as a comparison to other anchialine ponds in the vicinity.

At the Waikoloa Resort Development, artificially created anchialine ponds are being considered because of the proposed development and degradation of some of the existing anchialine ponds due to destructive human intrusion. As part of this consideration, very intense long-term bio-monitoring of the anchialine pond biota is proposed.

Another concern is the "leakage" of the harmful prophylactics for the control of disease that may be used in aquatic rearing facilities and the domestic sewerage that may enter the anchialine ponds. Pretreatment of some sort should be considered when necessary for each individual wastestream (prior to commingling), aside from dilution.

Class AA Water Status

For the waters along the NELH and HOST Park to remain a Class AA water and pristine for aquatic rearing purposes, it is recommended that stringent controls be developed, imposed and enforced on the tenants.

Please address air, water, solid wastes and sewage control commitments in the construction plans. We reserve the right to impose future environmental restrictions on the project at the time final plans are submitted to this office for review.

Melvin K. Koizumi

MELVIN K. KOIZUMI

cc: Mr. William M. Bass, Jr.
Ms. Marilynn C. Metz

COPY

March 4, 1986

MEMORANDUM

To: The Honorable Susumu Ono, Chairperson
Board of Land and Natural Resources

From: Director of Health

Subject: Conservation District Use Application & Final EIS
File No: HA-1/24/86-1862
Request: Hawaii Ocean Sciences & Technology Park, Keahole, Hawaii

The High Technology Development Corporation (HTDC) letter (item No. 4) of August 29, 1985, in response to a memorandum to the Office of Environmental Quality Control (OEQC) from the Department dated August 21, 1985, indicates that a Zone of Mixing (ZOM) is not required. It should be emphasized that a ZOM is not required, if the effluent water quality (WQ) meets both the basic WQ criteria and the specific WQ criteria for open coastal waters for Class AA waters. It appears that the specific WQ criteria is not mentioned in the EIS. The Administrative Rules (AR), Title 11, Chapter 54, Water Quality Standards, Section 11-54-06(b)(3) contains the specific WQ criteria.

Unless stringent controls are applied to the effluent WQ and treatment requirements, degradation will come to the point where the intake water may not be pristine enough to serve as rearing media for the aquatic facilities.

Please be informed that we have no objections to granting the permit.

LESLIE S. MATSUBARA

cc: OEQC
High Technology Dev. Corp.

The Natural Energy Laboratory of Hawaii

October 14, 1986

Mr. James K. Ikeda
Deputy Director for Environmental Health
State Department of Health
P.O. Box 3378
Honolulu, Hawaii 96801

Subj: Environmental Assessment and Supplemental Notice of Preparation Notice - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Mr. Ikeda:

Thank you for commenting on the subject NOP. Comments from your letters of April 25, 1985, August 21, 1985 and March 4, 1986 will be addressed in the dSEIS.

We look forward to your comments on the draft SEIS.

Best regards,

Jack P. Huizingh

Jack P. Huizingh
Executive Director

cc: MCM Planning

☐ 220 South King Street, Suite 1280 * Honolulu, HI 96813 * (808) 548-7017
☐ P.O. Box 1749 * Kailua-Kona, HI 96745 * (808) 329-7341

GEORGE R. ARIYOSHI
GOVERNOR OF HAWAII

RECEIVED
SEP 2 1986
NELH

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

SEP 19 1986

DOCUMENT NO.: 1707B

Mr. Jack P. Huizingh, Executive Director
The Natural Energy Laboratory of Hawaii
220 South King Street, Suite 1280
Honolulu, Hawaii 96813

Dear Mr. Huizingh:

SUBJECT: Environmental Assessment and Supplemental Impact Statement Preparation Notice-Development Plan For the Hawaii Ocean Science & Technology (HOST) Park and Proposed Expansion of the Natural Energy Laboratory of Hawaii (NELH) at Keahole, North Kona, Hawaii: Modification of Proposed Plan Action To Permit Alternative Methods of Seawater Return Flow Disposal At NELH

We have completed our review of the subject document and offer the following comments:

As the EA notes (p. 17), NELH is working with this Department on an archaeological mitigation plan to preserve sites and protect others until archaeological data recovery can occur. We will soon be providing NELH with details for data recovery. NELH has already agreed to preservation of specific sites. The EA notes that the plan will be in the Draft EIS. This action is acceptable for our concerns.

There are no public park concerns but environmental impacts on public use of the shoreline area should be addressed. Impacts on public use of nearshore and offshore waters could be of particular concern.

The initial proposal called for disposal of 16,100 gpm of seawater return flow by a mixed-water (warm and cold) discharge pipe in offshore areas. Budget cuts have since forced consideration of alternate seawater disposal methods, including direct disposal by canal, trenches, deep injection wells and/or a combination thereof. The disposal method chosen must not degrade the intake water vital to the facility operation.

Our concern is for the protection of groundwater resources. Although no adverse impacts are expected (page 21, item B), monitoring of the onland disposal seawater to assess the impact to groundwater should be included as it was in the Final EIS for the project.

We appreciate the opportunity to comment on your document. Should you have any questions, feel free to contact our Office of Conservation and Environmental Affairs at 548-7837.

Very truly yours,

SUSUMU ONO, Chairperson
Board of Land and Natural Resources

cc: OEQC
MCM Planning
P.O. Box 27506
Honolulu, Hawaii 96827
Attention: Ms. Marilynn C. Metz

The Natural Energy Laboratory of Hawaii

October 14, 1986

Mr. Susumu Ono, Chairperson
Board of Land Natural Resources
P.O. Box 621
Honolulu, Hawaii 96809

Subj: Environmental Assessment and Supplemental EIS Notice of Preparation - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Mr. Ono:

Thank you for commenting on the subject NOP. In response to your specific concerns:

a. Impacts on public use of the affected shoreline will be addressed in the draft supplemental statement.

b. Monitoring of onland disposal seawater to assess the impact to groundwater will be a recommended mitigating measure in the draft statement. In addition, a regional offshore monitoring program is also being proposed.

We look forward to your comments on the dEIS.

Best regards,

Jack P. Huizingh
Executive Director

cc: MCM Planning

☐ 220 South King Street, Suite 1280 * Honolulu, HI 96813 * (808) 548-7017
☐ P.O. Box 1749 * Kailua-Kona, HI 96745 * (808) 329-7341

Ø

University of Hawaii at Manoa

Environmental Center
Crawford 317 • 2550 Campus Road
Honolulu, Hawaii 96822
Telephone (808) 948-7361

RECEIVED
AUG 25 1986
NELH

August 21, 1986
PN:0048

Mr. Jack P. Huizingh
The Natural Energy Laboratory of Hawaii
220 South King Street, Suite 1280
Honolulu, Hawaii 96813

Dear Mr. Huizingh

Environmental Assessment / Supplemental Impact Statement
Preparation Notice
HOST and NELH
Keahole, North Kona, Hawaii

The above cited document outlines the potential environmental impacts to be discussed in the supplemental EIS being prepared to address alternative methods of seawater return flow disposal at the Natural Energy Laboratory of Hawaii, Keahole Point, Hawaii. This review was prepared with the assistance of Keith Chave, Oceanography; Frank Peterson, Geology; and Walington Yee, Environmental Center.

In general the document is an excellent example of scholarly work that clearly outlines and succinctly addresses the major issues that will be encountered by the proposed project. The drafters of this Environmental Assessment/Preparation Notice should be commended for a job well done. We offer the following comments for your use in developing the draft supplemental EIS.

It is proposed that the SEIS will have a comprehensive evaluation of the various waste disposal alternatives so as to assure non-contamination of the intake water supplies to NELH or HOST operations. In this discussion, consideration should be given to the possiblity of clogging problems either in drainage ditches or injection wells. The dimensions and physical characteristics of the proposed disposal trenches should be fully explained in the text and appropriate dimensional and geographical illustrations provided to assure that the reader of the SEIS will fully understand what is being proposed and where it will reside. For example, the lining of the trenches, if any, should be indicated. If lining is not anticipated then the potential seepage effects of the effluent on the nearshore coastal environment should be discussed in the SEIS. Biological clean-up of nutrients in the waste effluent should be systematically evaluated along with the other methods of disposal.

With regard to closed-cycle seawater discharge (p.8) it is stated that trace metals in the discharge would decrease rapidly as the metal becomes acclimated to the environment. The data on which this statement is based should be referenced in the document.

The list of candidate species (p. 9) contains a number of organisms incorrectly listed under the "Crustaceans" heading. Oysters (Crassostrea, (note spelling correction) Ostrea) Abalone, Opihi, Giant Clams (Tridacna) and Scallops, should be listed under a general "Mollusca" heading.

On page 15 para. 6, lines 4-5 it is incorrectly stated that Kiholo and Puako are several miles south of Keahole. They are north.

The anchialine ponds on the NELH site are said to have no biological significance. However, since so many of the existing ponds along the Kona coast have been destroyed, can the Keahole ponds still be considered of little biological significance?

We appreciate the opportunity to comment on this document and look forward to reviewing the draft supplemental EIS when it is completed.

Yours truly,

Jacquelin N. Miller
Acting Associate Director

cc: Patrick Takahashi
MCM Planning
OEQC
Keith Chave
Frank Peterson
Walington Yee

The Natural Energy Laboratory of Hawaii

October 14, 1986

Ms. Jacquelin N. Miller
Acting Associate Director
Environmental Center
University of Hawaii at Manoa
Crawford 317
2550 Campus Road
Honolulu, Hawaii 96822

Subj: Environmental Assessment and Supplemental EIS Notice of Preparation - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Jackie:

Thank you for the compliments on the subject NOP. In response to your specific concerns:

a. The possibility of clogging problems will be addressed in the dSEIS. The dimensions and locations of the various disposal facilities will be described in the document. It is not anticipated that the trenches will be lined, therefore, the seepage effects of the seawater on the nearshore coastal environment is discussed. Biological cleanup of nutrients will also be addressed.

b. The rapid decrease of trace metals in the discharge will be documented in the dSEIS.

c. The list of candidate species has been corrected as you suggest.

d. We are aware that Kiholo and Puako are north, however, the word processor keeps forgetting. We will correct it again and hope that this time it stays corrected. Thanks for pointing the error out to us.

e. The anchialine ponds at NELH have been surveyed again as part of the preparation of the dSEIS. Two of the three ponds are very small (120 sq. ft. and 220 sq. ft.) and shallow (2 feet deep at the deepest point at high tide). The third pond is larger (750 sq. ft.) and deeper (3 feet deep at its deepest at high tide). Only one of the smaller ponds supports a typical anchialine pond community. The draft SEIS will address the significance of these small, shallow ponds in relation to the cumulative effect of losing larger, more

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☐ P.O. Box 1749 * Kailua-Kona, HI 96745 * (808) 329-7341

significant ponds to resort development. The ponds will not be dredged or filled and they will be monitored for a minimum ten years under the conditions of the CDUA permit issued by the Board of Land and Natural Resources for construction of the proposed offshore pipelines.

We look forward to your comments on the draft SEIS.

Best regards,

Jack

Jack P. Huizingh
Executive Director

cc: MCM Planning

File

RECEIVED

AUG 1 1986

NELH

University of Hawaii at Manoa

Hawaii Natural Energy Institute
Holmes Hall 246 • 2540 Dole Street • Honolulu, Hawaii 96822

August 6, 1986

The Natural Energy Laboratory of Hawaii
220 S. King Street, Suite 1280
Honolulu, Hawaii 96813
Attention: Mr. Jack P. Huizingh, Executive Director

Dear Mr. Huizingh:

As requested by your letter of July 23, 1986, I have reviewed the Development Plan for The Hawaii Ocean Science and Technology (HOST) Park and Expansion of the Natural Energy Laboratory of Hawaii (NELH) dated July 1986.

This document is in accord with the facts known to me at this time, with the addition to paragraph 3.0 Open-Cycle OTEC Research of the following sentences on page 8. "These tests lead to the integration of the acquired information into a system which produces electrical energy and fresh water. This integration will be attempted in an Open Cycle OTEC test of about 200 KW output at the NELH.

I have retained the copy of the draft document as it contains much information about the NELH in a concise authoritative format.

Sincerely,

E C Higgins

E. Chipman Higgins

Hope this is helpful, Kip

ECH:sm

cc: Patrick K. Takahashi
MCM Planning

The Natural Energy Laboratory of Hawaii

August 21, 1986

Mr. Chipman Higgins
Hawaii Natural Energy Institute
University of Hawaii
Holmes Hall 246
2540 Dole Street
Honolulu, Hawaii 96822

Subj: Environmental Assessment and Supplemental EIS Preparation Notice - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Mr. Higgins:

Thank you for commenting on the subject preparation notice. Your suggested addition to paragraph 3.0 will be incorporated into the draft EIS. We are looking forward to your comments on the draft EIS.

Best regards,

Jack P. Huizingh
Executive Director

☐ 220 South King Street, Suite 1280 * Honolulu, HI 96813 * (808) 548-7017
☐ P.O. Box 1749 * Kailua-Kona, HI 96745 * (808) 329-7341

HOUSE OF REPRESENTATIVES
STATE OF HAWAII
STATE CAPITOL
HONOLULU, HAWAII 96813

RECEIVED
JUL 2_ 1986
NEL

July 25, 1986

Mr. Jack Huizingh
The Natural Energy Laboratory of Hawaii
220 South King Street, Suite 1280
Honolulu, Hawaii 96813

Dear Mr. Huizingh:

I acknowledge receipt of your letter dated July 23, 1986, regarding alternative methods of seawater return flow disposal.

Please be assured that if I have any comments - it will be sent to you prior to your August 22, 1986 deadline.

I also want to thank you for sending me a copy of your "Environmental Assessment and Notice of Preparation of Supplemental Environmental Impact Statement: Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH".

With warm personal regards.

Sincerely,

WAYNE METCALF
Hawaii State Representative
Third District

WM:to

The Natural Energy Laboratory of Hawaii

August 21, 1986

The Honorable Wayne Metcalf
Room 325
State Capitol
Honolulu, Hawaii 96813

Subj: Environmental Assessment and Supplemental EIS Preparation Notice - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Representative Metcalf:

Thank you for your letter concerning the subject preparation notice. We look forward to your comments on the preparation notice and on the forthcoming draft EIS. We will send you a copy of the draft EIS when it is available.

Best regards,

Jack P. Huizingh
Executive Director

☐ 220 South King Street, Suite 1280 * Honolulu, HI 96813 * (808) 548-7017
☐ P.O. Box 1749 * Kailua-Kona, HI 96745 * (808) 329-7341

HOUSE OF REPRESENTATIVES
STATE OF HAWAII
STATE CAPITOL
HONOLULU, HAWAII 96813

RECEIVED
AUG 05 1986
NELH

July 31, 1986

5431p

The Natural Energy Laboratory of Hawaii
220 South King Street, Suite 1280
Honolulu, HI 96813
Attn: Mr. Jack Huizingh

Dear Mr. Huizingh:

Thank you for the opportunity to comment on the environmental assessment and preparation notice entitled: Development Plan for the Hawaii Ocean Science and Technology (HOST) Park and Expansion of the Natural Energy Laboratory of Hawaii (NELH). I would appreciate it if the final environmental impact statement addresses the following questions:

(1) Discharges from the existing OTEC experiments and the Hawaiian Abalone Farm are currently being disposed of via a canal and two injection wells respectively. Since both disposal methods are among the alternatives under consideration, has NELH developed data on the impact of the various discharges on the brackish water lens and the open ocean that can be applied to the planned changes?

(2) When fully developed, discharges from the OTEC experiments and mariculture projects may contain a wide variety of chemicals and particulates. Have the specific types of projects already been determined? If not, on what basis can the quality of the discharges be discussed with any accuracy?

(3) According to the environmental assessment (p. 21), there are three anchialine ponds on the NELH site that would be impacted by the disposal of discharge from injection wells and trench. Are there additional anchialine ponds near the NELH site that may also be affected by such disposal methods?

I look forward to reviewing the environmental impact statement on this project.

Sincerely,

PETER APO
Chairman
Committee on Ocean and Marine Resources

cc: MCM Planning

The Natural Energy Laboratory of Hawaii

August 26, 1986

The Honorable Peter Apo, Chairman
Committee on Ocean and Marine Resources
State of Hawaii
State Capitol, Room 439
Honolulu, Hawaii 96813

Subj: Environmental Assessment and Supplemental EIS Preparation Notice - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Representative Apo:

We appreciate your careful review of the subject preparation notice. In response to your specific comments:

1. NELH has a continuing water quality program that monitors the canal and nearshore waters. Several intensive studies have also been made which indicate no adverse affects from the canal system. The studies that are being conducted in conjunction with the supplemental EIS will address the effects on the environment of increasing the seawater return flows by a substantial factor.
2. There is general agreement on the types of projects (both OTEC and mariculture) that will likely locate at NELH. The environmental impact analysis will attempt to characterize and project the effects of various chemicals and other substances that are used in these projects and their impact on the biological resources of the area. Acceptance of projects at NELH also requires the users to inform the Board and staff of the environmental aspects of their operations. In some cases, and, because NELH is a research and development facility, there are unknowns associated with each new project. Continuation and expansion of the existing monitoring program will be an important component of the disposal system(s) selected. The purity of the source waters is vitally important to the success and future of NELH.
3. NELH has 3 anchialine ponds located on its property in the northern portion past the end of the jeep trail. Although experts have stated that the ponds on the NELH site are biologically insignificant, they will be monitored as a condition of the recently approved CDUA for the project. The draft EIS will discuss the anchialine ponds in the area and identify those that might be affected by this project.

Thank you for your informed and perceptive comments on the subject NOP. We will address your concerns in the draft EIS and look forward to your comments at that time.

Best regards,

Jack

Jack P. Huizingh
Executive Director

☐ 220 South King Street, Suite 1280 * Honolulu, HI 96813 * (808) 548-7017
☐ P.O. Box 1749 * Kailua-Kona, HI 96745 * (808) 329-7341

STEPHEN K. YAMASHIRO
Chairman & Presiding Officer
SPENCER KALANI SCHUTTE
Vice Chairman

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AUG 0 . 1986
NEI H

JAMES L. K. DAHLBERG
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LORRAINE R. JITCHAKU-INOUYE
RUSSELL S. KOKUBUN
MERLE K. LAI
Council Members

COUNTY COUNCIL
County of Hawaii
Hawaii County Building
25 Aupuni Street
Hilo, Hawaii 96720

August 5, 1986

In Reply Refer To: C-705

Mr. Jack P. Huizingh, Executive Director
The Natural Energy Laboratory of Hawaii
220 South King Street, Suite 1280
Honolulu, Hawaii 96813

Dear Mr. Huizingh:

Thank you for your letter of July 23, 1986, informing us as to the status of the Seawater Return Flow Disposal project.

Please be informed that your communication has been referred to the Council's Committee on Economic Development, and will be discussed at its meeting on Tuesday, August 12, 1986, at the Honokaa District Courthouse.

We will provide assistance in the preparation of the supplemental EIS as requested and whenever possible.

Very truly yours,

Stephen K. Yamashiro
COUNCIL CHAIRMAN

The Natural Energy Laboratory of Hawaii

August 21, 1986

Mr. Stephen K. Yamashiro, Chairman
Hawaii County Council
25 Aupuni Street
Hilo, Hawaii 96720

Subj: Environmental Assessment and Supplemental EIS Preparation Notice - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Mr. Yamashiro:

Thank you for your letter concerning the subject preparation notice. We look forward to comments from the Committee on Economic Development. We hope that you will also review the forthcoming draft EIS. A copy will be sent to you when it becomes available.

Best regards,

Jack P. Huizingh
Executive Director

☐ 220 South King Street, Suite 1280 * Honolulu, HI 96813 * (808) 548-7017
☐ P.O. Box 1749 * Kailua-Kona, HI 96745 * (808) 329-7341

COUNTY OF HAWAII

PLANNING DEPARTMENT

25 AUPUNI STREET • HILO, HAWAII 96720
(808) 961-8288

DANTE K. CARPENTER
Mayor

ALBERT LONO LYMAN
Director

ILIMA A. PIIANAIA
Deputy Director

RECEIVED
AUG 13 1986
NELH

August 7, 1986

Mr. Jack P. Huizingh
Executive Director
The Natural Energy Laboratory
of Hawaii
220 South King Street, Suite 1280
Honolulu, HI 96813

Dear Mr. Huizingh:

Environmental Assessment and Supplemental Impact Statement Preparation Notice - Modification of Proposed Action To Permit Alternative Methods of Seawater Return Flow Disposal at NELH

Thank you for the opportunity to review the Environmental Assessment and Supplemental Environmental Impact Statement (EIS) Preparation Notice for the above-captioned matter.

According to the Preparation Notice, a Supplemental EIS is being drafted to evaluate on-land discharge scenarios since Federal funding for the construction of the mixed-water discharge pipe to dispose of the anticipated 16,100 gpm (23 mgd) of seawater is not available. Alternative disposal methods for this seawater, including direct disposal via canal, trenches, and deep injection well are being investigated.

It appears that the assessment on environmental impacts of alternative methods of seawater return flow disposal has already been discussed in Appendix C (Technical Evaluation of Seawater Return Flow and Wastewater Disposal Systems at NELH/HOST Park, Danes & Moore, June 1985) of the Final EIS for the Development Plan for the Hawaii Ocean Science and Technology Park and Expansion of the Natural Energy Laboratory of Hawaii. We therefore question the need to prepare a Supplemental EIS.

Enclosed for your information are comments from the County of Hawaii Department of Public Works.

Sincerely,

ALBERT LONO LYMAN
Planning Director

NH:aeb

enclosure

cc: MCM Planning
P. O. Box 27506
Honolulu, HI 96827
Attn: Ms. Marilyn C. Metz

DEPARTMENT OF PUBLIC WORKS
COUNTY OF HAWAII
HILO, HAWAII

Memorandum

DATE July 31, 1986

RECEIVED
AUG 1 3 1986
NELH

TO : Planning Department

FROM : Chief Engineer

SUBJECT: Environmental Assessment and Supplemental Impact Statement Preparation Notice
Development Plan for HOST and Proposed Expansion of NELH
Keahole, N. Kona, Hawaii

We have reviewed the subject document and our comments are as follows:

The alternative disposal method whether canal, trench or injection well shall not be located within the road right-of-way.

HUGH Y. ONO
Chief Engineer

961-8321

DHM/acs

The Natural Energy Laboratory of Hawaii

October 14, 1986

Mr. Albert Lono Lyman, Director
Hawaii County Planning Department
25 Aupuni Street
Hilo, Hawaii 96720

Subj: Environmental Assessment and Supplemental EIS Notice of Preparation - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Mr. Lyman:

Thank you for commenting on the subject NOP. The SEIS is being written because the on-land disposal of OTEC water was not discussed in the previous EIS. In response to the concerns of the Department of Public Works, disposal facilities will not be located in the road right-of-way.

We look forward to your review of the draft SEIS.

Best regards,

Jack P. Huizingh
Executive Director

cc: MCM Planning

☐ 220 South King Street, Suite 1280 * Honolulu, HI 96813 * (808) 548-7017
☐ P.O. Box 1749 * Kailua-Kona, HI 96745 * (808) 329-7341

For the Protection of Hawaii's Native Wildlife

HAWAII AUDUBON SOCIETY

P.O. BOX 22832
HONOLULU, HAWAII 96822

P. O. Box 275
Volcano, HI 96785

August 22, 1986

RECEIVED
AUG 25 1986
NELH

The Natural Energy Laboratory of Hawaii
220 S. King Street, Suite 1280
Honolulu, HI 96813
Attention: Mr. Jack P. Huizingh, Executive Director

Dear Mr. Huizingh:

Thank you for sending me the Environmental Assessment and Supplemental Impact Statement Preparation Notice — Development Plan for the Hawaii Ocean Science 7 Technology (HOST) Park and Proposed Expansion of the Natural Energy Laboratory of Hawaii (NELH) at Keahole, North Kona, Hawaii: Modification of Proposed Action to permit Alternative Methods of Seawater Return Flow Dispersal at NELH.

The concerns of the Hawaii Audubon Society focus on adverse impacts on native terrestrial and aquatic habitats from the several proposed alternative projects.

In particular, the Society will be looking for evaluations of potential damage to the following elements from the alternative systems for disposing of ocean water discharges from OTEC experiments and mariculture processes: damage to strand vegetation communities, damage to marine biota, damage to Hawaiian Stilt and Hawaiian Owl habitat, damage to ground water quality and to offshore water quality.

Thank you for the opportunity to make these comments.

Sincerely yours,

Mae E. Mull

Mae E. Mull
Member, BoaRD OF Directors and
Island of Hawaii Representative

The Natural Energy Laboratory of Hawaii

October 14, 1986

Mrs. Mae Mull
Hawaii Island Representative
Hawaii Audubon Society
Volcano, Hawaii 96785

Subj: Environmental Assessment and Supplemental EIS Notice of Preparation - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Mrs. Mull:

Thank you for commenting on the subject NOP. Damage to strand vegetation communities and Hawaiian Stilt and Hawaian Owl habitat were addressed in the previous EIS which was accepted by the Governor on September 20, 1985. Damage to marine biota, ground water quality and offshore water quality will be addressed in the draft SEIS.

We look forward to your review of the draft SEIS.

Best regards,

Jack P. Huizingh
Executive Director

cc: MCM Planning

☐ 220 South King Street, Suite 1280 * Honolulu, HI 96813 * (808) 548-7017
☐ P.O. Box 1749 * Kailua-Kona, HI 96745 * (808) 329-7341

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APPENDIX A

DISPOSAL OF OPEN CYCLE OCEAN ENERGY
CONVERSION WATER "VIA CANAL"

OCEANIT LABORATORIES, INC.

A P P E N D I X   A

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Oceanit Laboratories, Inc.
coastal & offshore engineering services • research & development

Disposal of Open-Cycle Ocean Thermal Energy Conversion (OC OTEC) Water "Via Canal" at the Natural Energy Laboratory of Hawaii (NELH) Keahole Point, Hawaii

November 1986

revision: 02-20-87

Century Square 1188 Bishop Street, Suite 1801, Honolulu, Hawaii 96813
TELEX: 7431404 MCI: OCEANIT Ph: (808) 531-3017

EXECUTIVE SUMMARY

Direct disposal of open-cycle Ocean Thermal Energy Conversion (OC OTEC) water, up to 16,000 gallons per minute (gpm), "via canal" at the Natural Energy Laboratory of Hawaii (NELH) will not affect the warm seawater intake system during most environmental conditions. However, when there is no longshore current other than tidal and currents flow in the ebb direction, i.e., towards the warm seawater intake, the materials discharged may compromise the water quality at the warm seawater intake by increasing nutrient levels and decreasing dissolved oxygen levels by a few percent from normal ambient levels. This change could interfere with controls on existing experiments that rely on the quality of the warm seawater.

In the event that heat exchangers are used for producing fresh water, no significant impact is expected from the discharged metallic ions resulting from heat exchanger corrosion. Furthermore, the small amounts of fresh water produced, and the resulting salinity changes, are not expected to have a significant impact on the marine receiving waters. In the event that chlorination is required to control biofouling, no significant impact is expected so long as the concentrations are kept below the current levels of chlorination for the

closed-cycle research projects, i.e., 0.1 ppm (parts per million) for one hour per day.

Nutrients in OTEC discharge are expected to be greater than those found in the receiving warm seawater environment. If we treat the nutrients as a conservative property, a worst-case scenario, we find that during ebb current conditions, without influences from other currents, the concentration of nitrogen could be relatively high and could act to increase the rates of biofouling. Although the nutrient concentrations found at the warm seawater intake, resulting from OC OTEC discharge, would be less than values calculated with our computer model, due to consumption, it would be prudent to investigate cause and effect relationships occurring as a result of discharge at this tidal current condition before discounting the potential impacts on the warm seawater intake.

Furthermore, changes in water quality resulting from degassing OC OTEC water would additionally increase the concentration of available nutrients and organic carbon in the discharge above that previously calculated -- due to lysing (disintegration of bacteria, plankton, etc.). This could result in a significant change in water chemistry, i.e., decrease in dissolved oxygen.

In general, as long as there is either a northward or southward current, as normally occurs, discharge "via canal" is acceptable for existing OTEC research projects at NELH. The discharge should not influence the water quality at the warm seawater intake. However, under an ebb tide condition, with no external currents, it is recommended that disposal of OC OTEC water occur in another manner until more detailed investigations provide additional information.

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I. INTRODUCTION

The Natural Energy Laboratory of Hawaii (NELH) is located at Keahole Point on the most western point of the island of Hawaii, illustrated in Figure I-1. It provides an excellent environment for conducting ocean-related research such as Ocean Energy Thermal Conversion (OTEC) and aquaculture.

Under the existing National Pollutant Discharge Elimination System (NPDES), Permit No. HI 0020893, discharges from OTEC research of up to 1500 gpm are acceptable. Currently, NELH discharges approximately 1000 gpm of mixed warm seawater, pumped from approximately 303 feet offshore at a depth of 45 feet, and cold deep seawater, pumped from approximately 2100 feet deep. The mixtures range from 1:1 to 1:6 depending on the demand from the experiments.

In anticipation of increased open-cycle (OC) OTEC research, discharge is expected to increase to 16,000 gpm with approximately 6,500 gpm deep-cold and 9,500 surface-warm seawater.

Oceanit Laboratories, Inc. (hereinafter "OLI") was contacted to investigate increasing the discharge "via canal" from 1000 gpm to 16,000 gpm. Results and findings are to be included in a supplemental environmental impact statement (EIS).

The specific considerations addressed in our study include the following:

1) Describe the effect on water quality from OC OTEC research on the warm seawater intake.
2) Provide a general computer model to simulate discharge of OTEC water at the shore -- "via canal".
3) Assess the influence on NELH's warm seawater intake from a potential 165 kw OC OTEC facility, discharging approximately 16,000 gpm "via canal".

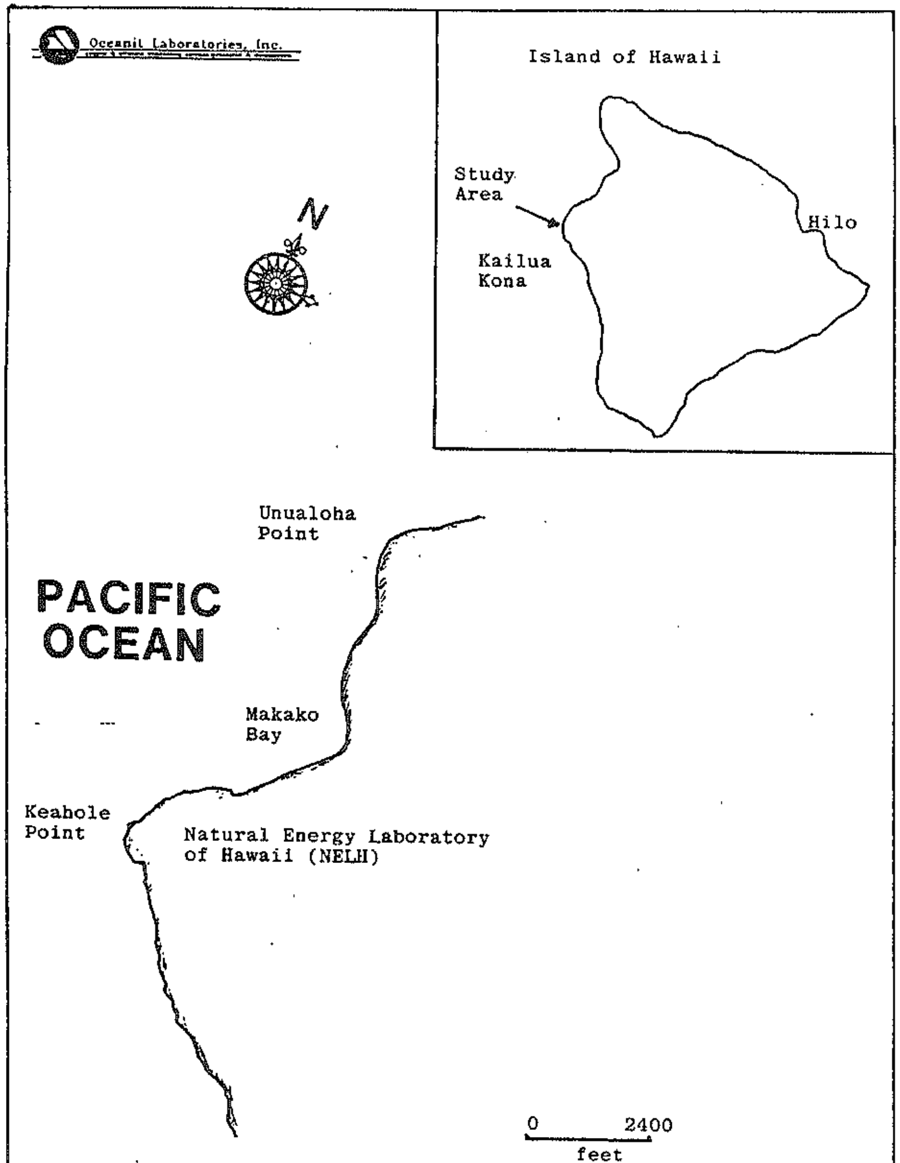


Fig. I-1 Location of study site, Keahole Point, Hawaii.

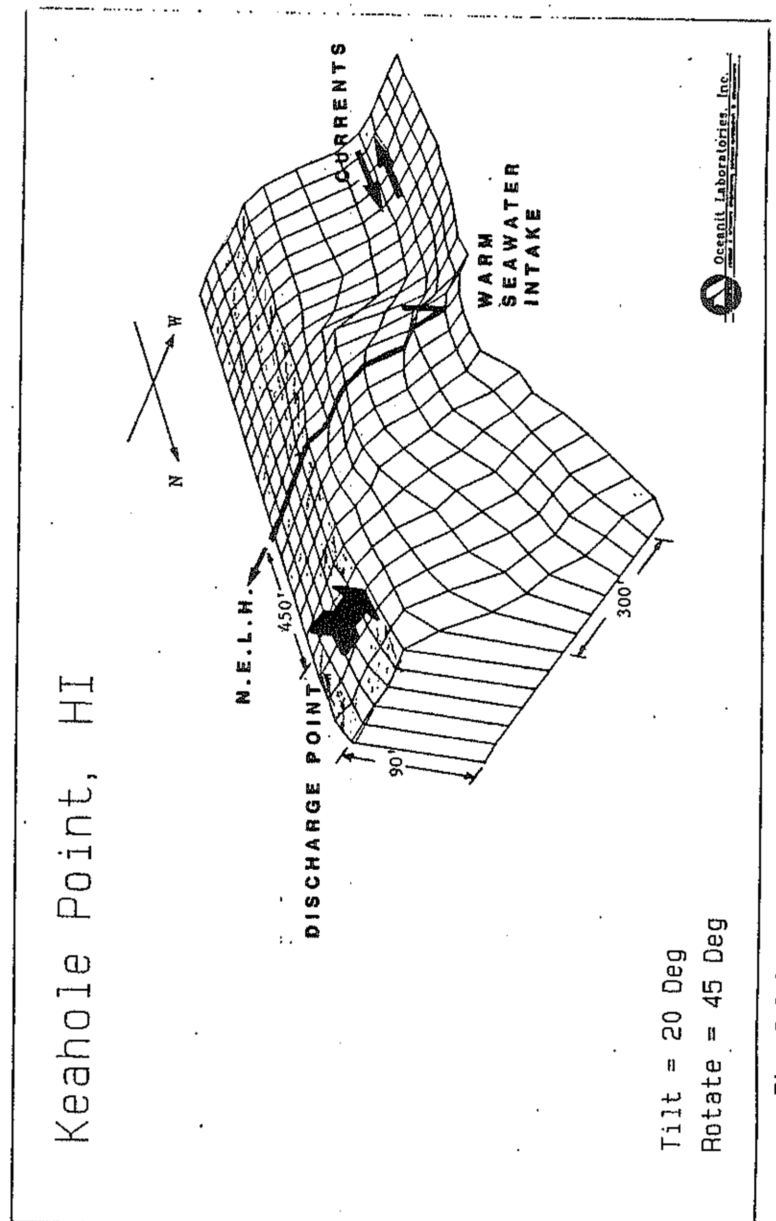


Fig. I-2 3-D representation of Keahole Point, Hawaii.

II. TECHNICAL CONSIDERATIONS

A. OPEN-CYCLE OTEC RESEARCH

The OTEC concept is believed to have started in the late 1800's with a French physicist named D'Arsonval who suggested the possibility of extracting heat energy from the ocean. The first working demonstration of the OTEC concept, open-cycle (OC) OTEC, occurred in the late 1930's with George Claude off the coast of Cuba [1].

OC OTEC power is generated by a large low pressure turbine driven by water vapor produced from the evaporation of warm surface seawater. The evaporated seawater, working fluid, is later condensed to a liquid by cold deep seawater. If condenser tubes are used, fresh water can be produced; otherwise the condensate is discharged with the cold seawater. To increase the efficiency of the evaporator and condenser, dissolved gases, primarily oxygen and nitrogen, will be removed from the warm seawater before it reaches the evaporator. The degassification process changes the available form of organic carbon and other nutrients due to the low pressure environment via lysing. An operational OC OTEC facility does not require heat exchanger tubes, either

for the evaporator or the condenser, except to produce fresh water. Therefore, most of the corrosion and biofouling problems associated from closed-cycle OTEC are eliminated.

The Department of Energy has identified the development of ocean energy technology as one of its long-range missions. Areas related to OTEC that are identified for future research include the following [2]:

- Research and Analysis on Thermodynamics
  * OC OTEC heat and mass transfer process feasibility (includes gas sorption, evaporation and condensation)
  * Advanced OC cycle turbine rotor research
  * Advanced theory for OTEC systems integration
  * Alternate OTEC power cycle
- Experimental Verification and Testing
  * Direct-contact heat and mass transfer performance validation
  * OC OTEC concept feasibility investigations
  * Heat exchanger performance improvement
  * Advanced technology for heat exchanger fabrication
  * STF (Seacoast Test Facility) upgrades
  * Small-scale cold water pipe (CWP) experiments
  * Modular-scale CWP experiments
  * Alternative ocean energy systems research and analysis (e.g., wave energy)
- Materials and Structural Research
  * Heat exchanger materials research
  * CWP design methods and installation procedures
  * Remote CWP inspection maintenance and repair technology
- Oceanographic, Environmental and Geotechnical Research
  * Oceanography
  * Environmental and legal compliance
  * Seabed and geotechnical studies

Various experiments have been planned to investigate OC OTEC concepts. Figures II-1 and II-2 illustrate experimental research that is currently either ongoing or under consideration.

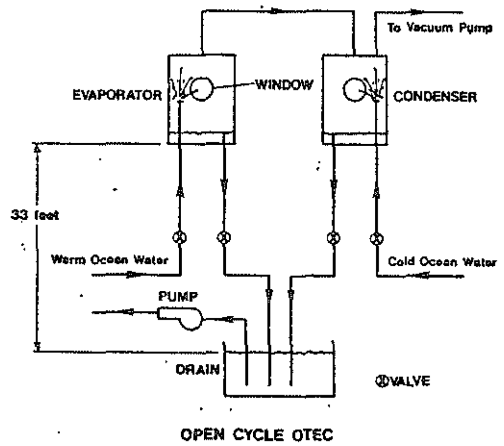


Fig. II-1 OC OTEC Evaporator Experiment (5).

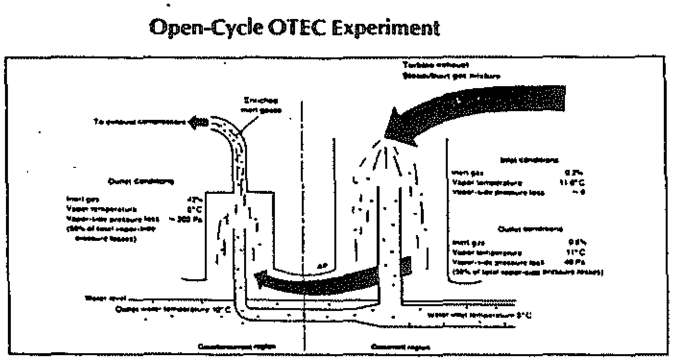


Fig. II-2 Example two stage direct contact condenser (3).

The Department of Energy OC OTEC experiment will be carried out in two phases [3] (see Figure II-3). In the first phase, evaporator and condenser modules will be in the form of one, 8-foot diameter pressure vessel. Heat and mass transfer experiments will be conducted with full scale geometries. In the second phase, additional heat transfer modules and a turbine will be added to permit completion of a cycle feasibility assessment. Figure II-3 gives more detailed specifications regarding the SERI's OC OTEC experiment [3].

The Pacific International Center for High Technology Research (PICTR) has identified certain areas of OC OTEC research as high priority areas, including in the following [4]:

- Implement component and system performance models for analyzing OC OTEC experiments; evaluate designs and scaling requirements for tests of the Claude cycle (simplest OC OTEC cycle that boils warm seawater and drives a turbine with low density steam).
- Test Claude OC OTEC components including direct contact condenser using seawater.
- Develop designs for turbines for OC OTEC applications.
- Perform systems-levels tests of Claude OC OTEC power system to investigate heat and mass transfer, and to determine systems performance characteristics.
- Develop conceptual designs for alternate commercial scale OC OTEC plants between 1 to 10 MW size.
- Perform preliminary design optimization analysis.
- Evaluate alternative cold water pipe design and installation techniques to accommodate Pacific Island conditions.
- Analyze the economics of alternative OTEC concepts for various Pacific Island communities.

Degassification is perhaps the most important open-cycle research problem because it directly affects the technical and economic feasibility of OC OTEC.

OC OTEC experiments planned for NELH include the following [5,6]:

- Problems of foaming and the release of non-condensable gases
- Evaporator/condenser efficiency as a function of spout size, length, configuration and fluid velocity
- Operational experience
- Effects of evaporator and condenser configurations
- Gas desorption from the seawater

Large scale OC OTEC operation could have adverse impacts on the environment for a variety of reasons [7]. The discharge of large volumes of degassed seawater could lead to environmental impacts on the marine biota. If the gases are redissolved in the discharge stream, the receiving waters could be impacted from seawater that is significantly different in character. In addition, infrared-absorbing gases that escape to the atmosphere could result in global atmospheric changes as well as global heat budget changes. However, when considering the small scale of the proposed 165 kw research facility, these concerns are not appropriate. Moreover, the research provided at the proto-type

facility could help to decrease the uncertainty in speculative environmental impacts of a larger scale OTEC facility.

It is important to maintain the warm seawater quality so that current closed-cycle OTEC research, concerned with materials selection and biofouling control methods, can continue [8]. Therefore, OC OTEC discharge must not significantly influence the warm seawater quality at the warm water intake.

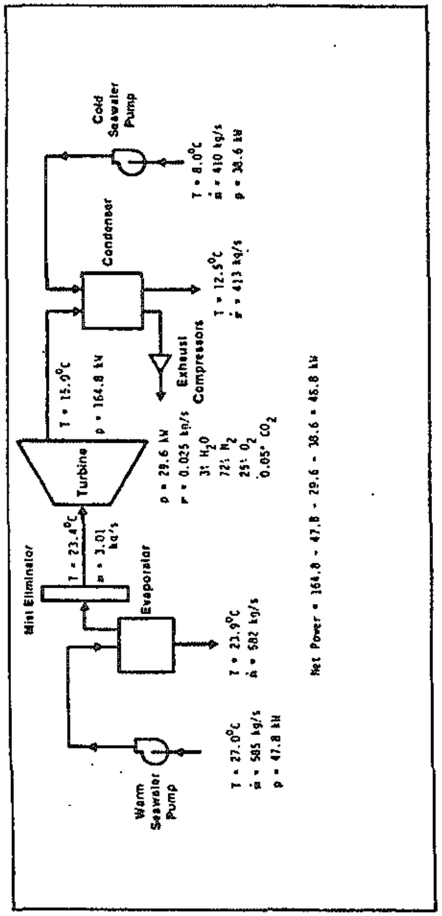


Fig. II-3 OC OTEC experimental flow diagram (3).

ENVIRONMENTAL CONCERNS

Major environmental concerns regarding large scale OC OTEC focus on potential effects of discharging substantial quantities of deoxygenated seawater as well as substantial quantities of carbon dioxide and other gases suspected of promoting a greenhouse effect. However, problems associated with a small scale prototype facility, such as the 165 kw OC OTEC facility planned for NELH, are considerably smaller, and include the discharge of deoxygenated and nutrient-rich seawater.

Currently, the 1000 gpm of seawater discharged at Keahole Point does not produce a nutrient-rich plume or any measureable adverse environmental impact, resulting from the mixture of 1:1 to 1:6 cold to warm seawater. This is because the inter-tidal ponding area transforms the nutrients into algae and seaweed [34]. However, before the same type of ponding area can be used for larger discharge volumes, additional investigations are required to determine the physical characteristics that cause the pond to act as a "reactor vessel" that adds oxygen, removes nutrients and increases the discharge water temperature to approximately that of the ambient seawater.

From an OTEC systems viewpoint, there are two considerations regarding the discharge of degassified seawater; the first is environmental, the second is related to the efficiency of the system. Due to the parasitic power losses that result from removing gases and pumping them to atmospheric pressure for disposal, there is interest in reinjecting the gases back into the seawater prior to disposal. This would have a two-fold benefit; it would discharge much more environmentally-acceptable seawater and would decrease parasitic power losses associated with pumping the gases. An illustration of this type of arrangement is given in Figure II-4 [32].

After discussing the problem of degassification and regassification with various investigators involved with OC OTEC, i.e., from the University of Hawaii, the University of Pennsylvania, the Solar Energy Research Institute, the Argonne National Laboratory and the Department of Energy, it became clear that regassification of the discharge plume was of interest and concern to all parties interviewed and will be addressed in one form or another in their respective research efforts. A brief summary resulting from conversations with people from each of these organizations is included in the following:

> Dr. Hans Krock of the University of Hawaii indicated that although reoxygenation of the discharge plume is possible by processing the seawater through turbulent motion, e.g., a small fountain, it is more useful to reinject the gases originally removed during degassification so that parasitic power losses can be minimized.

> Dr. Terry Penny of the Solar Energy Research Institute indicated that degassification and reinjection of gases (primarily O_2, N_2, CO_2) will be addressed in his research effort.

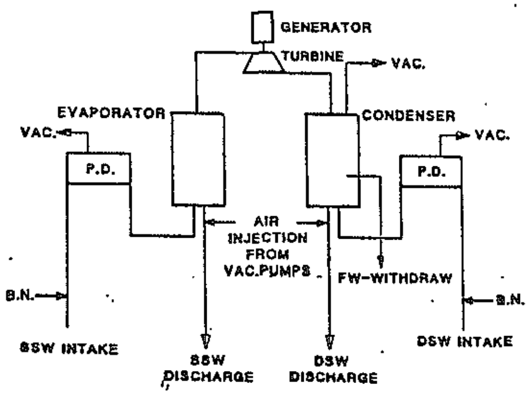
> Dr. Noam Lior of the University of Pennsylvania indicated research planned for NELH is directed at producing an operational OC OTEC facility. Questions concerning the reaeration of OTEC discharge will not be directly addressed because of limited resources. However, problems associated with the efficiency of the OC OTEC facility, i.e., noncondensible gases in the condenser, will be addressed.

> Dr. C. B. Panchal of the Argonne National Laboratory indicated that predearation is an important factor in making the condensers and evaporators operate efficiently. Research at NELH will address the problems associated with dissolved gas (O_2, N_2, CO_2) reinjection as well as removal. However, much more work is required before anything can be included as part of an OC OTEC system.

> Dr. David Johnson of the Solar Energy Research Institute indicated that the Department of Energy is not looking at reaeration of OC OTEC discharge as a separate task. However, reaeration will automatically be included as part of their proposed research because of the possibility of reducing parasitic power losses in addition to reducing possible environmental impacts associated with discharging oxygen-poor seawater.

> Mr. Carmine Castellano of the Department of Energy indicated that regassification of OC OTEC discharge is of concern because of a need to minimize environmental impacts. He indicated that reaeration could be accomplished using a spout-type arrangement. Another way to reaerate would be to use a hydraulic pump that would recombine the gases previously removed from the warm and cold seawater. However, problems associated with aeration are not yet resolved and require more research.

> Dr. Lloyd Lewis of the Department of Energy indicated that the feasibility of reinjection is not yet known. However, if sucessful, it could be used to reduce parasitic power losses in the OC OTEC process.



Schematic Design of Open Cycle OTEC Process
P.D. = Predeaeration
SSW = Surface Sea Water
DWS = Deep Sea Water
FW = Fresh Water
Vac = Vacuum
B.N. = Bubble Nucleation

Fig. II-4 Example of OC OTEC system that would use gas reinjection (32).

B. DISCHARGE WATER DESCRIPTION

OC OTEC discharge water will be composed of warm seawater after it has been degassed and exposed to a low pressure environment, and cold seawater after it has been used for condensing water vapor. The cold water will be degassed if used as a direct contact heat exchanger.

LYSING OC OTEC WATER CONSTITUENTS

Due to the pressure decrease in the evaporator, lysing (disintegration or dissolution of tissues or microoganisms) of plants and animals in the OC OTEC water will occur because of the internal boiling due to the drop in pressure. This will change the available form of nutrients in the water into perhaps a more easily assimilated form. Table II-1 illustrates the percent weight composition of the most prevalent elements found in microoganisms [16]. If we assume that the organic content of warm seawater at NELH is approximately 100 ug/liter and that most of these materials are from living animals and plants, we can estimate the increase in available nutrients in the mixed discharge water. For example, 14 percent of 100 ug/liter will provide 14 ug/liter additional nitrogen or approximately 0.014

ppm. In the case where we have 1,000 ug/liter of organic matter we would find an increase of 0.14 ppm in the discharge plume -- an increase in nitrogen by up to 50 percent above that calculated using a 1:1.5 mixture of warm and cold seawater. However, the total nitrogen content would not change if the total nitrogen includes all constituents in the seawater, i.e., nonfiltered seawater. Lysing only changes the molecular state of the available nitrogen not the total nitrogen. Similarly, available phosphorus could increase by 0.003 to 0.03 ppm -- an increase of 5 to 60 percent--although the total phosphorus would remain constant.

Table II-2 illustrates the elemental compositions of plants, animals and seawater, deep and surface, with respect to the numbers of atoms of nitrogen (N), phosphorus (P), carbon (C), calcium (Ca) and silicon (Si). It is important to note that the the ratio of available atoms of N and P in plant and animal tissue is the same as that found in deep seawater. However, caution should be employed when interpreting these numbers because they do not provide a distinction between the molecular state of the atoms of interest. For example, nitrogen could be in the form of nitrate, nitrite, ammonia or N_2 gas. Moreover, when nutrients are introduced from lysing, the N and P will be introduced in the same atomic proportions that currently exist in deep seawater.

TABLE II-1

Elemental cell composition [16].

Element	Percent Dry Weight
Carbon	50
Oxygen	20
Nitrogen	14
Hydrogen	8
Phosphorus	3
Sulfur	1
Potassium	1
Sodium	1
Calcium	0.5
Magnesium	0.5
Chlorine	0.5
Iron	0.2
All Others	0.3

TABLE II-2

Atomic composition ratios found in plant/animal tissue and seawater [17].

	P	N	C	Ca	Si
Soft Tissue	1	15	105	0	0
Hard Parts	0	0	26	26	50
Composite	1	15	131	26	50
Deep Seawater	1	15	1000	5000	50
Warm Surface Seawater	0	0	869	4974	0

DISSOLVED GASES REMOVED DURING OC OTEC

Degassing OC OTEC water, prior to evaporation, removes dissolved oxygen, nitrogen, carbon dioxide, and trace gases such as Ar, He, and Xe from seawater. Initial results at NELH indicate that about half of the nitrogen and oxygen normally found in cold deep seawater is removed under conditions that simulate OC OTEC degassification [7]. However, later research done at NELH with warm and cold seawater indicates that up to 95 percent of the dissolved gases can be removed under OC OTEC conditions [18, 32]. The majority of the gases removed will be oxygen and nitrogen. Because most usable nitrogen in the seawater is in the form of nitrate, nitrite, ammonia and kjeldal nitrogen, the nitrogen gas removed during degassification can be considered inert for most biological purposes and is not expected to result in a significant impact. Removal of dissolved oxygen will change the dissolved oxygen levels of the discharge water to values significantly below those found in the ambient warm seawater; the discharge plume will be oxygen poor compared to surrounding waters. Organisms exposed to the plume may be oxygen-starved [9]. This situation could be addressed with reoxygenation through a process of aeration.

TRACE METALS

Trace metals released in seawater from corrosion and erosion of metallic members within an OTEC facility will increase metallic ion concentrations in nearby and receiving waters. However, this is expected to have no significant impact on the nearby marine environment.

Heat exchangers are not required for OC OTEC, except for the production of fresh water. Of the heat exchanger candidate materials, aluminum is of the most interest. Aluminum concentrations below 10 mg/l have been found to have no effect on marine fish and shrimp; concentrations less than 0.2 mg/l did not significantly inhibit marine algae [9]. Calculations of metallic ion concentrations from aluminum heat exchanger corrosion for warm seawater corrosion (worst-case), indicate that resulting metallic ion concentrations would be less than concentrations found in the ambient seawater (see Appendix A). Therefore, no significant impact would result from any heat exchanger configuration of a 165 kw size.

CHLORINATION DURING OTEC OPERATION

Very little chlorine will be used in an OC OTEC operation because there are no warm seawater heat exchangers in the evaporator and, depending on the specific OC OTEC design, there may be no cold seawater heat exchangers in the condenser. In the event that heat exchangers are employed in the condenser, very little chlorine, if any, will be used to control biofouling because of the very low rate of biofouling found in cold seawater.

Chlorine is commonly used for waste treatment in water because of its ability to oxidize and disinfect [10]. In closed-cycle OTEC research it is produced electrochemically and insitu as sodium hypochlorite or bleach (NaOCl) immediately upstream of the section of heat exchanger tubing to be cleaned.

Recent closed-cycle OTEC research performed in warm seawater at NELH indicates that chlorination levels of only 0.1 ppm for 1 hour per day are required to prevent film formation and keep heat transfer fouling resistance from rising above the maximum tolerated values [11]. In addition, results from cold water research indicate that biofouling in the cold water heat exchanger is very low.

Based on results from closed-cycle OTEC research and the low levels expected for OC OTEC, chlorination of a 165 kw OC OTEC facility should have no significant impact on the marine environment. A more detailed discussion on chlorination is given in appendix C.

NUTRIENTS FROM MIXING WARM AND COLD WATER

Nutrient levels in the discharge plume will change as a function of the cold:warm seawater ratio in the mixture. Under the condition where 1.5 parts is warm and 1.0 is cold, the following nutrients are expected in the effluent:

TABLE II-3

Nutrient mixing in the OTEC effluent [18,21,36,37]

	Cold Seawater	Warm Seawater	1:1.5 mix	State Std GeoMean	NTE_1 10%[1]	NTE_2 02%[2]
D.O. (ppm)	1.0	6.0	4.0	*	*	*
D.O. (ppm)[3]	0.2	1.2	0.8	*	*	*
D.O. (ppm)[4]	1.0	1.2	1.1	*	*	*
NO2+NO3 (ug/L)	554.0	2.4	223.0	3.5	10.0	20.0
PO4 (ug/L)	93.0	4.7	40.0	5.0	9.0	13.0
pH	7.6	8.3	8.0	**	**	**
Temp (C)	8.3	26.1	19.0	----	----	----
TN (ug/L)	590.0	57.6	270.6	115.5	195.0	279.0
TP (ug/L)	94.0	10.9	44.1	16.0	30.0	45.0
Si (ug/L)	2180.0	97.0	930.2	----	----	----

D.O.=dissolved oxygen, NO2+NO3=nitrate+nitrite, PO4=orthophosphate, TN=total nitrogen, TP=total phosphorus, Si=silicon, * = not less than 75% saturation, ** = 8.1 +/- 0.5 pH units, state standards as per "Public Health Regulations, Chapter 37-A, Water Quality Standards" for a dry open coastline [31].
NTE_1=Not To Exceed less than 10 percent
NTE_2=Not To Exceed greater than 2 percent
3 = assuming 80% of oxygen gas is removed [36]
4 = hybrid cycle OTEC

Results indicate that a 1:1.5 mixture would exceed the state of Hawaii water quality criteria for nitrate plus nitrite, orthophosphate, total nitrogen and total phosphorus. However, neglecting variations in ambient current velocities, the concentrations in the discharged water would decrease to approximately 5 percent of the initial value within 100 feet of the discharge point. If water is discharged into a ponding area, similar to the one existing at NELH, concentrations would decrease. Theoretically, if the physical parameters that cause the ponding area to act as a reactor vessel could be scaled-up to accommodate the increase in discharge volume, concentrations could approach ambient seawater conditions.

III. DISCUSSION AND RECOMMENDATIONS

Concentrations at the warm seawater intake were found to be sufficiently diluted during most tidal and current conditions so that the water quality at the warm seawater intake is not influenced from the discharge. However, during an ebb tide, without external currents, i.e., resulting from large cyclonic/anticyclonic gyres, tradewinds, etc., constituent concentrations of the discharged water will be diluted by approximately one part in two-hundred at the warm seawater intake.

A 1:1.5 mixture of cold and warm seawater coupled with a dilution of one part in two hundred results in levels of dissolved oxygen slightly below the ambient and total nitrogen levels slightly above the ambient. In this simple case, values are within the statistical variations that naturally occur[27,28]. However, because the natural marine environment is more complex, further research is recommended, including measurements of the sensitivity of biofouling to nutrient and oxygen levels and an evaluation of the effect of an oxygen-starved and nutrient-rich plume on its nearby marine environment.

Under the worst conditions of current, results indicate that metallic ion concentrations from heat exchanger corrosion from a 165 kw closed-cycle OTEC facility (a worst-case compared to a 165 kw OC OTEC facility) are lower than concentrations found in the ambient seawater. Therefore, metallic ion contamination is not a consideration.

Chlorination is not expected to be an enviromnental concern with OC OTEC because heat exchangers are not expected to be used, except for the production of fresh water. In addition, the low biofouling levels found in cold seawater require very little chlorine, if any, to control biofouling. However, if the concentration of chlorine is kept to the present level used in the warm seawater closed-cycle OTEC experiments, (approximately 0.1 ppm for one hour per day), no adverse effects on existing experiments are anticipated.

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APPENDIX AA

HEAT EXCHANGER CORROSION

If we exclude copper-nickel alloys, because of their lack of compatibility with candidate working fluids for closed-cycle OTEC, and discount titanium and stainless steel, because of their relative immunity to corrosion in seawater under OTEC conditions [19], we are left with aluminum alloys. Due to the relatively low cost of aluminum in a commercial scale OTEC facility, it is an attractive candidate heat exchanger material. In general, research conducted at NELH [20,21,22] indicates that localized attack (site selective corrosion, e.g., pitting, crevice corrosion) does not occur in the warm water heat exchangers. However, under certain conditions the cold water heat exchangers still show signs of localized attack.

Results from localized attack found in cold seawater corrosion of aluminum are reported as average uniform surface corrosion for purposes of comparison and simplicity, even though the modes of corrosion are different. If we use the mathematics available for warm seawater corrosion of aluminum, assuming uniform attack, we can calculate metallic ion concentrations as a function of time and then relate our findings to cold seawater corrosion of aluminum, based on empirical data. Aluminum corrodes according to a parabolic oxidation rate law in warm seawater, found by Sullivan and Liebert [22,19]; we can predict the corrosion weight loss resulting from uniform corrosion of aluminum heat exchanger tubing by using equation A-1 [23].

$$W = k * SQRT(t) + C \qquad \text{Eqn.A-1}$$

where W = grams/area weight loss
k = parabolic rate constant
C = constant

The candidate aluminum heat exchanger materials that are under consideration are composed of greater than 90 percent aluminum with the balances made of the following materials:

Alclad 3003 (uses anodic cladding of Al7072)
Al 3003 1.2%Mn, 0.12%Cu
Al 3004 1.2%Mn, 1.0%Mg
Al 5052 2.5%Mg, 0.25%Cr
Al 7072 (cladding only) 1.0%Zn

The initial corrosion of aluminum alloys in warm seawater has been found to have a rate of approximately 3400 um/yr after 30 minutes of exposure [22]. Eventually corrosion rates decrease to approximately 3 um/yr [21]. In cold seawater the corrosion rates appear to be less than that found for warm seawater; however, due to localized attack, the long term corrosion rates are of special concern.

Results from our calculations will be compared to concentrations that are normally found in seawater as given in Table A-1.

TABLE A-1

General concentrations of metallic ions in seawater [24]

ion	Concentration ppm
Al	0.5
Zn	0.005
Mg	1272
Cr	less than $1X10^{-10}$
Cu	0.001-0.01
Mn	0.001-0.01

TABLE A-2

Deep and surface seawater concentrations of metallic ions in seawater [38]

ion	Concentration (deep) ppm	Concentration (surface) ppm
Al	.001	.0006
Zn	.0000065	.00044
Mg	1284	---
Cr	.00027	.00030
Cu	.000034	.00013
Mn	.000034	.000038

Although OC OTEC does not employ heat exchangers, except for the production of fresh water, we investigated possible metallic ion contamination that could result from the use of cold water heat exchangers. Due to the wealth of information regarding warm water heat exchanger corrosion, we calculated metallic ion concentration levels with warm seawater. We then extrapolated our findings to estimate production of metallic ion contaminants via cold seawater corrosion.

As a worst-case scenario we considered warm seawater corrosion in 200 meters of one-inch aluminum alloy heat exchanger tubing. A water velocity inside the tubing of about 6 feet/sec was used and calculations were made for a flow of 8,000 gpm.

In a 165 kw OTEC plant we expect to have approximately 9,500 gpm of warm and 6,500 of cold seawater to give a total discharge of approximately 16,000 gpm. However, in a OC OTEC facility the warm seawater heat exchangers would not be used and the cold seawater heat exchangers would be used only to produce fresh water. In this case there would be 6,500 gpm of cold seawater running through heat exchangers. However, because we have data describing warm seawater corrosion, metallic ion concentrations for warm seawater corrosion were calculated. Under these circumstances we estimate that cold seawater corrosion rates will be less than the corrosion rates found in the warm seawater,

e.g., 25-66 percent less. Additionally, 6,500 gpm of cold seawater will increase the metallic ion concentrations by about 18 percent. Therefore, results for warm seawater corrosion at 8,000 gpm will be high by about 7-48 percent.

The corrosion kinetics of aluminum follow the parabolic rate law as given by Equation A-1; rates decrease quickly with time. Consequently, metallic ion contaminants from heat exchanger corrosion are only of interest at times immediately following the start-up of a heat exchanger system. Results from our calculations are given in Figure A-1 and Table A-3.

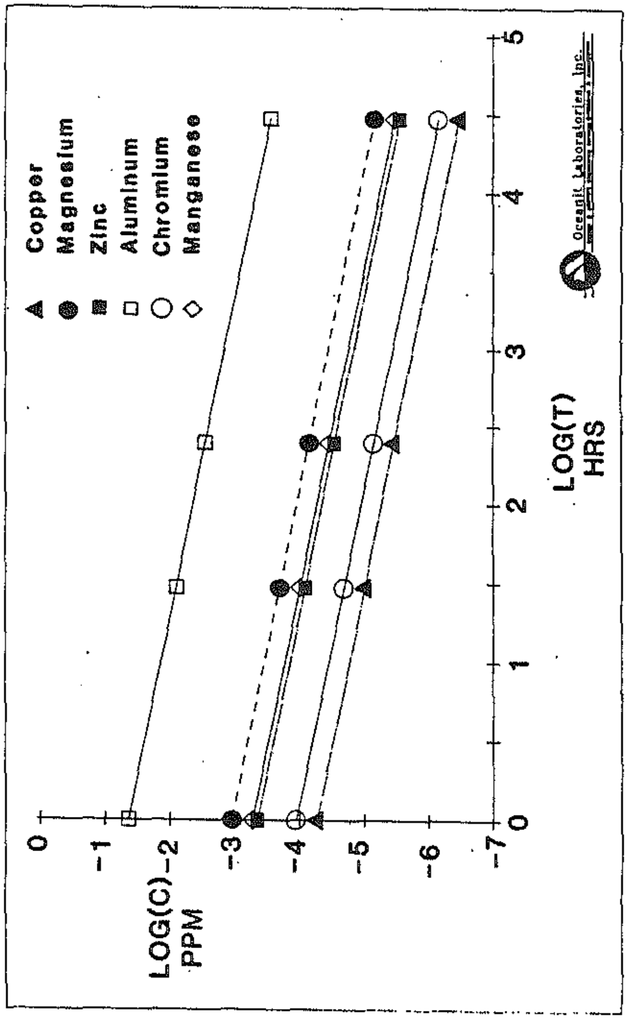

Fig. A-1 Metallic ion concentrations versus time for 200 meters of one-inch aluminum heat exchanger tubing. Calculations were made for warm seawater corrosion, assuming uniform attack, at flow rates of 8,000 gpm.

TABLE A-3

Calculated metallic ion concentrations in OTEC effluent from the corrosion of aluminum alloys 5052, 3003 and 7072

Time (min)	ppm Zn	ppm Al	ppm Mg	ppm Cr	ppm Mn	ppm Cu
1	.0004440	.0433835	.0011101	.0001110	.0005329	.0000533
5	.0001987	.0194108	.0004967	.0000497	.0002384	.0000238
10	.0001405	.0137303	.0003513	.0000351	.0001686	.0000169
15	.0001148	.0112137	.0002869	.0000287	.0001377	.0000138
22	.0000948	.0092623	.0002370	.0000237	.0001138	.0000114
30	.0000812	.0079341	.0002030	.0000203	.0000975	.0000097
60	.0000575	.0056150	.0001437	.0000144	.0000690	.0000069
90	.0000470	.0045877	.0001174	.0000117	.0000563	.0000056
180	.0000333	.0032488	.0000831	.0000083	.0000399	.0000040
250	.0000282	.0027592	.0000706	.0000071	.0000339	.0000034
500	.0000200	.0019558	.0000500	.0000050	.0000240	.0000024
1000	.0000142	.0013878	.0000355	.0000036	.0000170	.0000017
5000	.0000064	.0006297	.0000161	.0000016	.0000077	.0000008
10000	.0000046	.0004500	.0000115	.0000012	.0000055	.0000006
20000	.0000033	.0003230	.0000083	.0000008	.0000040	.0000004
30000	.0000027	.0002668	.0000068	.0000007	.0000033	.0000003

APPENDIX AB

NUMERICAL MODELING OF DISCHARGE

After discharged water is introduced into a coastal area dispersion is governed by two processes: diffusion and advection. The advection process is controlled by longshore currents that are typically produced from wave action, ocean currents, wind stresses and tides. Usually the flood and ebb tides are in opposite directions. The resulting currents change their magnitude and direction as a result of prevelent controlling factors; thus, they are difficult to predict.

NEARFIELD PLUME

Immediately after the discharge is introduced into the ocean, mixing processes start to occur. The water is discharged with a particular injection velocity that ultimately dies down due to the mixing entrainment. The region where this velocity is depreciated to about 10 percent of the injection velocity is called the nearfield or the region of initial mixing. The nearfield plume depends on the density difference between the discharge and receiving waters as well as the velocities of discharge and receiving water, and the characteristics of the diffuser and its alignment.

FARFIELD PLUME

After the initial mixing, the particles are moved mainly by random motions due to turbulent diffusion and advection. The turbulent diffusion occurs in such a way that the standard deviation of the concentration of any discharge patch increases with the square root of the time. The relation is given by equation B-1.

$$\sigma = SQR(2 * D * t) \qquad \text{Eqn. B-1}$$

where: σ = standard deviation
D = turbulent diffusion coefficient
t = time

In advective diffusion the process is governed by the partial differential equation given by equation B-2.

$$\frac{dC}{dt} + \frac{d(u * C)}{dx} = D * \frac{d^2C}{dx^2} \qquad \text{Eqn. B-2}$$

where: C = concentration (ppm)

In the model used for our work the process of advection and diffusion were handled separately. Advection of the slugs of discharge were simulated by using estimated velocities for the location. Displacements of slugs were simulated as discrete processes. The onshore-offshore currents were simulated using a random number generator with zero mean and standard deviation corresponding to that of a noise assumed for the location.

Diffusion was calculated after the final positions of slugs were determined at the end of the time-stepping. Contributions to adjacent grid locations were calculated using a normal distribution with a mean at the grid location and standard deviation calculated as a function of the eddy diffusion coefficient and age of the slug.

The relationship proposed by Krock [18] was used to calculate the diffusion in nearshore waters as given by Equation B-3.

$$D = A * L^{B} \qquad \text{Eqn. B-3}$$

where: L = length scale
B = power factor = 1 for nearshore waters
A = Coef. = 0.003 for nearshore waters

ASSUMPTIONS

The longshore mean current was estimated at 0.33 feet/sec and the amplitude of the semidiurnal tidal currents was 0.44 feet/sec [25]. Results from work done by Noda [26,35] indicate that the currents at Keahole Point generally flow in the northern or southern direction.

The model was run for the following test cases:

1) sinusoidal tidal current with period 12.5 hours and amplitude 0.44 feet/sec superimposed on a longshore current of 0.33 feet/sec flowing away from the intake
2) similar combination as in case #1 except with the longshore current moving towards the intake
3) sinusoidal tidal current in the absence of any longshore current

Results indicate that the concentrations under conditions 1 and 2 are extremely low, on the order of $1X10^{-10}$ times the concentration of the water from the discharge. However, in the absence of a longshore current, the discharged plume crosses directly over the intake. (Illustrated in Figure B-1.) Concentration variations at the intake, assuming complete mixing over the total water column, were calculated; the results are given in Table B-1. Time was measured from the beginning of the ebb tide. The ebb tide current direction flows toward the intake from the discharge.

TABLE B-1

Concentrations at the warm water intake at NELH during an ebb tide without other currents.

Time (hrs)	Concentrations (ppm)
0	0
3	$1X10^{-15}$
6	$3.2X10^{-5}$
9	$4.9X10^{-3}$
12	$1X10^{-13}$
oo	$6.29X10^{-3}$

If these conditions prevail over several tidal cycles, the final concentration at the intake will reach a value of 6.29×10^{-3} times the discharge concentration. However, it is very unlikely that this unusual condition would occur for more than one or two tidal cycles.

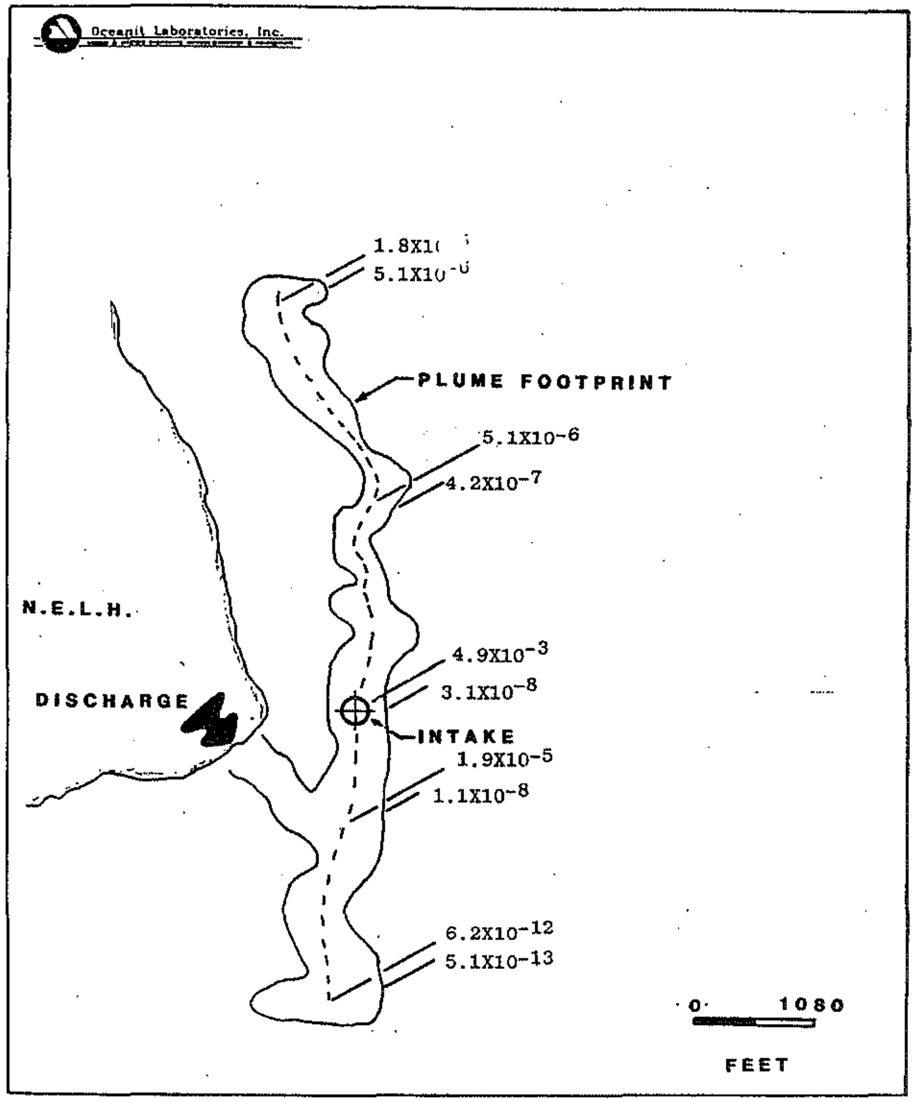

Fig. B-1 Plume footprint and concentration factors 9 hours after the beginning of an ebb tidal cycle, assuming a single point discharge of 16,000 gpm.

APPENDIX AC

SEAWATER CHLORINATION

Reaction kinetics of chlorine in water are related to the organic carbon content of the water, .i.e, waters of high organic content produce more halocarbons than waters of lower organic content. Research at NELH has shown that 250,000 ppm in a closed experimental system will produce approximately 550 ppm bromoforms [12].

When chlorine oxidizes material in seawater many different compounds may result, e.g., $CHCl_3$ (chloroform), CHI_3, $CHCl_2Br$, $CHClBr_2$. When chlorine oxidizes ammonia it produces ammonia compounds, including [12]:

Monochloramine	NH_2Cl
Dichloramine	$NHCl_2$
Trichloramine (nitrogen trichloride)	NCl_3

There are also a variety of end products produced from ammonia oxidation by chlorine, including [10]:

Hydrazine	N_2H_4
Hydroxylamine	NH_2OH
Nitrogen	N_2
Nitrous Oxide	N_2O
Nitrite	NO_2^-
Nitrogen Tetroxide	N_2O_4
Nitrate	NO_3

Chlorination of marine waters can result in the production of halogenated organics. Some of these compounds show mutagenic, carcinogenic, and/or cytotoxic properties [13]. Chlorine used for controlling biofouling may adversely affect the local marine environment since chlorinated compounds are highly toxic, even at low concentrations. In addition, once chlorine is released to the environment, its toxic by-products could impact non-target organisms [9]. Experiments by Sansone [14] measured the disappearance rates of two classes of chlorine-produced oxidants (CPO's) that have also been studied using coastal waters from the continental United States. The first class is "free available oxidants" (FAO), the most toxic of the oxidants produced from seawater chlorination; they also provide the best anti-biofouling activity. In continental coastal seawater they disappear in seconds to minutes. These compounds include hypohalous acids and hypohalites. The second category includes "combined residual oxidants" (CRO) that are halogenated compounds produced from the decomposition of FAO's, found to display long-term toxic effects on marine organisms. In the continental United States, CRO's disappear over the course of several thousand minutes.

Results indicate that because of the relatively low levels of biofouling found in an OTEC environment, i.e., found at NELH, lower levels of chlorine are required to maintain acceptable biofouling levels with respect to coastal continental waters. However, low biofouling levels also cause the reactive free oxidants to persist much longer in OTEC waters.

Past research indicated that the addition of 250 ppb of chlorine resulted in 0.081 ppb and 0.0021 ppb halocarbons in the warm surface and deep cold seawater, respectively. The low values were attributed to the very low organic carbon content of these waters with respect to coastal continental waters [14].

Based on work by Sansone [14] the halocarbon production from OTEC chlorination is unlikely to cause major environmental effects, particularly because of the rapid dilution of the discharge waters. The low levels of acetonitrile that would be produced through OTEC chlorination were not judged to be a serious environmental threat [15]. In addition, the formation of methyl halamines from OTEC chlorination are not expected to pose a significant environmental problem.

In order to give additional perspective to the issue of clorination, it should be pointed out that the maximum chloride concentration allowable in U.S. drinking water is 250 ppm [29]. An example of chloride concentration that may be familiar to those who have sampled the tap water in Orange County California (Water Factory 21) water is 120 ppm. Furthermore, the amount of residual chlorine typically found in sewage after treatment is approximately 1 ppm, providing a 98-99 percent reduction in bacterial populations [30]. These levels of chlorination are provided to give perspective to the 0.07 ppm (70 ppb) introduced insitu at NELH to control biofouling. The total chlorine residuals that are eventually discharged to the ocean are expected to be substantially less, e.g., 5 percent of initial chlorine level.

The effects of chlorination on aquatic biota are not necessarily the same as the effects of chlorination on people from use as a disinfectant in drinking water. Therefore, inferences on the effects of relatively small amounts of chlorine on the marine environment should not be easily rendered. Moreover, these numbers are provided so that general comparisons can be made.

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A D D E N D U M I

NEARSHORE WATER QUALITY CONSIDERATIONS FOR THE DISPOSAL OF OC OTEC AND MARICULTURE DISCHARGE VIA TRENCHES AT NELH, KEAHOLE POINT, HAWAII

December 1986

Century Square 1188 Bishop Street, Suite 1801, Honolulu, Hawaii 96813
TELEX: 7431404 MCI: OCEANIT Ph: (808) 531-3017

SUMMARY

Effects on nearshore marine water quality from shallow trench disposal of 16,100 gallons per minute (gpm) and 25,900 gpm OC OTEC and mariculture discharge, respectively, were investigated.

Conservative water quality properties in the discharged water are not expected to significantly change once water has entered the aquifer. Streamlines from the OC OTEC trench will not cross streamlines from the mariculture trench. Therefore, mixing of the two discharged fluids will not occur in the aquifer.

Water that enters the aquifer during simultaneous trench discharge is expected to enter the ocean at depths 0 to 150 feet. However, OC OTEC discharge is expected to enter the ocean statistically weighted in the upper depths, i.e., 0-50 feet. Mariculture discharge is expected to enter the ocean statistically weighted at greater depths. Water that enters the ocean environment in the shallow-water region (breaker zone) will quickly become diluted. Water that enters the ocean environment at depths greater than this is expected to stay within a layer for up to approximately 6 hours (average), depending on the depth and the wave climate. This layer will be better defined in deep rather than in shallow water and will become more dilute upon approaching the shore.

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I. INTRODUCTION

Recent interest in Open-Cycle (OC) Ocean Thermal Energy Conversion (OTEC) and related mariculture activities has caused the need for innovative methods of discharge disposal. Of the various disposal methods possible, discharge via shallow trench is being seriously considered. Site locations are given in Figure 1.

Discharge flows of interest include:

- o 16,100 gpm of OC OTEC discharge
- o 25,900 gpm of mariculture discharge

The specific objective of this report is to discuss the resulting combined water quality in the nearshore marine environment from discharge of OC OTEC and mariculture activities via two shallow trenches in or near the Natural Energy Laboratory of Hawaii (NELH) and the Hawaii Ocean Science and Technology (HOST) Park.

II. TECHNICAL CONSIDERATIONS

The ground water lens thickness was calculated to be less than 125 feet within the area of interest [1] . This lens is brackish and discharges freely along the coast in a narrow band a few feet wide in the intertidal zone.

A model study of OC OTEC disposal into a shallow trench, within 250 feet of the shoreline at the closest point, resulted in 80% of the discharge occuring over a horizontal distance of 600 feet along the shoreline, an average of 4,500 gpd per foot [2]. If discharge exits into the marine environment along the 0 to 50 feet bathymetric contours, results indicate an average of 2.5 gpd per square foot of ocean bottom. Discharge would be greater in offshore areas close to the discharge trench, i.e., 6.6 gpd per square foot. The proposed dimensions of the trench are approximately 5 X 5 X 193 feet. Minimum residence time was calculated to be 1 to 2 days.

Mariculture discharge via a shallow trench, located along the access road at the Host Park, was also modeled within 900 feet of the shoreline, at the closest point. Results indicate that 76% of the discharge would occur over a distance of 6,200 feet along the shoreline, an average of 4,600 gpd/foot. If we assume that the flow is distributed evenly between the 0 to 200 foot bathymetric contour, the average discharge is 1.2 gpd per square foot along the ocean bottom. Flow is be greater in areas closest to the discharge trench, e.g., 2.6 gpd/square foot for a distance 1200 feet along the shoreline. The proposed dimensions of the trench are approximately 5 X 5 X 374 feet.

Simultaneous discharge of both OC OTEC and mariculture was also modeled. Results indicated that 76% of the discharge occurred over a horizontal distance of 5,900 feet along the shoreline, an average of 7,800 gpd per foot. If discharge is distributed over the 0 to 150 foot bathymetric contour, an average of 2.8 gpd per square foot of ocean bottom would result.

WATER DESCRIPTION

OC OTEC water is expected to be high in nutrients and low in oxygen, assuming that oxygen cannot be introduced with injection or aeration. If aeration can be accomplished, high nutrients will be of most concern. Mixtures of 1 part cold to 1.5 parts warm result in water quality characteristics given in Table 1. Table 2 gives the water quality characteristics expected for mariculture discharge with a mixtures of 4 parts cold and 1 part warm (without mariculture additives). Typical ground water characteristics are given in Table 3.

TABLE 1

Nutrient mixing in the OTEC discharge [13,14,15,16]

	Cold Seawater	Warm Seawater	1:1.5 mix	State Std GeoMean	NTE_1 10%[1]	NTE_2 02%[2]
D.O. (ppm)[1]	1.0	6.0	4.0	*	*	*
D.O. (ppm)[1]	0.2	1.2	0.8	*	*	*
NO2+NO3 (ug/L)	554.0	2.4	223.0	3.5	10.0	20.0
PO4 (ug/L)	93.0	4.7	40.0	5.0	9.0	13.0
pH	7.6	8.3	8.0	**	**	**
Temp (C)	8.3	26.1	19.0	----	----	----
TN (ug/L)	590.0	57.6	270.6	115.5	195.0	279.0
TP (ug/L)	94.0	10.9	44.1	16.0	30.0	45.0
Si (ug/L)	2180.0	97.0	930.2	----	----	----

TABLE 2

Nutrient mixing in the mariculture discharge* [13,14,15,16]

	Cold Seawater	Warm Seawater	4:1 mix	State Std GeoMean	NTE_1 10%[1]	NTE_2 02%[2]
D.O. (ppm)	1.0	6.0	2.0	*	*	*
NO2+NO3 (ug/L)	554.0	2.4	443.7	3.5	10.0	20.0
PO4 (ug/L)	93.0	4.7	75.34	5.0	9.0	13.0
pH	7.6	8.3	7.7	**	**	**
Temp (C)	8.3	26.1	11.8	----	----	----
TN (ug/L)	590.0	57.6	483.5	115.5	195.0	279.0
TP (ug/L)	94.0	10.9	77.4	16.0	30.0	45.0
Si (ug/L)	2180.0	97.0	1763.4	----	----	----

D.O.=dissolved oxygen, NO2+NO3=nitrate+nitrite, PO4=orthophosphate, TN=total nitrogen, TP=total phosphorus, Si=silicon, * = not less than 75% saturation, ** = 8.1 +/- 0.5 pH units, state standards as per "Public Health Regulations, Chapter 37-A, Water Quality Standards" for a dry open coastline [3].
NTE_1=Not To Exceed less than 10 percent
NTE_2=Not To Exceed greater than 2 percent
1 = after 80% of gas removed [13]
* = without mariculture additives

TABLE 3

Estimated ground water nutrients [4,5,6]

D.O. (ppm)	8.7
NO2+NO3 (ug/L)	800
pH	8.2
Temp (C)	20.0
TN (ug/L)	1000
TP(ug/L)	100

Water in the anchialine ponds is a combination of salt water and fresh ground water. By assuming representative salinity of 7.5 parts per million (‰) and using conservation of mass, representative values of nutrients in these ponds can be approximated, as given in Table 4.

TABLE 4

Representative Anchialine pond nutrients

D.O. (ppm)	8.1
NO2+NO3 (ug/L)	630
pH	8.2
Temp (C)	21.3
TN (ug/L)	798
TP(ug/L)	81

D.O.=dissolved oxygen, NO2+NO3=nitrate+nitrite, TN=total nitrogen, TP=total phosphorus
* based on conservation of mass and an estimated salinity of 7.5 ‰.

TRENCH DISCHARGE

Water that is discharged into the trench will undergo very little change upon its introduction, remaining there for a fixed time before entering the ground. This is referred to as the residence time in the trench, and depends on the dimensions of the trench and the rate of discharge. In the case of mariculture and OC OTEC, the resident times for each recommended trench can be estimated to be 2.2 and 2.7 minutes, respectively. Evaporation expected during this time is very small and can be neglected. This brief residence time also prevents major changes in the water's chemical and nutrient content. Therefore, there is no significant change in water quality in the trench.

Water entering the pervious ground will travel toward the sea due to the resulting pressure gradient. The discharge flow will disperse as the water moves away from the trench. The maximum speed at entry into the trench can be approximated if we assume the same speed of entry at all water levels in the trench, approximated to be 0.037 and 0.031 f/s for OC OTEC and mariculture discharge, respectively. Velocity rapidly decreases with distance from the trench, and reduce to very small values in a short distance.

Mixing depends on turbulence, i.e., momentum exchange between fluid particles, and concentration gradients. At these low velocities very little mixing is expected until the ocean is reached. Mixing due to concentration gradients is expected to be insignificant and will be limited to the boundary between converging streamlines.

Water that enters the aquifer may initially react with the existing geology, e.g., the dissolution of carbonates, until equilibrium conditions are reached. After this, water from the two disposal trenches will remain relatively separate except at the interfaces between the two fluids and the existing ground water. In simple terms, water introduced into the OTEC trench could be identified as water 'X' and the water entering the mariculture trench could be identified as water 'Y'. After the waters are introduced, except for interaction with tidal motions and the interfaces between the two fluids, the waters remains as X and Y.

The mixing of these fluids and/or the displacement of the ground water by these fluids is very site-specific. In an ideal situation, the streamlines (by definition) resulting from the steady discharge of two fluids will not cross, i.e., there would be no mixing. However, without more data it is difficult to provide a better description of trench discharge into the aquifer; experimentation and site testing would be required.

Except immediately following the initial introduction of discharged water into the trench and aquifer (excluding biochemical reactions) concentrations are not expected to change during the waters residency in the aquifer. As water is discharged into the trenches the lava substrate is expected to act as a granular filter [7]. This filter can remove suspended solids, remove chemically precipitated phosphorus, chlorinated compounds and metallic compounds, e.g., heavy metals used as biocides. However, the filtering ability of the lava and the predictability of its performance, i.e., filtering mechanisms and limits, should be tested prior to full scale trench operation.

TRANSMISSION INTO THE OCEAN

Water that is transmitted into the ocean is subject to various forces that cause it to mix and disperse. However, it is not correct to assume that all of the discharge is instantly mixed into the water column as it enters the coastline. Moreover, dilution is a function of waves, currents, wave induced currents, relative densities and the bathymetry of the coastline.

When water is discharged into another body of water, mixing of the two occurs immediately. The initial stage of the mixing depends on the density differences between the discharge and the receiving water. If the density of the discharge is higher than the receiving water density at the discharge point, the water tends to sink to a layer where the density difference vanishes.

Turbulent motion occurs during the upward movement of discharge through receiving waters; dilution occurs rapidly. This results in the formation of a nearfield plume. After initial dilution, the water begins to diffuse and spreads due to advection by currents and eddy diffusion. This secondary dilution causes a farfield plume.

If low density fresh water is discharged close to the surface, as in the case of a natural stream outlet, the discharge tends to

stay at the surface and spreads horizontally into a large area. However, trench disposal introduces discharge from the bottom of the water column. Discharged water is expected to have a slightly higher density than the water in the upper levels; therefore, it is not expected to rise.

CURRENTS

Currents around Keahole Point vary from 12 inch/s to over 254 inch/s. The most dominant currents are in the range of 25 to 38 inch/s, i.e., the range expected for tides. Currents are strongest in the longshore direction. Results from the analysis of directional wave statistics indicate that although mean current speeds are in the north northwest direction, they also show large effects from tides.

WAVE INDUCED CURRENTS

The velocity distribution due to the presence of progressive waves is a function of depth, wave height and wave period. Water particles move in circular orbits in deep water; however, as the depth decreases, the particle paths become elliptical.

Water particle motion due to waves at the ocean's bottom is parallel to the bottom. Linear wave theory shows that the effect of the surface waves is limited to depths of one-half the wave length. At depths less than one-twentieth the wave length, particle motion is nearly horizontal -- as occurs with tidal motion and other long waves.

We can calculate the bottom velocity using equation 1.

$$Ub = \frac{pi*H}{T*\sinh(k*h)} \qquad \text{Eqn 1}$$

where: Ub = bottom velocity
H = wave height
T = wave period
k = wave number
L = wavelength
d = depth of water

Waves become unstable as water depths decrease -- eventually breaking occurs. Breaking waves create heavy turbulence and mixing in an area referred to as the 'breaker zone', typically located at wave height to depth ratios of 0.6 to 0.8. [8,9].

Complete turbulent mixing occurs in the breaker zone, which is a function of wave statistics, given in Table 5. Results indicate that the breaker zone occurs at depths less than or equal to 3.2 feet 52.5% of the time.

Table 5

Statistical distribution of breaker zone depths

Depth (ft)	% time fully mixed
0.6	99.8
1.9	99.6
3.2	52.5
4.5	12.9
5.8	6.3
7.1	1.7
8.3	1.0
9.6	0.8
10.9	0.2

Calculated statistical interpretation made from data measured by Noda [10].

Deep water waves are generally identified where the depth (h) is greater than one-half the wavelength (L). Shallow water waves occur approximately where depth is less than one-twentieth of the wavelength. No dilution occurs on the bottom as a result of deep water waves. The intermediate area between the deep and shallow water zones experiences some dilution; the shallow water zone experiences much more dilution.

If we consider waves with 7 second periods, we find that the division between deep and intermediate water occurs at a depth of 125 feet. The division between intermediate and shallow water occurs at a depth of 13 feet. If waves are 4 feet high in 25 feet of water, we expect to find horizontal particle velocities at the bottom of 2.7 f/s with horizontal displacements of 3.0 feet, resulting in some turbulent mixing.

Additional considerations include irregularities of the seabed. Although there are no detailed depth profiles available for measuring bottom undulations, we will assume that the standard deviation of the seabed is on the order of one-foot for profiles taken in the longshore direction. This standard deviation gives a Nikurradse roughness of about 32 inches [11,12]. The elevation where the Prandtl-Von Karman velocity field is exactly zero occurs at elevation 'Zo' and is only a function of roughness. The resulting layer between the seafloor and Zo, referred to as a psuedo-stationary layer, was calculated using equation 2 and was found to be one inch [11].

$$Zo = \frac{r}{33} \qquad \text{Eqn. 2}$$

Ground water seepage speed can be calculated from the discharge values given by Dames and Moore, i.e., 2.8 gal per day per square foot. This results in velocities of 3.84 inch/day or 0.16 inch/hour.

This seepage velocity results in an average resident time of 6.3 hours within the psuedo-stationary layer before the water is introduced into the upper levels, assuming that horizontal velocities within the layer are negligibly small. Once the upper levels are reached (greater than one inch) dilution will occur due to turbulence.

If we assume 50% dilution occurs when speeds are greater than 2 inch/s, we can statistically describe depths of dilution, as given in Table 6 and illustrated in figure 1. These results indicate the following:

- o depths less than or equal to 50 ft (0-50') are mixed 47.8% of the time
- o depths less than or equal to 100 ft (0-100') are mixed 27.5% of the time
- o depths less than or equal to 200 ft (0-200') are mixed 7.5% of the time

Table 6

Dilution in the nearshore marine environment

Depth (ft)	Probability of water column mixing due to waves
less than 3.5	100.0
4.5	76.0
6.0	56.0
7.0	53.0
10.0	50.4
25.0	50.0
50.0	47.78
75.0	40.0
100.0	27.5
125.0	17.5
150.0	12.0
175.0	10.0
200.0	7.5

Calculated statistical interpretation made from data measured by Noda [10].

Water column residence time in the nearby coastal area is governed by the current speeds and the time required to flush a volume of water out from the seepage area. We can approximate this time as follows:

Average width of seepage area	= 3500 + 2500	= 6,000 ft
Mean Current	= 32 cm/s	= 1.05 ft/s
Resident Time	= 6000	= 1.7 hours

The residence time of the water in the nearby coastal discharge area is about 1.7 hours. This time is not expected to be sufficient for the high concentrations to reach the level of the warm seawater intake mean current conditions.

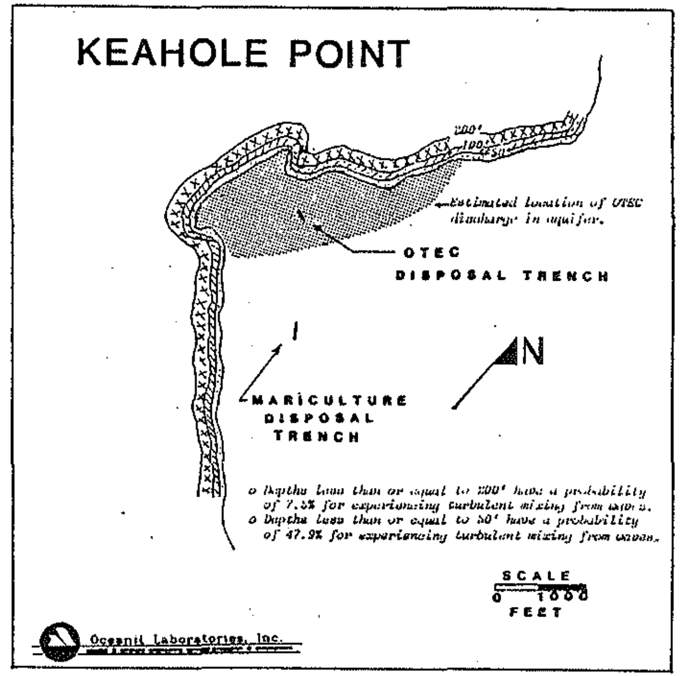

Fig. 1 Depths where turbulent mixing from waves occurs, based on wave statistics.

III. DISCUSSION

AQUIFER

Water that is introduced into the trench is expected to sink into the ground water because of its negative buoyancy. Water pumped into the trench will cause an increase in the ground water level in the nearby areas, as indicated by the flow net in Dames and Moore's report [2]. The resulting hydrography will resemble a "mound" of water. Any indention into the substratum that is connected to the existing ground water will show an increase in water level. For example, a pond within the .5 foot equal potential contour line will increase in depth by .5 feet.

ANCHIALINE PONDS

Nutrient levels of nitrogen, oxygen and silicon are expected to fluctuate in anchialine ponds, depending on the pond's communication between the ground water and the ocean. Water quality in the pond will depend on the specific configuration of the local geology and the ponds location with respect to the resulting trench flow net. Therefore, it is not possible to describe the resulting water quality in the pond except as one of the following: (1) unaffected by the trench disposal; (2) a

mixture of trench discharge and existing ground water; or (3) complete replacement of the ground water with discharge from the trench. Ponds outside the flow net are not expected to be influenced by discharged water. Pond water quality inside the flow net is best determined through measurements at the locations of interest.

MARINE WATER COLUMN

Dilution and dispersion of discharge in the nearshore marine environment is dependent on waves and currents. Wave statistics show that 50% of the time the water column is diluted from turbulence at depths less than or equal to 25 feet.

Due to irregularities on the bottom, a layer forms with an average thickness of one inch (averaged over entire area of seepage). Incorporating this result with statistical information on currents and waves yields the following:

- There is a 100% probability that turbulent mixing will occur at depths less than or equal to 3.5 feet (0-3.5'), primarily due to the location of the breaker zone. The probability of turbulent mixing decreases with depth. For example, there is a 50% probability that turbulent mixing will occur in depths less than or equal to 10 feet (0-10').

- Beyond 25 feet in depth, dilution occurs due to currents and orbital rotations from waves. There is a transition range from 10 to 25 feet of depth where turbulence from breakers contributes to dilution.

- As the discharged water seeps into the ocean bottom, its slightly higher density causes the build-up and formation of a layer, i.e., there are no buoyant forces to cause initial dilution. This layer builds to an average thickness of about one inch (based on an assumed roughness) before it is taken up into the upper levels for initial dilution. The average resident time of the discharged water in the bottom one-inch layer is about 6.3. hours. However, because the bottom is irregular, there will be zones with slightly thicker layers and zones with virtually no layer.

- After exiting the one-inch layer, currents will cause dilution in the water column. However, dilution will be slow because the vertical diffusion coefficient is only about one percent of the horizontal eddy diffusion coefficient.

- The discharged water will tend to creep and disperse along the bottom and move down to depths of equal density. In general, currents are expected carry water offshore before water can reach the level of the warm seawater intake.

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ADDENDUM II

OPEN-CYCLE OCEAN THERMAL ENERGY CONVERSION

COST ESTIMATE FOR DISCHARGE AERATION

December 1986

Century Square 1188 Bishop Street, Suite 1801, Honolulu, Hawaii 96813
TELEX: 7431404 MCI: OCEANIT Ph: (808) 531-3017

SUMMARY

Areation is commonly used in waste water treatment facilities; however, relatively little data is available on seawater areation. If general waste water practices are applied, costs and volumetric requirements can be estimated to be $34-57 per day and 43,000 cubic foot, respectively.

Initial investigations at the University of Hawaii indicate that these requirements could be reduced. Site specific seawater oxygen mass transfer data would be required to provide better estimates.

INTRODUCTION

Recent research concerning Open-Cycle (OC) Ocean Thermal Energy Conversion (OTEC) indicates that degassification of both warm and cold seawater will be required, depending on the details of the system used. As a result, it is anticipated that the oxygen level of OC OTEC discharge could be substantially below that found in the receiving waters. In the event that OC OTEC reinjection technology is developed, oxygen poor discharge will not be a problem. However, until this technology is developed a seawater aeration system would greatly enhance the environmental acceptability of the discharged OC OTEC water.

TECHNICAL CONSIDERATIONS

Aeration is a process commonly used in waste water treatment facilities. Here the objective is to transfer gas, typically oxygen, from air to water. Other benefits from aeration result in the displacement of gaseous or volatile impurities, the oxidation of inorganic impurities and the removal of organic impurities via biochemical digestion [1].

Aeration rates are driven by concentration gradients that exist between oxygen levels in the liquid state, i.e., water, and the gaseous state, i.e., air. Saturation in fresh water typically occurs at concentrations of 9.5 ppm [1].

Oxygen saturation concentrations are dependent on dissolved solids, pressure and temperature. Typically deep ocean water has dissolved oxygen levels of 1-2 and warm seawater typically has values of 6-8.

Various types of aerators are used for specific purposes, e.g., removing iron or hydrogen sulfide. Typically aeration is conducted with a gravity system or a cascade type aerator resembling a system with a tower that allows water to cascade over levels to a recovery basin [2,3].

Trade-offs occur with the specific function of the aerator and its operation efficiency. Operating efficiencies typically range between 4 to 12 percent [1,2].

Table 1

Typical aeration capacities [1,2]

	lb O_2/hp-hr
Submerged aerators	1.5 - 4.0
Surface aerators	2.0 - 3.5

DISCUSSION

Based on the above considerations some general cost analysis are included to illustrate the power and cost requirements for operating an aeration system.

Calculations were made with the following assumptions:

1) average of 2 lbs O_2/hp-hr oxygen transfer rate
2) density of 8.76 lbs/gal
3) oxygen demand of 3 and 5 ppm, increased oxygen required
4) flow rate of 23.2 mgd (16,100 gpm)

Table 2

Estimated oxygen demand versus cost

oxygen demand (ppm)	rq'd pump(hp)	Cost ($) per day	Cost ($) per year
3	12.7	34	12,444
5	21.2	57	20,742

note: based on rates for fresh water, 15¢/kw-hr

To put these numbers into prospective, operating an average clothes dryer all day will cost approximately $18 per day or $6,400 per year.

Initial investigations at the University of Hawaii indicate that rates of seawater aeration may be faster than those found for fresh water; this would cut aeration costs [4].

Results reflect the operating cost of aeration only and do not include the cost of equipment and other detailed design considerations. Volumetric requirements for 16,000 gpm would be approximately 43,048 cubic feet, e.g., a 10 x 65 x 65' container (approximately the volume of a medium sized house). This could be reduced by a factor of two or three, depending on specific oxygen transfer rates.

Our initial analysis indicates that aeration is feasible. However, because there is very little data on seawater aeration and oxygen transfer rates are very water specific, oxygen mass transfer data from Keahole Point seawater should be obtained. With this information, more accurate predictions can be made.

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APPENDIX B

IMPACTS OF OC OTEC AND MARICULTURE DISCHARGES FROM
THE NATURAL ENERGY LABORATORY OF HAWAII
ON THE NEARBY MARINE ENVIRONMENT

GK & ASSOCIATES

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GK & ASSOCIATES

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SUMMARY

In comparison to ambient waters, open cycle (OC) OTEC discharges would be altered in some physicochemical parameters and would contain elevated concentrations of inorganic nutrients. The temperature of the discharged water would be between 19°C and 19.4°C (66.2-67°F). Dissolved oxygen concentrations could be significantly lower than ambient, and near zero if degassing is employed. Nitrogen concentrations would be significantly higher than ambient offshore concentrations due to the contribution of the deep water to the mixed discharge and to lysing of cells in the OC OTEC process. These concentrations would, however, be on the order of one half of the nitrate concentrations in groundwaters presently seeping into coastal waters. Any consequent impacts would not result from the concentrations themselves, but from the volume of discharged water which would elevate the total nitrogen flux to coastal waters. OC OTEC will not introduce supplemental concentrations of heavy metals, and chlorine additions are unlikely. Pretreatment requirements necessary to protect the marine environment appear to include only reaeration of degassed waters prior to discharge.

Of the optional methods and locations for disposal of the OTEC discharges, the most environmentally benign is deep injection, but co-disposal with mariculture effluents appears to be acceptable and less costly. Subsurface disposal would allow sedimentation, filtration, chemical precipitation, adsorption, decomposition and, with adequate residence time, natural die-off of any entrained pathogens. Discharges via either canal or very nearshore shallow trench have the greatest potential to elevate nearshore nutrient concentrations and thus have the most potential to stimulate the algal turf at the shoreline. Inhibition of grazers in the surge zone would tend to allow an accumulation of macroalgal biomass. This may be aesthetically undesirable. Trench discharges at greater distances from the shoreline will allow greater plume spreading prior to entry into the sea and therefore less concentrated nutrient supplements and a less obvious biostimulatory response from the primary producers. Canal disposal would allow warming, disinfection by UV light, decomposition and nutrient uptake.

Potential mariculture organisms for use at NELH include microalgae, macroalgae, mollusks, crustaceans, and finfish. Constituents of discharges from these operations may include inorganic nutrients, dissolved organics, particulate matter, and chemical additives including selective toxicants, disinfectants, antibiotics/anti-parasitics and oxidants. Mariculture discharges would be disposed of into a trench some distance behind the shoreline. This trench would likely be filled with crushed lava to increase the available surface area for nitrifying bacteria and other in situ treatment processes. Trench disposal will serve to remove solids, precipitate some of the phosphorus and metals, allow decomposition to break down some of the organic material, and provide a matrix for bacterial action. Adsorption in a trench or in the substratum would be poor because of the lack of clays and organic soils in the area. Pretreatment requirements may include reaeration and possibly nutrient and process chemical removal. Mariculture at NELH will likely continue to focus on production technology, as mariculture designed for waste treatment is inefficient in terms of land use and may not be required as a mitigating measure. Culture of certain high-value algae may provide some economical nutrient stripping, but culture of higher organisms cannot be expected to provide a net improvement in discharge water quality.

PURPOSE AND SCOPE

The "Final Environmental Impact Statement for the Development Plan for the Hawaii Ocean Science and Technology Park and Expansion of the Natural Energy Laboratory of Hawaii" (HTDC, 1985) was based in part on the assumption that waters to be used in forthcoming OTEC experiments at NELH would be disposed of via a deep-ocean outfall to be funded by the U.S. Department of Energy. Subsequently, the U.S. DOE learned that it would be unable to fund the proposed expansion of OTEC facilities at NELH to the level they had originally proposed. Rather than installing separate seawater pipe systems, the U.S. DOE and the state entered into a cooperative cost-sharing agreement to provide the required ocean water for both projects with one seawater system. This combined system will include cold and warm water intake pipelines and a pump station to service both NELH and HOST Park activities.

The action evaluated includes pumping as much as 60 mgd (42,000 gpm) of warm and cold ocean waters to shore for use in OC OTEC experimentation and mariculture research and demonstration. The maximum volumes of water to be disposed of are as follows:

- OTEC--23 mgd (16,100 gpm--6,500 gpm cold, 9,600 gpm warm);
- mariculture uses--37 mgd (25,900 gpm--20,720 gpm cold, 5,180 gpm warm). For comparison, the maximum projected waste water volume anticipated from the adjacent HOST Park is about 100,000 gpm, of which it is estimated that about 80% would be warm water (HTDC, 1985).

Both NELH and HOST Park would gradually increase water usage over a period of years. Present OTEC experiments at NELH discharge about 1,000 gpm; mariculture discharges include about 800 gpm from Hawaiian Abalone Farms (HAF) disposed of into two injection wells, and about 200 gpm of other mariculture discharges disposed of by spreading over cinders. Initial discharge volumes from OC OTEC research would be 3,000-5,000 gpm of varying cold:warm water ratios for periods of hours to days. The full 16,100 gpm flow from an operational 165 kW OC OTEC plant would not occur until about 1991 and would then run continuously for periods of days to weeks extending over approximately 8 months to one year. Initial discharges from the HOST Park are estimated at 6,000 to 6,800 gpm.

The scenarios considered for disposal of NELH discharges include the following:

- o disposal of mariculture discharges into the ground via a shallow trench located along the NELH access road--this is the only option being considered for disposal of this fraction of the NELH discharge, but two optional locations were modeled (Appendix C);
- o co-disposal of mariculture and OC OTEC discharges into the ground via a shallow trench located along the NELH access road;
- o disposal of OC OTEC discharges directly at the shoreline via a shallow, surface "canal" similar to that presently being used for NELH discharges;
- o disposal of OC OTEC discharges into the ground via a shallow trench similar in design to the mariculture trench, but located seaward of the OC OTEC facility (two optional locations were modeled, see Appendix C);
- o disposal of OC OTEC discharges into the ground via deep injection wells located seaward of the present NELH facility.

The purposes of this report are as follows:

- o supplement the marine biological impact assessment provided in the original EIS to include land-based disposal of OC OTEC discharges;
- o describe and analyze the impacts of process chemicals which might be used in NELH mariculture operations;
- o provide a conceptual description of potential pretreatment options available for use prior to disposal of mariculture discharges;
- o update the previous cumulative impacts assessment in light of the large number of resort development projects being planned for nearby coastal areas.

SITE DESCRIPTION

The marine biological environment offshore of NELH/HOST Park was described for the original EIS (GK & Associates, 1985). Since then additional surveys in the area have been completed for neighboring projects.

Dollar (1986) carried out a qualitative marine biological reconnaissance survey of the area fronting the proposed O'oma II resort development immediately adjacent to and bounded on two sides by the HOST Park. His description of the area conforms with those previously summarized. The wave-washed intertidal platform has numerous tide pools where the seaweeds Ahnfeltia concinna and Ulva fasciata, encrusting red algae, sea urchins and juvenile fish are the most visible biota.

He identifies three offshore zones on the basis of substratum type, depth, physical conditions, and dominant coral species. A shallow, basaltic terrace extending from the shoreline to about 25 m offshore receives maximal wave energy. Pocillopora meandrina, a sturdy coral able to rapidly colonize new surfaces, is dominant. Seaward of the terrace is flat basaltic pavement, interspersed with lava extrusions and sand channels. The dominant coral is Porites lobata, found primarily as thick-lobed colonies. This zone extends offshore about 55 m into waters about 10 m deep, and is the zone of most active reef-building. Beyond this is an abrupt increase in slope where the substratum is dominated by unconsolidated rubble and sand. Here the dominant "finger coral," Porites compressa, forms dense thickets.

In addition to the corals, sea urchins and sea cucumbers are common on the reefs. Frondose benthic algae are notably rare, and those present, Turbinarea ornata, Padina spp., and varieties of encrusting red coralline algae for example, are hardy in structure.

Six categories of reef fish were found, including juveniles, planktivorous damselfishes, herbivores, rubble-dwelling fishes, swarming tetrodonts, and surge-zone fishes. The deep zone of finger coral harbored a high concentration of juvenile fishes. "Food fishes" were not abundant, but included parrotfishes, goatfishes, taape (Lutjanus kasmira - an introduced snapper), jacks and groupers. Butterfly fishes were relatively scarce, and Dollar attributes this to harvesting by aquarium fish collectors.

OPEN CYCLE OTEC WASTE DISCHARGE CONSIDERATIONS

The present action includes disposal of up to 16,100 gpm of water used in OC OTEC experiments. About 6,500 gpm of cold water would be mixed with about 9,600 gpm of warm water for disposal. The mixed water would be below ambient surface seawater levels of temperature, dissolved oxygen and pH, but contain higher concentrations of major plant nutrients. Using worst case data from the NELH water quality monitoring program, assuming the above proportions of warm and cold water, and assuming all parameters behave conservatively yields the following values: temperature -- 17.8°C (64°F); dissolved oxygen (in the absence of degassing) -- 3.98 ppm; pH -- 7.79 units; nitrate plus nitrite -- 17.1 ug-at/l; phosphate -- 1.48 ug-at/l; and, silicate --41.2 ug-at/l. Discharge concentrations would be modified by the OC OTEC process. Some warming will occur in the process. Noda (1985) estimates discharge temperatures of 19.0-19.4°C (66.2-67°F). Dissolved oxygen could be substantially lowered if one or both of the source water streams are degassed prior to use. Lysing of cells in the evaporator will increase the concentrations of dissolved nutrients over those given above.

The OC OTEC process selected for experimental work at NELH does not produce dissolved metal ions and would very likely not utilize chlorination because direct contact heat exchangers would be used (L. Lewis, DOE, pers. comm., Sep. 3, 1986).

MARICULTURE WASTE DISCHARGE CONSIDERATIONS

Potential components of discharges from OTEC-associated mariculture are summarized below using examples from representative species which have been identified as having some potential for mariculture at NELH. The major types of crops considered are microalgae, macroalgae, mollusks, crustaceans, and finfish.

Discharges from mariculture can be characterized by examination of solute levels resulting from continuous operation and from periodic manipulations to the system such as harvesting, cleaning or feeding which typically result in brief, low-volume, but concentrated, pulses of waste material. For example, Sparrow (1979) found that up to 25% of the wastes from typical salmonid hatcheries were generated in cleaning the tanks. Waste products of mariculture can be characterized as: organic wastes from crop metabolism and unused feeds, inorganic fertilizers, antibiotics and other disease treatments, chemicals used for maintenance of water quality or facility disinfection, and larvae or other propagules.

POTENTIAL SPECIES

MICROALGAE

Microalgae are grown in continuous or batch cultures. In many cases, water is recycled to preserve the chemical constituents of the medium. If so, the only discharge is from washing culture containers and equipment. Occasional, minor losses to the environment would also be expected from the harvest operation or periodic draindown of the raceways due to culture crashes or repairs. Such events may result in large volume discharges. If algae are grown as food for shellfish, they are generally transferred to the shellfish culture system from where effluents can be recycled or discharged.

Any water discharged from phytoplankton cultures would contain algal and bacterial cells, residual trace elements from the enrichment medium and elevated concentrations of dissolved organic carbon (DOC) and dissolved organic nitrogen (DON), which are extracellular metabolites found in any dense algal culture.

Enrichment media are used primarily to maintain stock cultures of phytoplankton in the laboratory. The ingredients are expensive and generally other nutrient sources such as commercial fertilizers are used for large-scale cultures. The composition of enrichment media

varies somewhat with species to be grown and the preferences of the grower. Two recipes of popular enrichment media for diatoms, naked flagellates and other eukaryotes such as _Chaetoceras_, _Dunaliella_, _Tetraselmis_ and _Pheodactylum_ are presented in Table 1. _Spirulina_ and other blue-green algae are generally cultured in a slightly different medium, as presented in Table 2. During normal operation, cultures are maintained in light-limited conditions, making all of the constituents of the enrichment present in some concentration. However, the concentrations of ambient nutrient salts are maintained at very low levels in order to reduce contamination of cultures by competing species.

Small containers may be disinfected with chlorine, however, the amounts derived from algal cultures are not likely to be a significant fraction of the total chlorine usage of a mariculture facility.

Table 1. The compositions of F/2 (R.L. Guillard, 1959) and Laws' media (E.A. Laws, pers. comm. to D. Robichaux, 1986)

F/2 Medium

$NaNO_3$	0.88 mM	Na_4-EDTA	11.7 µM
NaH_2PO_4	36.3 µM	$FeSO_4.7H_2O$	11.7 µM
$NaSiO_4$	0.1 mM	$CuSO_4$	0.04 µM
B12	0.5 µg/l	$ZnSO_4$	0.08 µM
Biotin	0.5 µg/l	$MnCl_2$	0.9 µM
Thiamine	100.0 µg/l	$NaMoO_4$	0.03 µM

Laws Medium

NH_3SO_4	0.1 g/l	F/2 trace metals
$(NH_3)_2PO_4$	0.2 g/l	
B12	0.5 µg/l	
Biotin	0.5 µg/l	
Thiamine	5.0 µg/l	
$NaHCO_3$	0.14 g/l	

Table 2. The composition of Zarrouk's medium for _Spirulina_.

$NaHCO_3$	16.8 g/l	H_3BO_3	3.0 mg/l
K_2HPO_4	0.5 g/l	$MnCl_2$	1.8 mg/l
$NaNO_3$	2.5 g/l	$ZnSO_4$	0.2 mg/l
$MgSO_4$	0.2 g/l	$CuSO_4$	0.08 mg/l
K_2SO_4	1.0 g/l	MoO_3	0.015 mg/l
NaCl	1.0 g/l	NH_4VO_3	0.023 mg/l
$CaCl_2$	0.04 g/l	K_2CrO_4	0.096 mg/l
$FeSO_4$	0.01 g/l	$NiSO_4$	0.048 mg/l
EDTA	0.08 g/l	$Ti(SO_4)_3$	0.04 mg/l
		$Co(NO_3)_2$	0.044 mg/l

MACROALGAE

Macroalgae are grown in continuous cultures which discharge water in proportion to the size of the tank or pond. In many cases, the discharge is regulated primarily to maintain the proper temperature rather than to limit discharge concentrations of nutrients.

Macroalgal culture media are generally less complex and less expensive than microalgal culture media because large quantities are required to fertilize continuous cultures.

Several species of macroalgae are currently produced at NELH. They are: Macrocystis pyrifera (giant kelp), Porphyra tenera (nori) and a mixture of species used for stripping inorganic ions from the present discharge. The precise methods for cultivation of Macrocystis are proprietary, and additives are unknown. The cultivation of nori requires no additional enrichment at the growout stage, and has some potential for use as a mitigating measure for discharge of inorganic nitrogen and phosphorus. Research is ongoing to determine depth, flow and harvest manipulations necessary for optimization of nutrient stripping in shallow channels. Nutrient stripping rates of up to 1.2 g-N/m^2/day and up to 0.67 g-P/m^2/day are reported from initial data at NELH (Robichaux, 1986). Other species of macroalgae with potential for growth in OTEC effluents could provide a net improvement to water quality by increasing dissolved oxygen, and reducing inorganic nitrogen, phosphorus, and trace metals concentrations.

Occasionally, macroalgal culture tanks or raceways would be emptied and scrubbed with chlorine to disinfect them. This would result in discharges of chlorine and chlorine produced oxidants to the waste stream. Recommended concentrations for short term disinfection are 1000-2000 ppm, but in normal washdown operations these would be diluted greatly prior to release into the disposal system.

MOLLUSKS

Marine mollusks which are, or have been, cultured in OTEC discharges at NELH are abalone (Haliotis sp.), oysters (Crassostrea, Ostrea), clams (Tapes, Mercinaria, Tridacna), and opihi (Celana sp.). Bivalve mollusks are filter feeders and as such effective at removing suspended particulate material such as phytoplankton, detritus and inorganic carbonate precipitates. Much of the material filtered is redeposited as feces or pseudofeces which would be flushed into the effluent stream periodically. Wastewater from an existing oyster growout facility was characterized by Rothwell and Losordo (1979). Data from this facility are presented in Table 3.

Potential chemical additives to mollusk cultures include antibacterial and antifungal agents, especially at the hatchery stage. These would generally be added only as necessary, and in relatively small quantities. Copper sulfate or one of the latter generation copper compounds may be used as selective toxicants to fouling filamentous algae in oyster tanks. These compounds would not be added to other

Table 3: Waste Characterization of an Oyster Growout Facility on Oahu (From Rothwell and Losordo, 1979)

Parameter	Influent[1]	Draindown[1]	Normal Effluent[2]		Cleaning and Harvesting Effluent[3]	
			Average	Range	Average	Range
Temperature (°C)	27.0	25.5	27.8	25.0-31.0	26.0	25.3-26.3
Salinity (‰)	31.2	25.8	30.7	29.5-32.0	27.4	25.1-31.5
Alkalinity*	145	--	141	130-152	137	133-141
pH	7.7	7.6	7.97	7.82-8.10	7.54	7.10-7.80
Dissolved oxygen**	3.1	6.6	7.0	6.6-7.4	6.0	4.3-7.2
Fecal coliform***	0.0	0.0	2.8	0.0-7.7	5.7	0.0-9.7
Total COD	3.5	20.0	7.5	4.1-16.0	29.1	24.0-32.9
Soluble COD	3.5	15.3	8.1	4.1-16.0	14.0	10.3-18.5
BOD_5	1<	--	1<	0-1.0	--	6.5
Suspended solids	3.4	14.0	1.1	0.7-2.3	70	15-130
Settleable solids (%)	n.a.	36	n.a.	n.a.	82.5	79-86
Volatile suspended solids (%)	n.a.	n.a.	n.a.	n.a.	24	21-28
Total Kjeldahl nitrogen	0.18	0.62	—	0.44	1.5	0.96-1.96
NH_4 - N	0.129	0.067	0.204	0.127-0.282	0.077	0.040-0.142
NO_2 - N	0.001	0.030	0.039	0.027-0.059	0.029	0.022-0.036
NO_3 - N	0.032	0.780	0.666	0.226-1.320	0.877	0.586-1.320
PO_4 - P	0.010	0.013	0.043	0.030-0.056	0.076	0.055-0.131
Chlorophyll a (mg/m^3)	—	0.68	--	0.03	2.26	0.84-3.68
Phaeopigments (mg/m^3)	—	1.28	--	0.05	3.22	1.31-5.13
Duration (hours)	continuous	0.33	--	continuous	4	4-6
Volume (liters)	545,000 ℓ/day	12,000	--	545,000/day	26,000	22,000-34,000

Notes:

- * mg/ℓ as $CaCO_3$
- ** All values presented as mg/liter except where specified
- *** Colonies/100 ml
- 1 Single sample
- 2 Four samples
- 3 Three samples

cultures of mollusks as filter feeders would concentrate the copper adsorbed on particulate matter, and grazing mollusks such as abalone and opihi utilize filamentous algae as feed. Isopods and other parasites have been reported to infest oysters grown in dense cultures and natural waters. We are not aware of any effective chemical for treatment of these endoparasites; however, if there is a chemical treatment the nature of the chemical should be investigated prior to its introduction into the discharge system, as it may significantly impact the resident epifauna in the discharge trench.

CRUSTACEANS

Potential species of crustaceans for cultivation at NELH are shrimp (Penaeus), lobster (Homarus, Panulirus) and brine shrimp (Artemia). Of these species, Artemia is the only filter feeder. Artemia cultures would utilize phytoplankton or other particulate organic feeds which would subsequently be discharged intact or as wastes. Artemia also produce extremely durable cysts undr some circumstances, but their escape would only provide food for resident fish species.

Both shrimp and lobster are omnivorous and require high protein feeds for adequate nutrition in cultivation. Their metabolic wastes, uneaten feeds and residuals of various chemical treatments would appear in the discharge stream. The identities of all potential chemicals which might be used in crustacean cultures at NELH are not known; however, the waste stream from an existing shrimp culture enterprise was characterized by AECOS, Inc. (1982) (Table 4). The discharge in that case is an order of magnitude lower in nutrients than that of a typical Oahu secondary sewage treatment plant discharge. With filtration, the shrimp discharge would be comparable to that of a tertiary STP.

In addition to the parameters shown in Table 4, the discharge permit for this operation includes provisions for regular additions of formalin and a chelated copper compound which act as in situ antibacterial and antifouling agents, respectively. Formalin was expected to appear in the effluent at a concentration of 7.1 ppm for approximately 50 hours per week. Similarly, the copper compound (Cutrine-plus) was reportedly used at concentrations of 4-6 ppm in tanks; resulting in effluent concentrations of 0.3 ppm for periods of 10 hrs per day. Additional chemical wastes may be generated in cleaning tanks with chlorine or other disinfectants.

FINFISH

Potential species of finfish for cultivation at NELH are primarily carnivorous or omnivorous. Techniques which have been developed at NELH (Katase, et al. 1985) for coho salmon, steelhead trout, and rainbow trout utilized flow-through culture systems with regulated feeding of formulated feeds. Discharges from these tanks could be expected to have elevated levels of ammonia, nitrate and phosphate, and reduced levels of dissolved oxygen. Tanks were periodically drained

TABLE 4 - A SUMMARY OF WATER QUALITY INFORMATION RELEVANT TO THE PROPOSED SHRIMP OPERATION

	Nitrate-Nitrite	Ammonium	Total Nitrogen	Ortho-Phospate	Total Phosphorous	Chl a	Turbidity	Non-filterable Residues	BOD
	(----------ug/l					----------)	(--NTU--)	(------mg/l	------)
State Water Quality Standards Open Coastal Waters (geometric means)									
wet period	5.0	3.5	150	7.0	20.0	0.30	0.50	20.0	
dry period	3.5	2.0	110	5.0	16.0	0.15	0.20	10.0	
Geometric means of site survey dry season	3.4	3.2	220*	1.9	7.4	0.03	0.75*	1.6	
Combined Effluent Characteristics of proposed shrimp operation (arithmetic means)	388	1278	2646	148	395		14.9	11.9	5.5
Primary STP (1,2)			24,000		8,000		6.6	86	67
Secondary STP (2,3)			17,000		7,000		5.4	37	20
Tertiary STP (4)			100-1,000		2,000		0.5	1	1

1. Pearl City Primary Treatment Plant (Young and Chau, 1970).
2. Average of 8 STP's on Oahu (Young and Chau, 1970).
3. Gakstatter, et al, 1978.
4. Eckenfelder, 1970.

* greater than not to exceed value more than 10% of the time - State Water Quality Standards

and cleaned with chlorine. Larger scale finfish culture may utilize in situ antifouling techniques such as additions of copper sulfate, or chelated copper in order to reduce labor costs in manually cleaning these tanks.

Ectoparasites have been reported in many fish culture operations. Most fish culturists rely on antiparasitic agents which are added at intervals designed to prevent the target species from completing its life cycle.

CHEMICAL ADDITIVES

The following is a partial list of chemicals in popular use among mariculturists. It is by no means comprehensive; however, many of the chemicals not found in the following list are similar or identical to those presented below. The microalgal culture media described above are not reproduced here.

Aquatic Herbicides/Selective Toxicants

Aquathol-K (oxabicycloheptane-dicarboxylic acid): A contact weed killer for use on submerged aquatic vegetation along pond margins, also toxic to phytoplankton. Used in concentrations around 100 ppm. Probably would not be used at NELH because weeds would not be a problem on lava. Large ponds there require impervious liners.

Copper Control/Cutrine-Plus (Copper-triethanolamine-diethanolamine complex): Control of filamentous and planktonic algae. Chelated copper used in concentrations of up to 1.0 ppm. Periodicity ranges from several times per year in stagnant ponds to daily in high intensity raceways. Average concentration in current high-tech shrimp culture is slightly over 1 ppm on an annual basis. Potential use in crustacean and finfish culture at NELH.

Copper sulfate: Traditionally used as an algecide in fresh water and to a limited extent in marine waters in concentrations up to 10 ppm. Limited application at NELH because of its limited effectiveness in seawater..

Diquat (1,1-ethylene-2,2-bipyridylium dibromide cation): A commonly used herbicide lethal to most vascular aquatic plants such as duckweed, hydrilla and water hyacinth. Probably would not be used at NELH because vascular aquatic plants would not be a problem.

Rotenone: Toxic to fish at concentrations of 0.2-20 ppm. Is used for nonselective irradication of fish from ponds and lakes. Limited application at NELH, except perhaps as part of an anchialine pond restoration program.

Disinfectants

Argentyne (Polyvinylpyrrolidone-iodine, 10%): Time release iodine for disinfection of eggs suspended in hatchery tanks. Used as a 100 ppm

solution for short periods during hatchery operations. Total amounts depend on hatchery size and frequency of the hatchery cycles. Very small quantities might be used. Maximum strength before dilution in the discharge would be non-toxic to eggs.

Benzalkonium Chloride (N-alkyl quaternary amines): Disinfectant for tanks and other hard surfaces. Used as a 1-2% solution as necessary for cleaning equipment.

Chlorine (Sodium or calcium hypochlorite): The most widely used disinfectant for hard surfaces, equipment and tanks. Used as 200-1000 ppm solutions as necessary.

Antibiotics/Antiparasitics

Antibiotics: Many of the traditional antibiotics (Erythromycin, Neomycin, Penicillin, Sulfamerazine) are used to reduce bacterial contamination in phytoplankton stock cultures or as treatment for culture animals. Due to the expense, these chemicals are not generally used in large quantities. One popular antibiotic, Chloramphenicol, has been restricted, and is no longer sold over the counter in the United States.

Chloramine-T (Sodium para-toluene-sulfonchloramide): Chlorine-based treatment for bacterial gill disease in salmonids and other finfish. Concentrations of 6-10 ppm not more than 1/day.

Formaldehyde: The universal bacteriocide. Used for in situ disinfection of fish and shrimp, and preservation of specimens. Concentrations of 5-50 ppm are used for short intervals in culture water. Average additions for operational shrimp culture facilities are 2 ppm in the effluent stream on an annual basis.

Malachite Green: Traditionally used in conjunction with formalin as antiparasitic, antibacterial, and antifungal agent. Concentrations of 0.05-0.1 ppm are effective. Regulations restrict its use in the United States due to its resistance to natural degradation.

Potassium Permanganate: Used in concentrations of 1-5 ppm to relieve oxygen shortage, rotenone detoxification, removal of organic contaminants, and bacterial/parasitic control.

Prefuran/Furance/P 7138 (Nifurpirinol): A general treatment for bacterial, fungal and parasitic infections. Used either as treatment of known infections (1-2 ppm), or as a prophylactic (0.05-0.1 ppm).

Trichlorfon/Masoten/Dylox/Dipterex/Chlorofos/Metrifonate/Neguvon (Dimethyl-trichloro-hydroxyethyl) phosphonate: Used commonly for treatment of ectoparasites such as anchorworm, flukes or isopods. Concentration is roughly 0.25 ppm; treatment no more frequently than once per week.

Of the above compounds, most are added to cultures of living organisms, some at very fragile stages of their life cycles. At the maximum dosages they are intended to kill or inhibit bacteria, fungi or small parasites. Deactivation in sulture systems, and dilution in the disposal system, would render them completely innocuous to anchialine pond or marine biota. Of more concern are those compounds, essentially all chlorine-based, used in higher concentrations when living culture organisms are not present. There is the potential for excessive use of chlorine compounds by technicians in washdown operations, although in a practical sense, the very high cost of these compounds will induce management oversight and use restrictions. It is likely that dilution in washdown and comingling with other discharges in the waste stream will provide adequate mitigation of potential impacts, but monitoring of residual oxidants in the disposal trench is recommended. If excessive concentrations occur, a policy of neutralization of washdown waters with sodium bisulfate could be instituted.

New chemicals will undoubtedly be added to this list in the future. Each of these chemicals is toxic to some organisms at some concentrations, and each mariculture operation should be required to demonstrate that its chemical additives and patterns of usage would not detrimentally effect other mariculturists, the OTEC experiments, the treatment system, the anchialine ponds or offshore ecosystems. Surveilance and monitoring are recommended.

MARICULTURE AND TRADITIONAL METHODS FOR EFFLUENT PRETREATMENT

The use of aquaculture systems for waste water treatment has received increasing attention in recent years. The level of technology studied has varied from essentially unmanaged, natural wetlands to highly managed raceways. Numerous plant and animal species have been examined in this context, although the bulk of the work to date has been with freshwater systems.

Both natural and constructed wetland systems have been used to further treat secondary sewage effluents, with removal percentages for BOD_5, suspended solids, nitrogen and phosphorus up to about 90% (Reed, et al., 1979). These systems, however, do not provide the opportunity for process control and require relatively large land areas, i.e., on the order of 20-60 acres per million gallons of waste water applied.

Basic waste water treatment pond technology has been modified for use with free-floating aquatic plants, particularly water hyacinth and duckweed. Again, treatment efficiencies can be high, but land requirements are also high, i.e., on the order of 5-15 acres per million gallons of wastewater applied, depending on the treatment goal. These systems have been found to be generally uneconomical because of the necessity to harvest and dispose of up to 50 dry tons of plant biomass per acre per year (Reed, et al., 1979).

Aquaculture of plants and animals, principally fish, has been combined with traditional waste water technology in successful sewage treatment systems, although systems using higher forms of animals are reported to be less efficient, require more land, and are more difficult to manage than those using plants only. Additionally, these systems cannot

generally be optimized for both treatment efficiency and protein production.

A pilot-scale marine polyculture system for removal of nitrogen from secondary effluents was tested at Woods Hole (Ryther, 1975). Effluents were diluted with seawater and sequentially passed through phytoplankton ponds, shellfish raceways, and macroalgal production units. The overall nitrogen removal efficiency was 89%, but the shellfish production unit was not successful and it appeared that comparable treatment could be accomplished with only the macroalgal unit.

Kawasaki, et al. (1982), created laboratory-scale artificial food chains to recycle dissolved nutrients in secondarily treated domestic waste waters. Sequential monocultures of a unicellular green algae, an herbivorous cladoceran crustacean, an herbivorous or carnivorous teleost fish, and a filamentous green algae were employed. Virtually all nutrient removal was found to occur in the first stage.

To devise a treatment system for NELH effluents it is first necessary to define the goals of treatment in terms of what "pollutants" are to be removed. Table 5 summarizes the primary contaminants of concern in the NELH effluents.

Table 5. Contaminants of concern in NELH effluents

Contaminant	Reason for Concern
Suspended solids	May lead to clogging of a disposal trench or injection well. Offshore disposal via canal may adversely affect corals by sedimentation and algae by increased turbidity.
Biodegradable organics	Consist principally of proteins, carbohydrates, and fats. Measured as BOD or COD. In very high concentrations, oxidation in the environment may deplete natural oxygen resources.
Pathogens	Bacteria and viruses may affect resident species.
Nutrients	Carbon, nitrogen, phosphorus, and trace elements are essential for growth. High concentrations may cause biostimulation. Very high concentrations may be toxic.
Heavy metals	May be toxic in relatively low concentrations, may accumulate biologically and on adsorptive surfaces.
Aquaculture additives	Those most likely to be used at NELH include copper-based selective toxicants, iodine and chlorine-based disinfectants, antibiotics, and formaldehyde.

Refractory organics	May be toxic in relatively low concentrations, may accumulate in the environment, biologically and on adsorptive surfaces, and may decay slowly. Examples include surfactants, phenols and pesticides.

(After Tchobanoglous, et al. (1979))

Mariculture-based treatments could provide mitigating influences on suspended solids, organic matter, heavy metals and nutrients, but except for the possibility of culturing certain high-value algae, appear uneconomical. Trench or well disposal systems would provide in situ treatment in terms of removal of suspended solids, organics, pathogens and possibly reduce metal concentrations. The primary purpose for mariculture waste treatment would be nutrient removal.

OTHER TREATMENT TECHNOLOGIES

PHYSICAL

Sedimentation--Removes settleable solids, some colloidal solids and incidentially reduces BOD, nutrients, heavy metals, refractory organics, and pathogens. Will occur naturally in trenches and injection wells.

Filtration--Mechanical removal of particulates. Will occur in trenches and injection wells. Often the filter medium provides a substrate for bacterial growth and associated biological treatment. Lava slag (1-2 mm diameter) has been used successfully as a percolating filter to treat aquaculture discharges prior to reuse in fish culture (Naegel, 1979). Filling the disposal trench with crushed lava would increase mechanical and biological filtration.

Air Stripping--This physicochemical process works best at a pH above 10. Ammonium ions are converted to gaseous ammonia and vented to the atmosphere.

Adsorption--Colloidal solids removed by interparticle attractive force (van der Waals force). Will occur in trench and in injection wells, but is a reversible process unless particles are removed.

Others--Dilution, distillation, heating, freezing, UV irradiation. Dilution will be particularly important for NELH discharges. UV irradiation would occur in canal disposal.

CHEMICAL

Precipitation--Effective removal of phosphorus and heavy metals by formation of or co-precipitation with insoluble compounds. Phosphorus precipitation is most efficient at high pH ($>$10), but will occur to some extent in disposal trenches and injection wells.

Adsorption--Effective removal of phosphorus and heavy metals, less effective removal of refractory organics by attachment to substrate or plant surfaces. For tertiary treatment of municipal waste water, adsorption onto activated carbon is most commonly used. Contact times of 25-35 minutes are optimal for fixed-bed adsorption of biological and chemical secondary effluents, respectively (Chow and David, 1978). Activated carbon treatment can remove chlorine and chloramines, but it would probably not work well in a seawater matrix.

Ion Exchange--Numerous resins are available for energy-efficient, large-scale separation processes, however, their use in a seawater matrix may result in rapid breakthrough times.

Zeolitic Molecular Sieves--These porous, crystalline aluminosilicates are widely used for adsorption separation processes. More than thirty natural zeolites and over 100 synthetic varieties are used to selectively exchange cations. Clinoptilotite, a natural mineral, is widely used for ammonia removal. Many others exhibit selectivities for various nonferrous metal cations, including copper, nickel, cadmium and zinc (Sherman, 1978). Potential uses at NELH would include ammonia and heavy metals stripping, but aluminum would not be taken up and for most zeolites, major ions in seawater would be selectively taken up before ammonium. Seawater or a salt solution is used to recharge zeolites.

Ozonisation--Treatment with the powerful oxidant, ozone, splits even refractory organic compounds. Acts to sterilize a fluid, but residual ozone is highly toxic, and its production is not energy-efficient.

Decomposition--Primary effects on refractory organics and pathogens. Chemical decomposition or alteration of less stable compounds by phenomena such as UV irradiation, oxidation, and reduction. Will occur in trenches and in injection wells.

Disinfection/Sterilization--Chlorine compounds are most commonly used. Oxidants such as iodine and bromine compounds, hydrogen peroxide and potassium permanganate are sometimes employed. Surface active chemicals are also used.

Others--Dialysis, reverse osmosis, solvent extraction, coagulation. These do not appear useful for NELH discharge waters.

BIOLOGICAL

Bacterial Metabolism--Effective treatment of colloidal solids, BOD, nitrogen, and refractory organics. Will occur in trench and in injection wells. Heterotrophic bacteria can enzymatically deaminate food remnants, urine and feces into ammonium. Autotrophic bacteria (nitrifiers) convert ammonium into nitrate using oxygen and carbon dioxide. Under anaerobic conditions, denitrification, production of gaseous nitrogen from nitrite and nitrate, proceeds with utilization of organic carbon sources (Naegel, 1979). Activated sludge treatment employs, in sequence, a highly aerated nitrification basin, a settling basin, and a denitrification basin. Immersion elements, also called rotating biological contactors (RBCs), provide a greatly enhanced surface area for nitrification. To maintain highly aerobic conditions, liquid oxygen is sometimes injected.

Plant Metabolism--Dissolved organics may be taken up by plants. Some extracellular metabolites may be toxic to pathogens.

Plant Absorption--Nutrients, metals and organics are taken up.

Natural Die-Off--Sufficient time in an unfavorable environment will destroy pathogens. Will occur where residence time in the ground is sufficient, such as in the mariculture disposal trench or the injection wells.

Many of these treatments will naturally occur in the disposal systems being evaluated. Canal disposal of OTEC discharges would allow treatment by plant metabolism and absorption, decomposition and disinfection by UV light. Disposal into the ground would result in sedimentation, filtration, chemical reactions, decomposition and natural die-off of pathogens.

FATE OF DISCHARGES TO A CANAL, TRENCH OR INJECTION WELL

In the event a canal is chosen for disposal of OTEC waters, uptake of solutes by aquatic vegetation would provide some waste treatment. Approximately five species of marine algae dominate discharge streams now existing at Keahole Point. These communities are capable of removing inorganic nitrogen and phosphorus at rates of 1.2 g/m^2/day and 0.67 g/m^2/day respectively (Robichaux, 1986). In addition, algae in the canal remove CO_2 at rates of over 26 g/m^2/day. Trace metals such as iron, copper and zinc are absorbed at rates in the range of 1-10 micrograms/m^2/day, when concentrations are non-toxic. Roughly 20% of the inorganic material absorbed is transformed into dissolved organic nitrogen and phosphorus which is released back into the discharge stream. Depending on currents the discharge stream would be diluted by from $6x10^{-3}$ to $1x10^{-10}$ by the time the plume reaches the warm water intake.

Commercially valuable algae such as nori, (Porphyra sp.) or ogo (Gracilaria sp.) could be produced in the discharge for the dual purpose of treating waste and reclaiming some of the expense of waste treatment. Strong recommendations for further investigation of this potential have come from researchers and commercial seaweed growers who are familiar with the NELH facility, but the trade-off between land area and efficiency of nutrient stripping needs more research and economic evaluation.

Using the uptake data from the canal, an uncovered, unfilled disposal trench 10' X 100' (93 m^2) would remove 111 g-nitrogen and 62 g-phosphorus daily, with 20% being re-released. With this design, less than 5% of the inorganic nutrient load would be removed under the best conditions. Nutrient removal by algae in a disposal trench will not be an efficient treatment strategy. More treatment would result from

filling a trench with crushed lava and allowing bacterial decomposition, sedimentation and filtration to occur. A covered trench is the preferred design.

Disposal of OTEC waters through a trench within 100 feet of the shoreline would create a subsurface plume, 67% of which would discharge over a distance of 600 feet along the shoreline at an average rate of 26,000 gpd/foot (Dames and Moore, 1986). The Dames and Moore model assumed that this plume would intersect the bottom at depths between 0 and -50 feet. Discharge rates would average 26 gpd/ft^2 with a maximum of 72 gpd/ft^2. Minimum residence times would be less than a day.

Disposal of OTEC waters through a trench within 250 feet of the shoreline would create a subsurface plume, 80% of which would discharge over a distance of 4,100 feet along the shoreline at an average rate of 4,500 gpd/ft. The model assumed that this plume would intersect the bottom at depths between 0 and -50 feet. Discharge rates would average 4.5 gpd/ft^2 within a maximum of 6.6 gpd/ft^2. Minimum residence times would be 1-2 days.

Disposal of mariculture waters into a trench set back 750 feet or more from the shoreline would create a plume extending from 0 to -200 feet. Eighty-five percent of this discharge would occur along 4,300 feet of the shoreline, with flows averaging 7,300 gpd/foot. Flux through the bottom would average 1.9 gpd/ft^2, with maximum values of about 4.2 gpd/ft^2. The residence time would be 5 to 35 days.

Disposal of mariculture waters into a trench set back 900 feet or more from the shoreline would create a plume extending from 0 to -200 feet. Seventy-six percent of this discharge would occur along 6,200 feet of the shoreline, with flows averaging 4,600 gpd/ft. Flux through the bottom would average 1.2 gpd/ft, with maximum values of about 2.6 gpd/ft. The minimum residence time would be 9-61 days.

If OTEC discharges are co-disposed of in the mariculture trench closer to shore, 77% of the discharge would occur over 3,800 feet of shoreline (12,200 gpd/foot). If the flow remained between 0 and -200 feet, flux through the bottom would average 3.2 gpd/ft^2, with maximum values of about 5.9 gpd/ft^2. Residence times would decrease to between 3 and 23 days.

If OTEC seawater is disposed of in a trench within NELH at the same time as mariculture discharges are disposed of into a trench along the NELH access road, 76% of the discharge would occur over 5,900 feet of shoreline (7,800 gpd/ft). If the flow was distributed between 0 and -150 feet, flux through the bottom would average 2.8 gpd/ft^2.

Adsorption of chemical solutes in a trench at NELH will be poor due to the lack of clays or organic soils. Tasato and Dugan (1980) report limited adsorption of nitrogen and phosphate compounds in volcanic cinder and carbonate sand. Their study used volcanic soils of the Tantalus series which are much older and more oxidized than those at Keahole Point. Without further study it must be assumed that the adsorption of chemical solutes will be insignificant in the proposed trench.

The natural groundwater lens beneath Keahole Point occurs as an unconsolidated lens of brackish (5 ppt) water roughly 125 feet thick and has a flow rate averaging 2-5 mgd/mile. The maximum volume of water disposed of in the trench will be either 37 mgd or, if OTEC wastewaters are co-disposed of there, 60 mgd. In either case, dilution of the discharge by groundwater will be insignificant. The aquifer surrounding Keahole Point is expected to experience reduced temperatures, increased salinity, and increased solute concentrations. The natural quality of the aquifer renders it unsuitable for municipal or agriculture uses. Impacts resulting from these changes include potential alteration of the anchialine ponds in the area if the plumes reach them, and potential offshore impacts.

After entering the aquifer, the rate of adsorption and oxidation of organic chemicals and metabolites is considerably slowed. Inorganic ions in the discharge, including ammonia, will pass through the ground relatively unaffected due to the short residence time (less than 6 days) and lack of soils or clays in the Keahole Point region.

Ishizaki, Burbank, and Lau (1967) studied the fate of soluble organics in sewage flowing through thin cracks in basaltic lavas. They found that the primary effect was clogging of the cracks by bacteria and their extracellular metabolic products. Little or no treatment was observed on biochemical oxygen demand (BOD), organic carbon, ammonium, or other standard parameters of waste treatment. The poor waste treatment capacity of the lavas is due in part to their low surface area, and suggests that clogging of the disposal trenches (or injection wells) is possible. If a trench were filled with crushed lava, its waste treatment capacity would increase and it could be excavated and refilled if clogging occurred. Organic material entering a disposal trench system will be remineralized to end products which depend largely on the amount of available oxygen. Under aerobic conditions, carbohydrates and proteins are oxidized to CO_2, H_2O, NO_3, SO_4, and microbial cell tissue. In the absence of oxygen, the same inputs become reduced end products such as methane, hydrogen, ammonium, hydrogen sulfide, and a variety of intermediate products such as organic acids, alcohols, amines and mercaptans. It is likely that the proposed disposal trenches will be predominantly aerobic; however, pockets of particulate accumulation may provide reducing environments which allow denitrification of nitrates and nitrites to ammonia, nitrogen gas or nitrous oxide.

Of the metals which may be present in the mariculture discharge, copper is the element which requires closest monitoring. At levels in the range of 1-10 ppb copper is an essential plant nutrient; however, in concentrations of 0.5 ppm and over it becomes extremely toxic (Table 6), and is commonly used as an herbicide. Management of the disposal system to provide treatment of mariculture effluents requires that copper concentrations in the effluent be maintained below toxic levels. Data from an operational shrimp farm on Oahu show copper concentrations

appearing in the effluent average 0.016 - 0.02 ppm inside the effluent ditch, with maximum reported values of 0.03 ppm. Short exposure to concentrations in this range should not be detrimental to algae or bacteria. Considerable further dilution would occur by comingling waste streams in the disposal system, and negative impacts on anchialine pond or marine biota are highly unlikely.

Table 6. Lethal concentrations of copper as copper-triethanolamine (Cutrine-plus)

Blue-Green algae	0.2	ppm	Argent (1986)
Phytoplankton	0.2-0.5	ppm	"
Filamentous algae	0.5-1.0	ppm	"
<u>Ulva, Gracilaria</u>	1.0	ppm	"
Small fish	0.2	ppm	Skea & Simonin, 1979

Precipitation of various chemicals is promoted in the presence of multivalent cations such as calcium, barium, strontium, magnesium, iron, aluminum, cadmium, zinc, manganese, and chromium and other metals which can form insoluble precipitates with carbonates, sulfates, phosphates, florides and hydroxides. Deep seawater is supersaturated with respect to calcium carbonate and other dissolved minerals. Addition of cations and warming of the effluent favors precipitation of these minerals which may contribute to clogging of a trench or injection well. These reactions occur slowly under natural conditions; however, high flow and changes in temperature may result in accumulation of inorganic precipitates in quantities sufficient to slow the rate of infiltration.

Disposal of OTEC waters by deep (300 feet) injection wells would create a subsurface plume confined to depths between -300 and -400 feet. Eighty-five percent of this discharge would occur over a distance of 30,000 feet, averaging 660 gpd/foot. The average discharge rate would be 1.2 gpd/ft^2, and the maximum rate would be 2.9 gpd/ft^2. A minimum residence time of about three months was calculated (Dames and Moore, 1986). An injection well system would provide the least amount of in situ treatment of the disposal options under consideration. Active mechanisms would include filtration and precipitation. Clogging is distinctly possible, and has occurred in smaller, shallower wells used by HAF. Adsorption and oxidation would not provide significant in situ treatment.

Dames and Moore, Inc. noted the probable occurrence of lava tubes and other zones of high permeability in the subsurface geology. If lava tubes are present in close proximity to the disposal trench or to the injection well, discharges may have a hydrologic residence time considerably less than expected, and discharges passing into the receiving waters will be more concentrated than expected. If no direct channels are encountered, the lava structure is expected to provide a matrix for accumulation of bacterial biomass which would allow limited biological treatment.

FATE OF MARICULTURE WASTES IN SEAWATER

Chlorine

Chlorine is the most widely used disinfectant and cleaning agent currently in use in aquaculture. The product is marketed as liquid or dry sodium or potassium hypochlorite.

Chlorine additions to the waste stream are expected to be periodic at any specific location, however, as the disposal trench is designed to service multiple facilities, it is conceivable that some chlorine will enter the stream on a nearly constant basis. Data reported by Epply, et al. (1976) indicate free chlorine and chlorine produced residuals are toxic to marine phytoplankton in the range of 0.01-0.1 ppm in seawater. Figure 1 shows the depression of photosynthesis as a function of chlorine concentration.

When added to seawater, chlorine reacts with ammonium, other nitrogen forms, halogens, and dissolved or particulate organic material, collectively referred to as the chlorine demand of a water mass. These precursors are oxidized to form chloramine, bromamine, bromoform, and a wide variety of halocarbons, some of which have been identified as dangerous in drinking water. The disappearance of reactive chlorine has been examined at NELH by Sansone and Kearney (1985). Due to the paucity of dissolved organic carbon (DOC) in oligotrophic waters, the rate of chlorine disappearance, as measured by the accumulation of halocarbon residuals, is considerably reduced.

In estuarine waters, Crane, et al. (1980) reported the deactivation of chlorine concentrations of 5 mg/l to be complete within 30 min. of its release, while in both surface and deep waters from Keahole Point this reaction was not complete after 30,000 to 40,000 min. (21-28 days) (Figure 2).

The chlorine demand of tropical seawater is considerably lower than would be expected for mariculture discharges which presumably have high organic loads. If the free oxidants are dissipated within the tanks and supply trenches, there seems to be little cause for restriction of their disposal; however, if the addition of chlorine exceeds the demand of the receiving waters in the trench, the existing literature suggests that the natural waters surrounding Keahole point will provide little in situ treatment capacity. Rough calculation of the chlorine demand of particular discharges can prevent excessive discharge of free oxidants and save money in operating expenses. Periodic monitoring of chlorine residuals at various points in the system is recommended and, if excessive concentrations are detected, a policy of decholorination of washdown waters with sodium bisulfate could be instituted.

Formaldehyde

When used as an antibiotic alone or in conjunction with other theraputic agents, formalin (dilute formaldehyde) has been shown to be effective at reducing bacterial, fungal and parasitic infections at

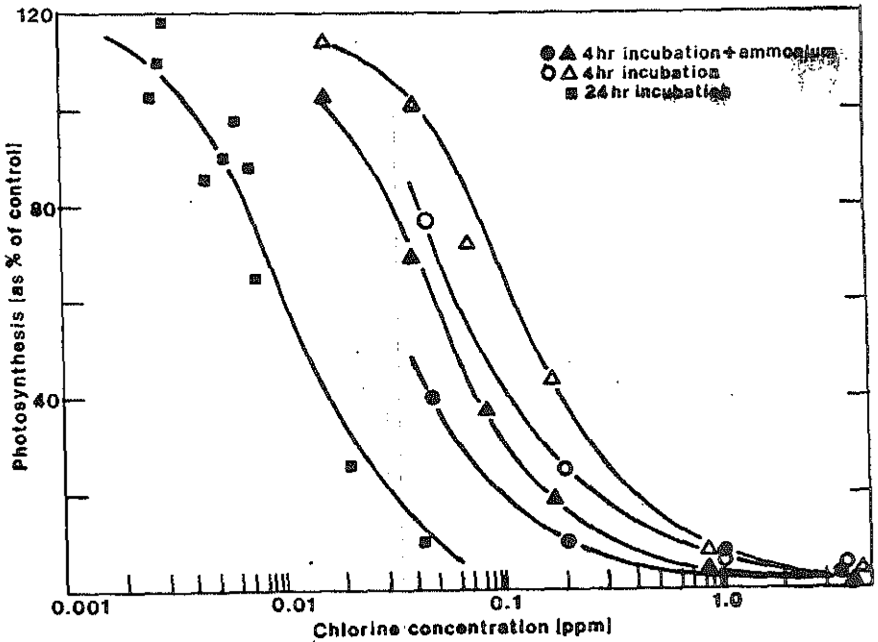

Figure 1. Inhibition by chlorine of photosynthetic carbon assimilation by natural assemblages of marine phytoplankton. Data from several experiments on different days.
(Source: Eppley, et al., 1976)

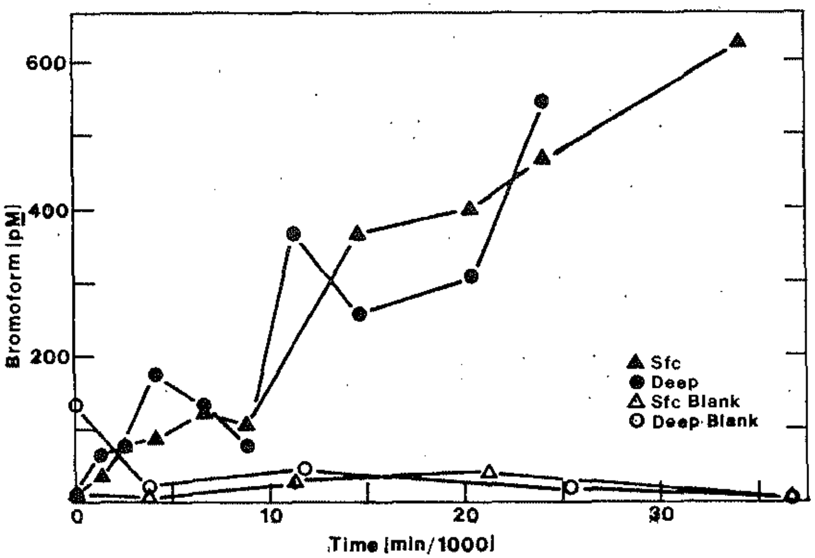

Figure 2. Time variation of bromoform in chlorinated and nonchlorinated (Blank) surface (Sfc) and deep NELH seawater.
(Source: Sansone and Kearney, 1986)

concentrations of up to 250 ppm (Hinton and Eversole, 1980). Thresholds for inhibition of cell division in microalgae, bacteria, and protozoans are in the range of 0.4-25 ppm. LD50 concentrations for rainbow trout eggs and fingerlings are roughly 500 ppm and 100 ppm respectively.

Biological degradation of formalin occurs with or without oxygen to end products of CO_2 and H_2O. This breakdown, measured as standard BOD, shows only 40% activity after 5 days. Residence in the substratum should be sufficiently long to insure its complete oxidation prior to reentering the source waters. Wastewater treatment methods for formalin include adsorption on activated charcoal (adsorbability: 0.018 g/g-Carbon, 9.2% reduction at 1 g/l influent concentration); absorption in trickling filters (up to 3.45 lbs/cubic yd.) or in activated sludge filters. The probable concentrations of formalin appearing in effluent from mariculture operations will be absorbed by bacteria and algae in the supply and disposal trenches. Assuming the average residence time in the ground is greater than 30 days, it is doubtful that any formalin will reach the receiving waters. Preliminary treatment in the disposal trench is dependent on the standing crop of bacteria which is susceptible to poisoning by infrequent pulses of formalin above concentrations of 20 ppm in the discharge. It is recommended that any formalin used as a disinfectant be diluted out into the discharge stream as necessary to prevent high concentrations from appearing in the disposal trench.

Copper sulfate, chelated copper compounds

The use of copper sulfate is a traditional method for reducing phytoplankton populations in ponds or biofouling in tanks. Its use is more effective in fresh waters than in marine or other "hard" waters, due to its tendency to precipitate as copper carbonate. This is also true of other trace metals which may be residual nutrients from algal cultures. These carbonate salts are relatively insoluble and are expected to be removed in the disposal trench.

Cutrine-plus and copper control are more effective in marine systems because of the chelating agent triethanolamine which oxidizes very slowly. After 20-day BOD tests only 6.2% of the theoretical oxygen demand was met. As a result, the copper triethanolamine complex is likely to remain active through all of the treatment processes described above. Both copper and triethanolamine can be removed by activated charcoal (0.067 g/g-carbon). Triethanolamine is toxic to algae and bacteria in concentrations in the range of 2-60 ppm (Attachment 1), but the copper complex would not be expected to appear in the discharge in concentrations higher than 1 ppm. (Federal regulations restrict the discharge of copper from power plants and other point sources to concentrations less than 1 ppm.) Further dilution by mixing of the various waste streams in the disposal system will preclude negative impacts on anchialine pond and marine biota.

Dimethyl-(trichloro-hydroxyethyl) phosphonate

This chemical is sold under a variety of trade names listed in a previous section. LD50 values for algae and fish are high (ca. 100 ppm) while toxicity in crustaceans and insects appears at concentrations of 0.2-20 ppb. No data were obtained for rates of environmental degradation. Again, however, the key factors are that it is used safely incultures of living organisms and it would be greatly diluted in the disposal system.

Malachite Green

This has been used until recently in conjunction with formalin as a theraputic drug in fish culture. However, federal regulations have severely restricted its use in natural waters due, in part, to its resistance to oxidation and biological degradation. No significant reduction in activity after 3 weeks in freshwater was reported by Bills, et al. (1977). Many aquaculturists use chemicals from overseas suppliers to reduce expenses. Malachite green may represent a serious threat to OTEC source waters if used at the proposed site, and it is recommended that its use there be prohibited.

IMPACTS AND MITIGATION

OTEC EFFLUENTS

OC OTEC effluents will be characterized by relatively low dissolved oxygen concentrations, low temperatures, high nutrient concentrations and possibly a very small amount of chlorine, but no additional heavy metals. Of potential concern to the nearshore ecosystem are the altered oxygen and nutrient concentrations and lowered temperatures of the OTEC discharges. The dissolved oxygen concentration in the mixed discharge could be as low as 3.98 ppm without degassing. Recent research indicates that as much as 95% of the oxygen could be degassed, although 50-60% removal is more likely. Canal discharge would have the effect of aerating the discharge stream, probably to values near saturation. Photosynthesis in the canal would add oxygen during daylight hours, but respiration would decrease oxygen during the night. The resulting balance of these processes would require empirical testing, and pre-dawn measurements of oxygen at the seaward end of the canal are recommended if this disposal method is adopted. Discharges containing reduced concentrations of oxygen will tend to depress metabolic activity of the coastal community, but rapid mixing and dilution in the surge zone and advection would minimize the areal extent of this impact.

If degassing of the OTEC waters takes place, then a reaeration pretreatment will be necessary prior to discharge to avoid severe metabolic stress to communities resident in the canal and nearshore. Krock (Pers. comm., G. Krasnick, July 31, 1986) has stated that reaeration of degassed OTEC waters is a more economical process (in terms of either energy or dollars) than venting the removed gases to

the environment, but research is necessary to accommodate this requirement in process design.

OTEC waters disposed of into a trench at NELH would not benefit from the turbulence and photosynthesis which would characterize passage through the canal. Oxygen concentrations would likely further decrease somewhat due to bacterial activity in the trench. Again, actual equilibrium values would have to be empirically determined. Trench disposal would considerably diffuse entry of these waters to the sea, and rapid mixing at entry would tend to mitigate impacts. Recommended mitigation measures are reaeration of degassed waters and offshore monitoring.

Oxygen concentrations in OTEC waters disposed of into injection wells would experience none of the alterations discussed above for a canal or trench, and will remain at much the same oxygen concentration through the substratum. The potential impacts would be much as those for trench disposal, but the flux of discharged water through the bottom would be lower per unit area (1.2-2.9 gpd/ft^2).

The temperature of discharged OTEC water would be below ambient for all discharge options. Considering that some warming would occur as the waters flow through the OTEC system, the worst case discharge temperature is 19-19.4^oC (66.2-67^oF). Reduced temperatures created by the entry of the cold effluent into the nearshore environment are expected; it is anticipated that mixing, diution and advection will reduce thermal impacts to the biota of the area. Lowered temperaturesmay slow metabolic rates and reduce oxygen requirements of the benthos. It should be noted that many of the nearshore species found along the Kona coast occur in the northwestern Hawaiian Islands (see Grigg and Tanoue, 1984) where winter sea surface temperatures drop to 19.2^oC (Dana, 1971) lending support to the concept of minimal impacts. Canal discharge would provide considerable warming and thermal impacts of this disposal method would be expected to be very minimal.

Trench disposal of OTEC waters would afford some warming, but not as much as canal discharge. The major difference would be that the former will greatly diffuse the flux and allow much greater initial dilution in the receiving waters.

OTEC waters disposed of via injection wells would receive the least amount of warming in disposal, but would receive the greatest dilution prior to entry into receiving waters and would enter waters of lowest ambient temperatures. At -300 to -400 feet ambient temperatures vary between about 20 and 25^oC (68-77^oF) depending on depth and season. Any impacts would be very slight.

Nutrient concentrations in OTEC discharges would be elevated over those of receiving waters. If we assume that nitrogen is the limiting macronutrient and the OTEC mixed discharge of 16,100 gpm contains 17.1 ug-at N/l, then a "canal" area about 433 feet on a side would be necessary for complete nitrogen removal. About 920 pounds dry weight of algae would be produced daily. In reality, the nitrogen in the OTEC discharge would be higher than this due to lysing of entrained cells. OLI (1986) estimated this additional nitrogen to be on the order of 20%, and a corresponding increase in treatment area would be necessary. On the other hand, complete nitrogen removal is certainly not necessary. The offshore ecosystem is adapted to a constant influx of nutrient-rich brackish groundwater. Walsh (1984) found an inverse relationship between nitrogen and salinity in nearshore surface seawater samples off Keahole Point which indicates that groundwater of about 8 ppt would be expected to have a nitrogen concentration very similar to that of the mixed OTEC discharge. Measurements of the nitrate concentration in groundwaters at Waikoloa indicate values in the range of 40-50 μg-at/l, slightly above the concentrations in undiluted deep ocean waters (R. Brock, Pers. comm. to G. Krasnick, Oct. 11, 1986). Thus nutrient concentrations in the OTEC discharge should not of themselves be a concern, although discharge of these waters at a point source (end of a canal) would be qualitatively different than seepage through the bottom, and quantities disposed of would eventually exceed normal seepage volumes. The impact of canal discharge would likely be more diffuse. As it appears that this water would be similar in nutrient content to existing natural inputs algae from the benthos will adequately mitigate impacts. Some localized increase in herbivorous biomass (i.e., fish, limpets and smails) could be expected.

Disposal of OTEC waters via injection well would result in the highest nutrient concentrations at discharge because of the lack of opportunities for biological treatment within the disposal system. As for oxygen and temperature, however, the flux from injection wells would be most diffuse at entry to the receiving waters. According to modeling done by Noda & Associates (1985) for the deep ocean outfall concept, the density of the plume would match ambient densities of -250 feet in summer and -380 feet in winter. The former is at the lower limit of the mixed layer, but above the top of the nutricline. Some stimulation of phytoplankton production is likely but mixing and advection would likely obscure these impacts. Entrainment of these waters in an eddy system could have the indirect impact of raising the bottom of the photic zone and the nutricline depth range, but these would not be significant impacts.

APPLICABILITY OF MARICULTURE TO TREAT NELH WASTES

In any aquaculture process a very large number of interrelated factors, some uncontrollable, act to determine overall system efficiency and productivity. Klontz, et al. (1978) list more than 40, of which about eight are primary. It is not possible to simultaneously manage an aquaculture system for maximum productivity and maximum waste treatment. Therefore, commercial aquaculturists may not be interested in implementing a system for waste water treatment unless a subsidy is provided. A mariculture system for treatment of wastes at NELH could be the responsibility of NELH itself, as facilities manager. The primary purpose of such a facility would be to reduce the nutrient content of the effluents. To significantly reduce nutrient loading would require a large land area. This is not to say that some

treatment would not occur incidental to mariculture operations at NELH. Algae culture would serve to reduce nutrient loading; but culture of higher organisms would increase loading.

A more fundamental question than whether mariculture waste treatment is appropriate is whether nutrient removal is necessary. As described in the previous NELH/HOST Park EIS, the offshore benthic algal community is maintained at a very low standing crop by grazing and physical stresses imposed by wave action, especially in the intertidal zone. Nutrient subsidies would not be expected to greatly increase macroalgal biomass, except in the case of discharge at the shore via canal and for a portion of the trench seepage because grazing is inhibited in the surge zone. Calm water conditions would be less destructive to intertidal macroalgae, but conversely would allow greater access by grazers. Phytoplankton growth responses would lag nutrient uptake by a day or more, during which time advection would carry the cells away from the area and mixing would dilute cell concentrations.

Localized nutrient subsidies from squaculture effluent may, in some instances, have a very positive impact on fish communities. Studies of nearshore resident fish communities at Kahuku, Oahu have shown that marine shrimp aquacultural effluents released in the intertidal area via canal result in large increases in the biomass of fish and marked differences in fish community structure. Fish species that may be assigned to the herbivorous, carnivorous or detritivore tropphic categories appear to increase in numbers and standing crop. Many of these species are commercially important including goatfishes - Family Mullidae, surgeonfish - Family Acanthuridae, Squirrelfishes - Family Holocentridae, jacks - Family Carangidae, mullets - Family Mugilidae, rudderfishes - Family Kyphosidae, and aholeholes - Family Kuhliidae. It is hypothesized that the release of shrimp larvae, particulate wastes as well as in situ algal production stimulated by nutrient loading are responsible; fish standing crops may locally exceed 4,200 g/m^2 (Brock, 1985). In contrast, fish communities in the most productive natural reefs will attain 200 g/m^2 (Goldman and Talbot 1975, Brock, et al., 1979). Average Hawaiian coral reef fish standing crop is 60 g/m^2 (Brock, 1954, Brock, et al., 1979).

The only potential reasons for reducing nutrient content in the discharge would be if canal or trench disposal is selected and stimulation of the nearshore algal turf is aesthetically unacceptable. In this case, treatment with rotating biological contactor (RBC) technology might be more efficient than with mariculture. Either method would require disposal of biomass generated in the process. If a commercially valuable seaweed could be utilized in a canal system and sufficient land area would be made available, then this might be technically and economically viable.

APPLICABILITY OF OTHER PRETREATMENT OPTIONS

In addition to inorganic nutrients, mariculture wastes may contain dissolved and particulate organics, antibiotics, disinfectants including chlorine, iodine and formaldehyde, toxicants including copper-based compounds and perhaps various life stages of non-native species. Trench-disposal of these discharges will filter out particulates, and organics will be acted upon by bacteria in the pores of the substrate. Chlorine and copper-based derivatives are not expected to appear in the combined waste waters in toxic concentrations, as discussed above.

RELEASE OF EXOTIC SPECIES

Importation of exotic species to Hawaii is controlled by a multi-tiered review and permit system administered by the Plant Quarantine Branch of the Hawaii Department of Agriculture. All potential imports and the facilities for holding them must undergo a thorough review prior to approval. Disposal of mariculture effluents into a trench will effectively preclude escape of these species under normal operating conditions. Catastrophic occurrences could result in discharge of exotic species to coastal waters. However, temperate-water species such as have been the focus of much of the prior research at the facility would not be expected to survive in the warm surface waters off Keahole.

CUMULATIVE IMPACTS OF PLANNED DEVELOPMENTS

The recent surge of resort development planning for West Hawaii has implications for NELH. Adjacent to and south of the HOST Park site are the proposed O'oma II and Kohanaiki developments, respectively. Each is anticipated to include golf courses and substantial other landscaped areas. Domestic wastes are projected to be disposed of into or onto the ground. Coastal waters nearby may receive nutrient subsidies as well as rations of various pesticides and other pollutants typical of urban runoff. If this occurs, it may well be that the usefulness of the NELH facility will be compromised. Impacts to the warm water intake may occur, however, at this time there is no way to assess these potential impacts. It may be that in coming years, the purpose and use of the NELH facility may change to depend less on the pristine quality of the coastal waters for such things as materials testing.

WATER QUALITY MONITORING PROGRAM

Purpose

A water quality monitoring program is proposed to document the effects or lack of effects resulting from construction and operation of new facilities at the Natural Energy Laboratory of Hawaii (NELH) and the Hawaii Ocean Science and Technology Park (HOST Park) at Keahole Point, North Kona, Hawaii. Reasons for implementation of a water quality monitoring program are as follows:

- o to protect the source waters used for experimental and production purposes at both facilities;
- o to protect the natural ecosystems present in offshore coastal waters and in the coastal anchialine ponds;

- o to comply with the requirements of the Conservation District Use Permit (CDUP) and the National Pollutant Discharge Elimination System (NPDES) permit for the NELH;
- o to determine whether or not the State of Hawaii water quality standards (Administrative Rules, Title 11, Chapter 54) are being met;
- o to furnish data to the DOE in support of biofouling and corrosion studies; and
- o to assist in implementation of mitigation measures recommended in the HOST Park EIS (HTDC, 1985).

Potential Causes of Water Quality Degradation

Water quality reductions may result from construction and operation of the NELH or HOST Park facilities. Construction of pipelines and installation of subsurface pump stations would cause transient increases in turbidity and disrupt benthic communities along the line. Discharges associated with operations of the facilities could potentially cause long-term degradation of water quality.

Discharges of the NELH and HOST Park are characterized elsewhere in this EIS and in the Host Park EIS. Expansion of the NELH will provide the capacity for testing of open cycle (OC) OTEC components and processes and allow additional mariculture experimentation. Components and characteristics of the NELH OC OTEC discharges which are of concern to maintenance of water quality and ecosystem integrity are:

- o reduced temperatures;
- o reduced concentrations of dissolved oxygen; and
- o increased concentrations of plant nutrients.

Other factors have been suggested as potentially having the capacity to produce negative impacts on nearby ecosystems. These include reduced pH and buffering capacity, dissolved metals concentrations, and chlorine residuals. While the latter two factors are not expected to be associated with the OC OTEC discharges, they may result from ongoing heat exchanger experiments.

Mariculture experimentation at the NELH will result in discharges with the following components and characteristics of most concern:

- o elevated concentrations of inorganic plant nutrients;
- o increased concentrations of dissolved and particulate organic matter; and
- o pulses of chemicals used to clean facilities or maintain water quality in culture containers (especially chlorine compounds).

HOST Park discharges will reflect the mixture of park uses as it develops. Mariculture will be a major activity at the park, and resulting discharges will be similar to, but larger in volume than, the

NELH mariculture discharges. Potentially, large volumes of domestic wastes could also be generated.

NELH presently employs four septic tanks for disposal of domestic wastes. At full development, the volume of domestic waste from the NELH is projected to fall in the range 19,000-27,300 gpd. The HOST Park development plan proposes additional septic tanks as well as leaching fields to dispose of, for development scenarios A, B and C, respectively, 60,000-80,000 gpd, 104,000-142,000 gpd and 159,500-223,300 gpd.

Locations of Potential Impacts

Discharges from the expanded NELH facility may be disposed of in several ways, as described elsewhere in this EIS. Plumes resulting from these discharges were modeled mathmatically, and the results are described above.

Disposal of HOST Park discharges into a trench approximately 2000 feet inland, at the initial flow increment of 20 mgd (13,900 gpm) would create an underground plume 2.7 miles wide at the shoreline and reach 0.9 miles inland. It would require between 187 days and 3.6 years before the disposed ocean water re-emerged at the shoreline. At total development, 144 mgd (100,000 gpm), the plume would be 22.4 miles wide at the shoreline and would reach 2.4 miles inland. The residence time would be between 26 and 144 days.

Disposal of HOST Park discharges into large-diameter, deep injection wells would require 3 wells for the initial flow (20 mgd) and about 15 wells for full development (144 mgd). Significant discharges would occur along about 6,400 feet of the shoreline. Flow thickness would be about 400 feet, and the flux would average about 2.2 gpd/ft^2.

The area of influence of these plumes would be dominated primarily by the HOST Park mariculture plume and secondarily by the NELH mariculture plume. The combined area influenced would include waters along the coast fronting NELH, HOST Park and adjacent properties from the shoreline out to bottom depths of at least -200 feet. Concentrations of discharge waters would be highest directly offshore of the respective disposal trenches and less at increasing distances. Concentrations of plume tracer parameters could be expected to exhibit a relative low offshore between the two mariculture plumes.

Disposal of OTEC waters by canal would create a comparatively concentrated plume off Keahole Point, whereas co-disposal with NELH mariculture waters would provide a much greater degree of dispersion prior to entry to the sea.

Injection well disposal methods would substantially alter the offshore areas most directly affected by the discharges. For the NELH OTEC waters the affected area would encompass about six miles along the coast, but the discharge would emerge at depths of about -300 to -400 feet. HOST Park injection wells would also displace the principal area

of impact offshore to include areas at least 400 feet deep. Neither of the injection well options are preferred due to economic and technical (potential clogging) considerations. The water quality monitoring stations identified below are not therefore based on anticipation of use of these options. If injection is later utilized, monitoring stations would have to be relocated.

Affected Environments

From the above descriptions, it may be concluded that the primary geographic area of concern will be a band offshore of the two facilities out to water depths of at least -200 feet. The offshore bathymetry of this area indicates that the -200 feet contour lies at only about 600-800 feet offshore. Beyond this, the bottom slopes more gently to depths of -400 feet at about 2,000 feet offshore. The benthic community out to depths of approximately -200 feet is dominated by several species of corals, encrusting algae and sea urchins. Beyond this the rocky slope grades into a sandy plain harboring large aggregations of taape (Lutjanus kasmira).

In the water column above the benthos are populations of phytoplankton, zooplankton (including fish eggs and larvae), micronekton and nekton. Marine mammals and threatened or endangered species may also pass through these waters.

Onshore, the anchialine ponds will be affected by the displacement of groundwater around the NELH by the discharge plumes.

Potential Impacts

Degradation of water quality parameters is a negative impact to the extent that biota are affected or that human use and enjoyment of the environment is compromised. A water quality monitoring program should therefore be designed to provide insights to an understanding of these impacts. Baseline data regarding water quality, biota, human use, etc, are required, as is an appreciation of how water quality perturbations may influence biota and/or human use. Present plans for both facilities include a gradual increase in volumes of water to be used. This will allow the monitoring program to provide early detection of any impacts. In addition, the potential impacts are reversible. That is, if discharges are halted, the affected ecosystems could be expected to revert to baseline conditions. Key characteristics or components of the discharge streams and the nature of their potential impacts are discussed below.

Reduced water temperatures. Discharge water temperatures from either facility would not be below 19 C, and lethal impacts are not expected on any affected populations. Impacts will be greatest on the sessile biota; these components may experience physiological and metabolic alterations due to the lowered ambient emperatures. These changes may include reduced spawning periods and lowered metabolic rates. The growth of major space occupiers such as corals may decline retarding overall reef growth (carbonate accretion) and in the long-term altering community structure by changing the competitive balance among species. Species dominance in the benthos would probably change and macrothalloid algae (particulary crustose forms) may become more evident. The physical and biological alteration could lead to avoidance by some motile forms such as fishes but many herbivorous fish and invertebrate species could locally become more abundant due to increased food resources (fleshy algae and detritus).

Reduced dissolved oxygen concentrations. Reaeration of OTEC discharges is strongly recommended to avoid potentially severe toxic effects. Aquaculture discharges could also be depleted in oxygen, especially in the pre-dawn hours. Rapid dilution at entry to the ocean would tend to mitigate against negative impacts regardless of the disposal option adopted, but some sub-lethal reductions of metabolic rates could occur.

Increased nutrient concentrations. Nutrient subsidies could increase algal uptake rates, growth and standing crops. Fleshy macroalgae are notably sparse off the coast except in the surge zone where grazing is inhibited, so impacts of stimulation of the benthic algal community beyond the surge zone might be expressed as increased population sizes of herbivores and higher trophic levels rather than elevated algal standing crops. Offshore phytoplankton densities are very low in these clear, oceanic waters. Nutrient subsidies may increase uptake and growth rates, but the time lag between uptake and growth responses (on the order of a day), advection by offshore currents and grazing by herbivorous zooplankton would all act to minimize elevations of phytoplankton concentrations.

Mariculture additives. Biocides, by definition, are toxic to some species in some concentrations. Of primary concern from mariculture operations are chlorine and its derivitives.

Monitoring Plan

Locations

To be able to determine causal relationships between discharges and impacts, a comprehensive network of monitoring locations is required. Water quality, biological and operational data must be collected. Recommended monitoring locations are grouped and numbered for later reference below.

NELH Stations:

1. Cold water intake
2. Warm water intake
3. OTEC disposal trench
4. Mariculture disposal trench

HOST Park Stations:

5. Cold water supply
6. Warm water intake
7. Disposal trench

Groundwater stations:

8. Monitoring wells
9. Anchialine ponds at NELH and Keahole Airport, adjacent to the NELH access road
10. Wawaloli spring

Offshore stations:

11. One-half mile north of Keahole Point
12. Directly offshore of the OTEC disposal trench
13. Directly offshore of the NELH mariculture disposal trench
14. Off Kolihi Point
15. Directly offshore of the HOST Park disposal trench
16. One-half mile south of Station 15.

Each station would be situated offshore where water depth reaches 100 feet (Figure 3). Discrete samples from near-surface, midwater and near-bottom would be collected. Permanent inshore benthic monitoring stations would be situated shoreward of each offshore water quality station. Data to be collected would include (as appropriate) species present, estimates of abundance, distributional characteristics and biomass estimates; all major macrobiota should be sampled. In conjunction with the benthic sampling, a simple tally of human shoreline use characteristics should be made.

Parameters

Parameters to be monitored at the water quality stations are listed below and numbered for reference in the monitoring plan matrix. Analytical methods to be used are those appropriate to the character of the water to be tested and the expected concentration of the parameter to be measured.

1. Temperature
2. Salinity
3. pH
4. Turbidity
5. Light extinction
6. Nitrate + nitrite nitrogen
7. Ammonia nitrogen
8. Total dissolved nitrogen
9. Total particulate nitrogen
10. Total nitrogen
11. Orthophosphate
12. Total dissolved phosphorous
13. Total phosphorous
14. Total organic carbon

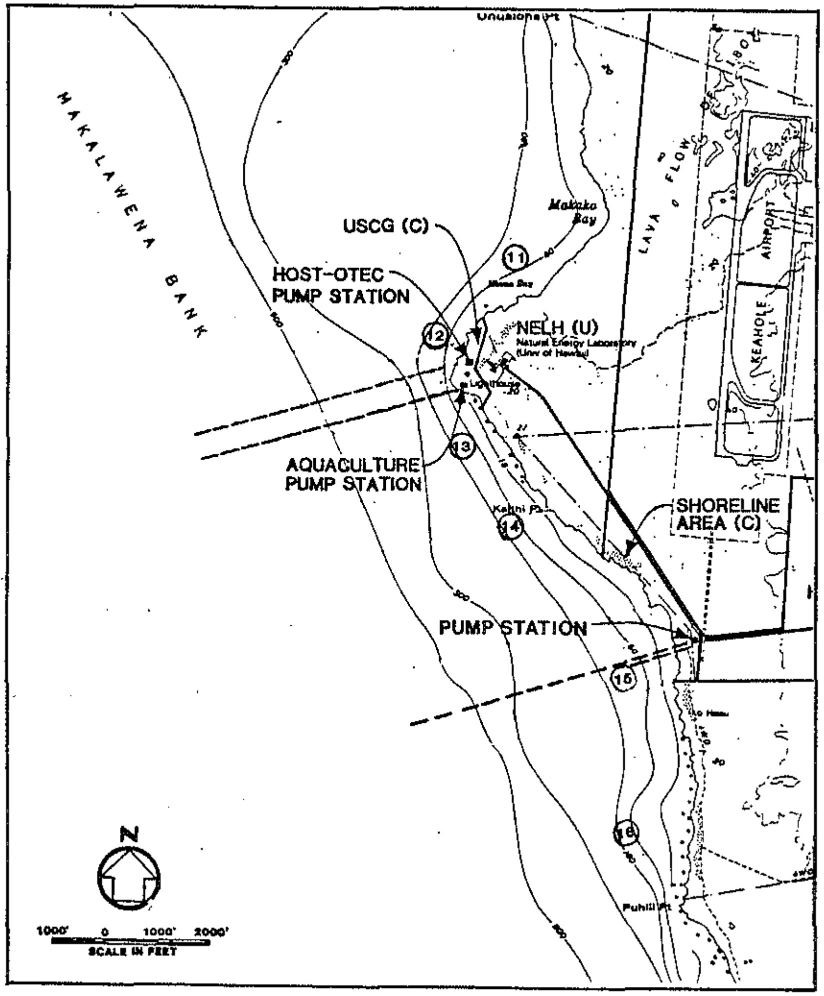

Figure 3. Locations of offshore monitoring stations for the combined NELH/HOST Park water quality program.

15. Total particulate carbon
16. Particulate inorganic carbon
17. Silicate
18. Dissolved oxygen
19. Total suspended solids
20. Total residual oxidant in discharge stream
21. Discharge flow rates
22. Total dissolved gas
23. Fecal bacteria
24. Copper
25. Chlorophyll *a*
26. Biota

In addition to the water quality and biota monitoring, it is recommended that continuous records of climatological parameters, tides and offshore currents be maintained. Currents could be monitored by using several dedicated meters attached to the cold water pipe with power and data transfer handled from NELH via cables.

Frequency

The frequency of monitoring should be designed to allow early detection of the potential effect anticipated. Frequency should be greatest during construction and start-up and later be reduced when consistent patterns are established with confidence. Monitoring frequency should also be adjusted to document the effects of discrete OTEC experiments such as degassing and mariculture operations with relatively high potential impacts, such as tank washdown. The monitoring plan should be frequently reevaluated to provide for modifications based on new results as they become available. The entire network should be reviewed annually. A logical vehicle for this would be an annual report which should comprehensively evaluate the data collected during the previous year, compare them with baseline conditions and discuss relationships between discharges and any observed changes from baseline conditions. Interim data reports should be made available quarterly. Reports should be circulated among the major agencies with interests in the results, especially the State Department of Health, the Fish and Wildlife Service, the National Marine Fisheries Service and the Army Corps of Engineers.

The following frequency codes are used in the monitoring matrix.

1. Continuous
2. Daily
3. Weekly
4. Monthly
5. Semi-annually

Monitoring Matrix

The matrix below summarizes the frequency with which each parameter should be monitored at eacn stationin tne first year; subsequent monitoring schedules should be dependent on the rapidity of growth at NELH and the HOST Park facilities.

PARAMETER	STATION NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	2	2	2	2	2	2	2	3	3	3	4	4	4	4	4	4
2	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4
3	-	-	2	2	-	-	2	3	3	3	4	4	4	4	4	4
4	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4
5	-	-	-	-	-	-	-	-	-	-	4	4	4	4	4	4
6	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4
7	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4
8	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4
9	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4
10	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4
11	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4
12	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4
13	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4
14	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4
15	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4
16	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4
17	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4
18	2	2	2	2	2	2	2	3	3	3	4	4	4	4	4	4
19	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4
20	-	-	2	2	-	-	2	3	3	3	4	4	4	4	4	4
21	-	-	1	2	-	-	2	-	-	-	-	-	-	-	-	-
22	2	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	4	4	4	-	-	-	-	-	-
24	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4
25	3	3	-	3	3	3	3	-	3	-	4	4	4	4	4	4
26	-	-	-	-	-	-	-	5	5	-	5	5	5	5	5	5

Notes:
Daily monitoring times should be varied to document diurnal cycles.
OTEC discharge monitoring should be coordinated with timing of experimental runs.
Only initial monitoring frequencies are shown.

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APPENDIX C

TECHNICAL EVALUATION OF SEAWATER RETURN FLOW DISPOSAL BY DEEP INJECTION WELLS AND SHALLOW TRENCH

DAMES & MOORE

APPENDIX C

DRAFT ENVIRONMENTAL ASSESSMENT AND SUPPLEMENTAL EIS
HYDROLOGICAL SECTION
MODIFICATION OF PROPOSED ACTION TO PERMIT ALTERNATIVE
METHODS OF SEAWATER RETURN FLOW DISPOSAL AT NELH
KEAHOLE, NORTH KONA, HAWAII

Dames & Moore Job No. 03014-119-11
August 15, 1986

GENERAL HYDROLOGY

The climate of the Keahole region is arid in the coastal area but changes gradually to humid in the Hualalai undissected upper slope. The area receives little tradewind rainfall; instead, much of the moisture is accounted for by orographic showers that form within sea breezes which move onshore and upslope. The mean annual rainfall ranges from less than 20/inches along the coast to as much as 75 inches on the lee of Hualalai crater.

Pan evaporation is typically high, in the general range of 0.18/inches per day for the winter and 0.36 inches per day for the summer as measured at Anaehoomalu (Kay et al., 1977). There is no pan evaporation measurement for the Keahole region. Neither perennial nor intermittent streams normally reach the ocean. The sources of groundwater recharge come primarily from the small residual of rainfall after abstraction by evapotranspiration in the upland area and to a lesser extent from the infrequent cyclonic-storm rain affecting the entire area. All groundwater discharges are natural as there is no groundwater development of any kind. These discharges are primarily diffused and not usually visible along the shoreline; only one shoreline spring near Wawaloli Beach, noticeable during low tide, has been observed.

GEOLOGY

The Natural Energy Laboratory of Hawaii (NELH) site in the Keahole Point region consists of primitive basalts of the Hualalai volcanic series, the principal effusive rock of Hualalai volcano (Stearns and MacDonald 1946). The series are composed of heterogeneous, poorly-layered, laterally and vertically restricted units of aa, clinker, and pahoehoe consisting predominantly of basalts and olivine basalts. Individual units extend laterally no more than several hundred feet and vertically less than 100 feet. The average lava flow thickness is about 10 feet. A late trachyte effusion from Puu Waawaa occurs about 15 miles northeast of Keahole.

The lavas for several miles around Keahole Point congealed as flank flows having regional dips of less than 5 degrees; no surficial evidence exists of intrusive rocks, neither dikes nor sills. The

Hualalai volcano, although one of the oldest on the Island of Hawaii, erupted as recently as 1800 to 1801 when the Kaupulehu lava flow reached to within 2,000 feet of Keahole Point. This flow still retains its original appearance because, in the semiarid climate of the coastal sector of western Hawaii, weathering is an extremely slow process. The 1800 to 1801 and previous visible flows have broken, rough surfaces transected by irregular vertical fractures. Lava tubes and other large openings, many of them collapsed, are common.

Except for volumetrically insignificant, spotty accumulations of marine sediments near the coast, all of the exposed rocks are the original, in place basaltic lavas. The depth of weathering is slight, even on the oldest strata, and soil formation is incipient at best. The marine sediments, less than a few feet thick in the most favorable locations, consist of sporadic occurrences of calcareous sand, cemented beach rock, and coral and basaltic gravels driven on shore by stormy seas. These sediments are restricted to a narrow zone along the coast below an elevation of about 10 feet above sea level.

No unusual structural features exist in the region. The nearest rift zone is at least five miles to the north. There is no evidence of faulting or other regional deformation. Indeed, for many miles around Keahole, the geology is that of low dipping flank flows of primitive basalt, a favorable condition for highly permeable aquifers.

GROUNDWATER OCCURRENCE AND AQUIFER CHARACTERISTICS

A thin Ghyben-Herzberg lens underlies the coastal region of western Hawaii from Keahole northward to beyond Kawaihae and southward to beyond Keauhou. In the Keahole vicinity, the lens is brackish, probably less than 125 feet thick and discharges freely along the coast in a narrow band a few feet wide in the intertidal zone. The basal lens water does not meet the U.S. Drinking Water Standards (250 mg/l chlorides, 500 mg/l TDS) even at the top of the lens and at a distance about 3 miles from the shoreline. Chloride, for example, measured to be about 5,000 milligrams per liter (mg/l) to 520 mg/l, and total dissolved solids (TDS) to be about 10,000 to 1,200 mg/l over this distance.

In some places, the lens is visible where the basaltic surface has collapsed and where marine sediments have filled depressions in the original surface near the shore. Maciolek and Brock (1974) describe exposures of the lens (anchialine ponds) along the Kona coast. Small ponds with a surface area of less than 100 square feet exist several hundred yards north of Keahole; however, the nearest ponds of exceptional value are the Kahanaiki Ponds located near Wawahiwaaa Point, 2.25 miles south of Keahole.

The quality of the surge channel water near Wawaloli Beach is influenced by the basal lens discharge to the extent that the coastal water quality standards are exceeded in terms of nitrogen and phosphorus (WRRC, 1980). The principal sources of the nutrients in the basal lens are, however, believed natural rather than man-made. Likewise, the ocean water also exceeds the same nutrient standards.

Previous investigations by the Water Resources Research Center of the University of Hawaii (Adams et al., 1969) found no unusual groundwater conditions in the Keahole region. The infrared scan of the coastline did not show any evidence of substantial freshwater outflow. The resistivity traverse indicated evidence of only brackish water at elevations below the 300-foot topographic contour, lying about 2 miles inland, and interpretation of the audio-magnetotelluric survey suggested the presence of only a very thin layer of fresh water.

Observations made by the Water Resources Research Center of the University of Hawaii (1980) in conjunction with the geophysical results of previous studies show that an unconfined Ghyben-Herzberg lens containing brackish water underlies the area to at least 5 miles north of Keahole, at least 3 miles to the east, and more than 5 miles to the south. Evidently no structural or lithologic barriers interfere with hydraulic continuity throughout this region. The hydraulics of groundwater flow can therefore be described in terms of a highly permeable basaltic aquifer carrying a continuous thin basal lens of brackish water underlain by salt water.

The brackish water of the lens flows toward the coast along a regional gradient of about 1 foot per mile. The head in well 4360-1 (Kalaoa), 3 miles inland of Wawaloli Beach, was 3.2 feet when drilled, implying an average gradient of 1.1 feet per mile. Kanehiro and Peterson (1977) gave an average gradient of 1 to 2 feet per mile for the reach between Kiholo and Puako, north of Keahole. The brackish water discharges preferentially at indentations in the coast, such as Wawaloli Beach. Groundwater flow lines converge toward these indentations while diverging at head lands. The largest visible discharge of the lens in the Keahole area is near Wawaloli Beach.

The salt water below the lens in the near-shore area is alternatively driven inland and seaward by tidal action so that its dynamics cannot be expressed in terms of a unidirectional, uniform flow field. In hydraulic analysis, however, the salt water is usually treated as being static. This assumption avoids insuperable obstacles to both analytical and numerical solutions of the flow equations. The extrusive basalts of the Hualalai volcanic series are very permeable and, like most flank flows of the major volcanoes of Hawaii Island, constitute aquifers of exceptional hydraulic characteristics. For the area between Kiholo and Puako, 12 to 22 miles north of Keahole but including Hualalai lavas, Kaneh ro and Peterson (1977) reported regional hydraulic conductivity of 3,369 feet per day as computed by tidal analysis and of 9,092 feet per day as computed from the flow equation in which the discharge was obtained by hydrologic budgeting. A probable outflow rate, from the lens, of 6.38 mgd/mile was calculated by the budget approach. For the Keahole area, a figure of 2 to 5 mgd/mile is likely based on comparison of drainage area sizes (Keahole vs Kiholo and Puako).

Hydraulic conductivity values of the above order are applicable to the Keahole region. Expressed as a range, hydraulic conductivity is likely to be greater than 2,000 feet per day but less than 10,000 feet per day; the probable regional value is 4,000 to 5,000 feet per day. On a local scale, of about 100 feet or less, the hydraulic conductivity may be very low or extremely high, but for aquifer analysis a regional value of 5,000 feet per day is reasonable. Effective porosity of basalts cannot be conveniently measured; a conservative value of 0.10 is commonly employed.

Hawaiian basalt aquifers are anisotropic with respect to hydraulic conductivity. This anisotropy is a result of layering of sequential lava flows in the seaward direction, and as a result lava tubes oriented in the direction of the flow. The layering tends to orient highly permeable zones such as clinker layers between flows in a seaward direction. Estimates of the ratio of anisotropy have ranged from 5-1 to 200-1, horizontal to vertical. The basalts in the Keahole area are also highly fractured, and in localized areas may transmit water more readily vertically than horizontally. The overall anisotropy would therefore be expected to be at the lower range, approximately 5-1.

The groundwater lens is characterized as an unconfined, thin lens with a typically flat gradient and a flow direction from the mountains toward the ocean. The 1980 University of Hawaii study showed that the coastal part of the lens experiences appreciable ocean tidal influence. At distances of up to 336 feet inland, tidal efficiencies ranges from 69 percent to 100 percent. Further inland at 600 feet, the efficiencies decreased to 43 to 68 percent. There is no simple accurate method for separating the tidal component from the head measurement to reveal the true groundwater head associated with the unidirectional ambient seaward flux. Also, it is not possible to measure the actual basal lens thickness without a drilled hole of sufficient depth. By applying the Ghyben-Herzberg ratio, however, the approximate thickness is calculated to be less than 125 feet within the area of concern.

ON-LAND OCEAN WATER DISPOSAL

It is anticipated that the OTEC activities will generate an ocean water outflow quantity of approximately 16,100 gpm. From additional mariculture operations at NELH, an ocean water outflow quantity of approximately 25,900 gpm is anticipated. Therefore, additional ocean water outflow quantity may eventually approach 42,000 gpm at full development.

Three possible schemes of on-land disposal have been studied to return the anticipated outflow quantity to the ocean. The disposal schemes examined involve possible combinations of shallow trench and deep well disposal. The disposal schemes examined are:

- o Disposal of OTEC discharges by deep wells, and disposal of mariculture discharges in a shallow trench along the existing road towards HOST Park (See Plot Plan, Plate 1).
- o Disposal of OTEC and/or mariculture discharges in a shallow trench along the existing road towards HOST Park.
- o Disposal of OTEC discharges in a shallow trench within the NELH laboratory compound and disposal of mariculture dishcarges in a shallow trench along the existing road towards HOST Park.

The disposal schemes are similar in the basic engineering concept, which is to convert the used ocean water into groundwater flow. The schemes would take advantage of the storage capacity, porosity, and the filtration effect of the lava formation to provide dispersion, diffusion and residence time before the water is discharged to the ocean as underwater seepage flow along the coast. In addition, both the deep well and shallow trench disposal schemes would utilize gravity as the prime moving force and thus conserve energy.

The hydraulic and environmental impacts of the disposal schemes were evaluated by means of analytical computer modeling. The basic hydraulic parameters such as coefficient of storage, coefficient of transmissibility, porosity, hydraulic conductivity and transmissive flux were obtained from published data of the basaltic aquifer in the Keahole region. The detailed assumptions and findings are presented in the Appendix.

EFFECTS OF ON-LAND OCEAN WATER DISPOSAL

Disposal of OTEC Discharges by Deep Wells

The disposal of OTEC discharges (16,100 gpm) by deep wells was modeled using an analytical computer model based on the Theis non-equilibrium equation. Boundary conditions were set based on offshore bathymetric data. The bathymetric data indicates that the -300 foot bathymetric contour runs approximately north to south at a distance of roughly 800 feet offshore from Keahole Pt. at the closest point. Based on this data, the ocean boundary was modeled using an image well point equidistant from the approximate north to south -300 foot bathymetric contour. Injection below -300 feet was selected based on injecting below the ocean thermocline.

Because of higher density due to lower temperature, and relatively close proximity to the shoreline, the injected OTEC discharges were modeled based on the flow being confined to a zone from elevation -300 to -400 feet. It is anticipated that the discharge would actually not be confined to this zone, but may go deeper due to lower temperatures and consequent higher densities relative to the ambient groundwater. There would also be a tendency for the sea water return to rise because of hydraulic head increases caused by injection. This tendency would, however, be somewhat counteracted by the density

(temperature) gradients and by the constant head condition imposed by the ocean when the seawater return water reaches areas overlain by the ocean. We therefore believe assuming a flow confined to the -300 to -400 foot zone would be appropriate and possibly conservative.

For the above modeling, we calculate that 85% of the discharge would occur over a distance of 30,000 feet along the -300 foot bathymetric contour, an average of 660 gpd/foot. Assuming that the flow was distributed evenly between the -300 to -400 foot contour would result in an average of 1.2 gpd/square foot of ocean bottom in this zone. Discharge would actually be greater in offshore areas in near proximity to the injection point. At these locations, the flow would be approximately 2.9 gpd/square foot between the -300 and -400 bathymetric contours. The distribution of deep well injection discharge is depicted on Plate 2.

A minimum residence time of approximately three months is calculated, using an expanding cylinder model (see Appendix).

Disposal of OTEC Discharges in a Shallow Trench within NELH Laboratory Compound

The disposal of OTEC discharges (16,100 gpm) in a shallow trench within the NELH laboratory compound was modeled using an analytical computer model based on the Theis non-equilibrium equation. Boundary conditions were set based on shoreline geometry. Keahole point is formed by the confluence of an approximate north-south and an east-west shoreline. Based on this, and because disposal would occur close to the shoreline (within approximately 100 feet of the shoreline at the closest point) the disposal was modeled using three image well points, in accordance with the theory of images, to model the two perpendicular ocean boundaries.

For the above modeling, we calculate that 67% of the discharge would occur over a horizontal distance of 600 feet along the shoreline, an average of 26,000 gpd/foot. Assuming that the flow was distributed evenly between the 0 to -50 bathymetric foot contour would result in an average of 26 gpd/square foot of ocean bottom in this zone. Discharge would be greater in offshore areas closest to the discharge trench. At these locations, the flow would be approximately 72 gpd/square foot.

Minimum residence times were calculated using an expanding sphere and expanding cylinder model (see Appendix). Because of the proximity of the shoreline, minimum residence times will be less than one day.

Disposal in a Shallow Trench Along the Existing Road Towards HOST Park

The disposal of mariculture discharges (25,900 gpm) in a shallow trench was modeled using an analytical computer model based on the Theis non-equilibrium equation. Boundary conditions were set based on shoreline geometry. Keahole point is formed by the confluence of an approximate north-south and an east-west shoreline. Based on this, and because disposal would occur close to the shoreline (within approximately 750 feet of the shoreline at the closest point) the disposal was modeled using three image well points, in accordance with the theory of images, to model the two perpendicular ocean boundaries.

Based on average distance from the shoreline, and assuming an anisotropy of approximately 5 to 1, the flow was modeled for a flow thickness of 200 feet. For the above modeling, we calculate that 85% of the discharge would occur over a distance of 4,300 feet along the shoreline, an average of 7,300 gpd/foot. Assuming that the flow was distributed evenly between the 0 to -200 foot bathymetric contour would result in an average of 1.9 gpd/square foot of ocean bottom in this zone. Discharge would be greater in offshore areas closest to the discharge trench. At these locations, the flow would be approximately 4.2 gpd/square foot.

For disposal of combined mariculture and OTEC discharges (42,000 gpm), the modeling indicates that 77% of the discharge would occur over a shoreline distance of 3800 feet, an average of 12,200 gpd/foot. Assuming that the flow is evenly distributed between the 0 and -200 foot bathymetric contour results in an average of 3.2 gpd/square foot of ocean bottom in this zone. Discharge is greatest in offshore areas closest to the discharge trench. At these locations, the flow would be approximately 5.9 gpd/square foot. Minimum residence times were calculated using an expanding sphere and expanding cylinder model (see Appendix), and are tabulated below:

		Minimum Residence Time
Mariculture Discharge	25,900 gpm	5 to 35 days
Combined Discharge	42,000 gpm	3 to 23 days

Effects of Discharge on Groundwater

The proximity of the proposed discharges to the shoreline and the location on a point (Keahole) limits the effects on the groundwater table. The land configuration results in much less groundwater flow occurring under the site (due to the groundwater divergence caused by the presence of a point of land), and the presence of two ocean boundaries in near proximity to the discharge locations results in relatively rapid migration of discharges to the coastlines.

The deep well injection probably would not have significant effect on the thin lens of brackish water found in the general area. The injected OTEC discharges would be discharged in a zone from elevation -300 to -400 feet. We anticipate that the discharge would not be confined to this zone, but may go deeper due to lower temperatures and consequent higher densities relative to the ambient groundwater. There would also be a tendency for the sea water return to rise because of hydraulic head increases caused by injection. This

tendency would, however, be somewhat counteracted by the density (temperature) gradients and by the constant head condition imposed by the ocean when the seawater return water reaches areas overlain by the ocean. We therefore believe assuming a flow confined to the -300 to -400 foot zone would be appropriate.

The primary effect caused by disposal in shallow trenches would be the disruption and displacement of the existing brackish water lens. The lens is unsuitable for groundwater development, but apparently is the source of water for some stands of kiawe trees located north of Keahole Point. Trees that have deep root systems that reach the groundwater level probably would not survive the displacement of the brackish water lens by the saline ocean water plume.

The disposal by trenches would displace the existing groundwater flow in the immediate vicinity of Keahole Point. The area of displacement varies with the amount of discharge and locations, with the discharge of OTEC discharges within the NELH laboratory compound having the least effect, and the discharge of combined OTEC and mariculture discharges at the road towards HOST park having the largest effect. Flow nets showing flow patterns for the various discharges analyzed are presented on Plates 3 through 5.

The brackish water lens also is the source of water for some anchialine ponds in the vicinity of Wawahiwaa Point approximately 2 miles south of the proposed ocean water disposal area of the NELH site. These ponds are not within the projected disposal plume, for NELH discharge. The effect of the discharge of the ocean water return into the ocean is being analyzed separately.

DESIGN CONSIDERATIONS

Deep Well Disposal

Large diameter deep disposal wells have been used successfully in Hawaii to dispose of large quantities of treated industrial wastewater. For the OTEC activities, a disposal requirement of 16,100 gpm, it is estimated that 4 wells (2 primary and 2 backup) would be needed. The wells would be located immediately makai of the NELH laboratory. The wells would be approximately 2 feet in diameter, 400 feet deep and spaced at least 100 feet apart. The wells would be cased with solid casing from 0 to 300 feet to limit discharge to a depth below 300 feet and with either open hole or slotted casings from 300 to 400 feet. The wells may need to be deepened if low permeability zones are encountered which reduce capacity. It is estimated that each well could handle about 11.5 mgd (8,000 gpm). Therefore, for a 16,100 gpm operation, only 2 of the 4 wells will be operating. The extra wells are standby capacity for planned maintenance or in case of 1 or more wells becoming inoperative due to clogging. The piping system and well head design would require careful engineering for smooth operation and ease of maintenance.

Alternatively, a forced injection system can be used. However, it would be a complex mechanical installation that would require continuous electrical energy consumption and frequent maintenance. Therefore, a forced injection system is not recommended for NELH.

Shallow Surface Trench Disposal

Proposed locations of shallow surface trench disposal are along the roadway alignment from NELH towards the proposed HOST Park and along the makai boundary of the facility or inland within the NELH compound. We understand that current planning calls for trench excavation, and replacement with a perforated pipe and crushed lava or gravel. This would not enable maintenance of the trench, but the end of the trench would be designed to enable extension should clogging occur or if additional capacity is required during the phased development of NELH activities.

For the roadway towards the proposed HOST Park, the proposed disposal trench orientation is roughly parallel to and approximately 750 feet from the shoreline. The ground elevation in the area is approximately 10 feet above sea level. For disposal of the anticipated projected quantity of ocean water of 16,100 gpm from the OTEC activities, the theoretical trench dimensions could be 5 feet wide, 5 feet deep, and 225 feet long. For planning purposes, it would be prudent to allow for twice the theoretical trench length. The extra trench length would provide an allowance for non-homogeneity of the hydrogeologic characteristics of the proposed disposal area subsurface materials and to mitigate silting and clogging problems that may occur in the initial start up stage. The trench should also be designed to allow for extension, if additional capacity is required or to replace clogged areas.

The performance of the disposal trench should be monitored to collect operation and maintenance data for subsequent phases of the expansion program. Assuming that the technical parameters used in the theoretical computations can be validated by the actual performance, the disposal trench can then be incrementally extended to handle more disposal quantity as NELH facilities expand. Theoretically, a 362-foot disposal trench 5 feet wide by 5 feet deep could handle the projected additonal disposal quantity of 25,900 gpm from mariculture operations. Therefore, for the total proposed additional ocean water outflow of 42,000 gpm, the theoretical trench dimensions could be 5 feet wide, 5 feet deep, and 587 feet long.

The available length of the disposal area is more than 2,000 feet. The length of the trench, however, can be shortened by digging a deeper trench. A 10-foot wide by 10-foot deep trench would require theoretical trench lengths of 98 feet, 158 feet, and 256 feet, respectively for disposal quantities of 16,100, 25,900 and 42,000 gpm, respectively, without allowing for any safety factors.

For the trench within the NELH laboratory compound, the proposed disposal trench orientation is roughly parallel to and approximately 100 feet from the shoreline. For disposal of the anticipated projected quantity of ocean water of 16,100 gpm from the OTEC activities, the theoretical trench dimensions could be 5 feet wide, 5 feet deep, and 144 feet long. A ten foot wide by ten foot deep trench would require a theoretical trench length of 59 feet. The above discussions regarding increasing the design length and monitoring the performance of the trench would apply.

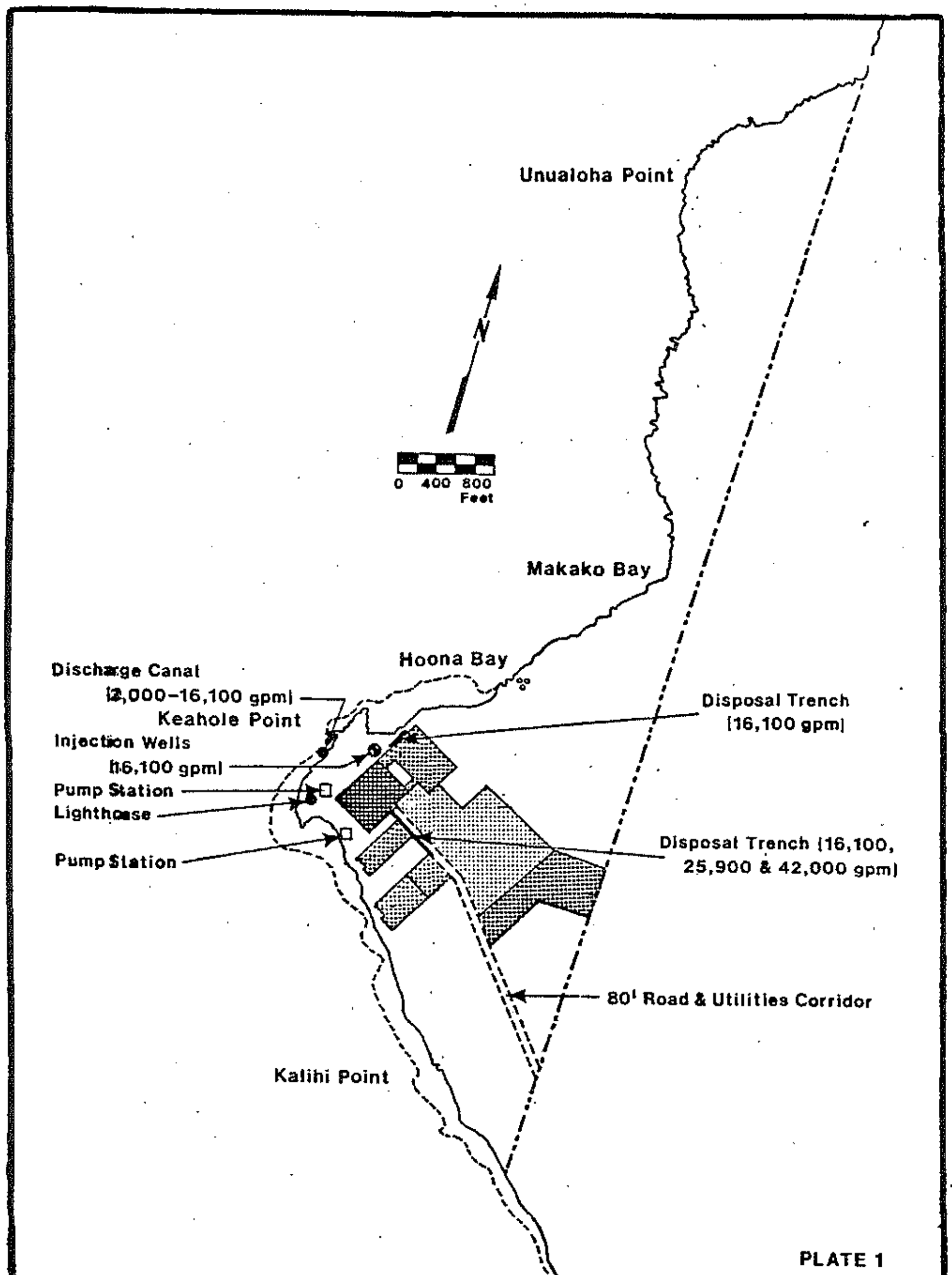
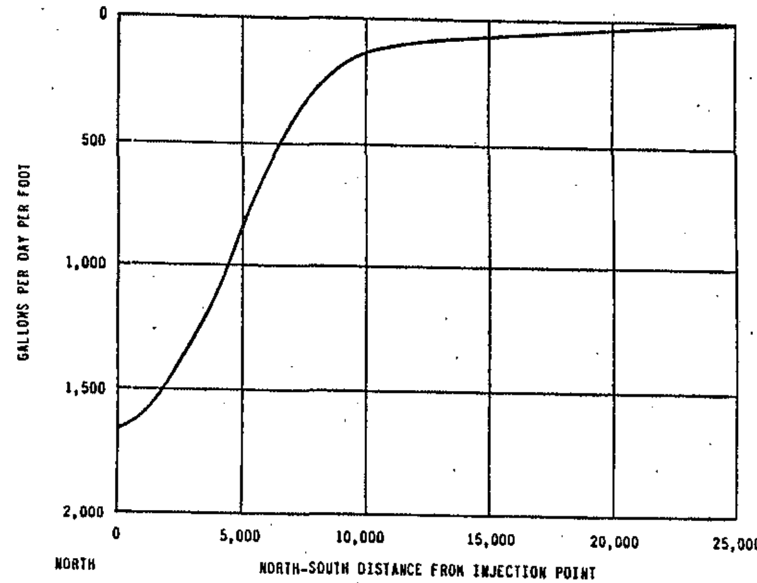
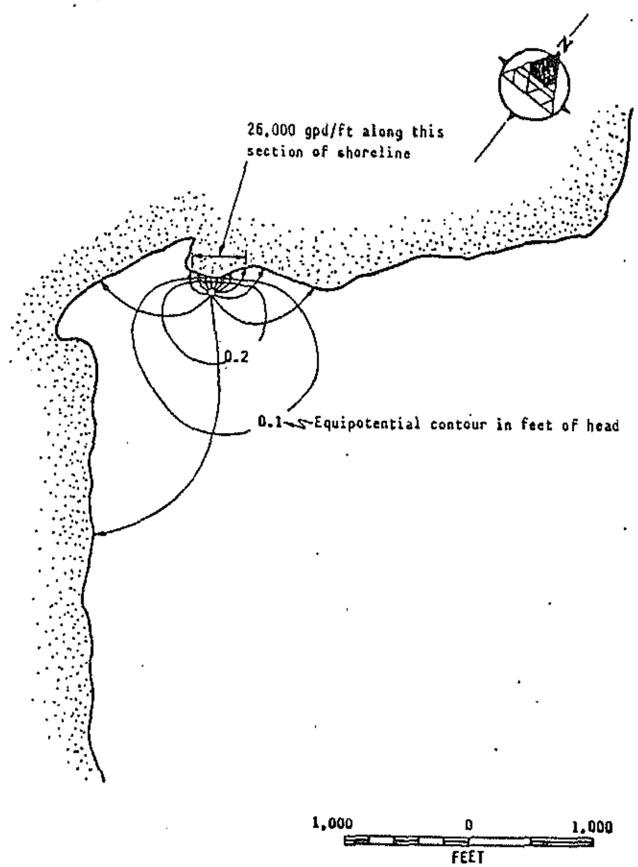


PLATE 1
BJ GRAPHICS



DISTRIBUTION OF DEEP WELL INJECTION DISCHARGE (16,100 GPM)
ALONG APPROXIMATE 300 FOOT CONTOUR

PLATE 2
DAMES & MOORE

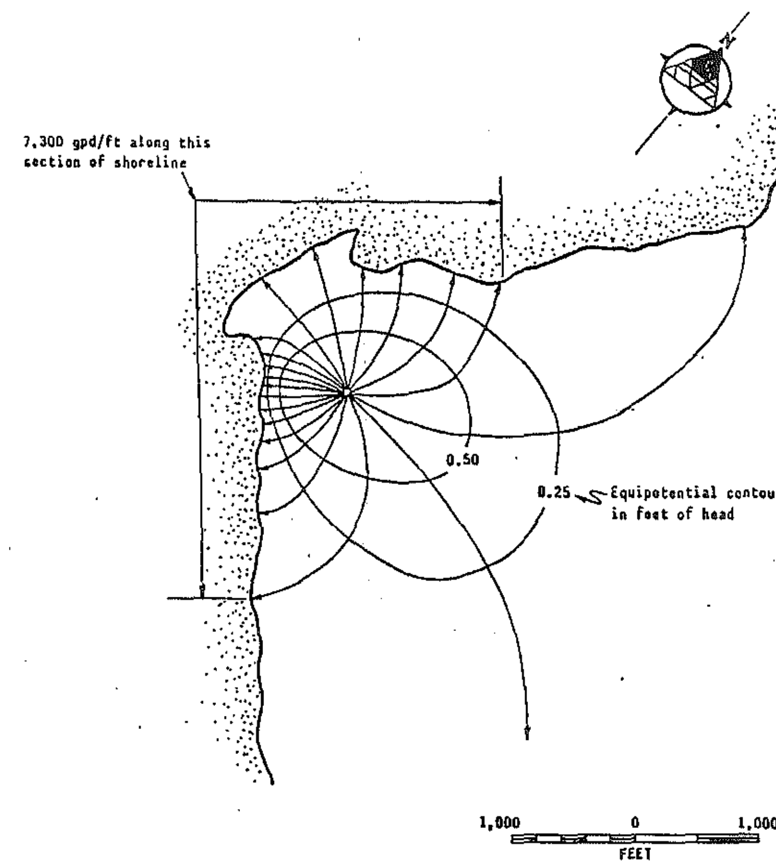


FLOW NET

DISCHARGE TO DISPOSAL TRENCH WITHIN NELH

(16,100 GPM)

PLATE 3
DAMES & MOORE

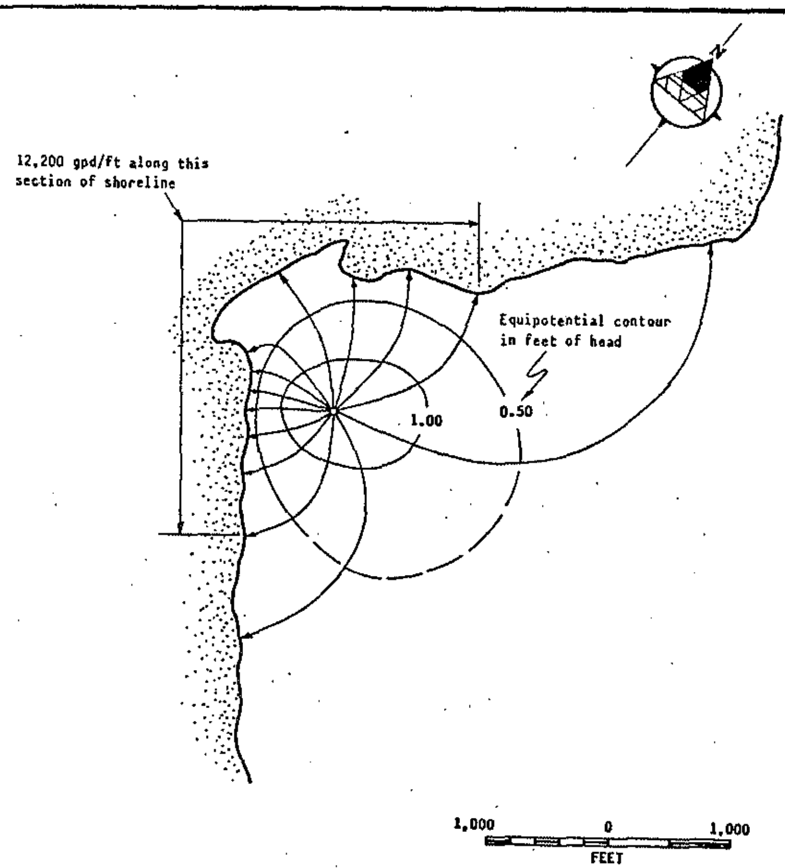


FLOW NET

DISCHARGE TO DISPOSAL TRENCH ALONG ROADWAY TO NELH

(25,900 GPM)

PLATE 4
DAMES & MOORE



FLOW NET

DISCHARGE TO DISPOSAL TRENCH ALONG ROADWAY TO NELH

(42,000 GPM)

PLATE 5
DAMES & MOORE

APPENDIX

HYDRAULICS OF ON-LAND OCEAN WATER DISPOSAL

1. Known Hydraulic Parameters and Assumptions.

   a) The regional hydraulic conductivity k is assumed to be 5,000 ft/day. Hydraulic conductivity values reported by Kanehiro and Peterson (1977) were 3,369 ft/day as computed by tidal analysis and 9,032 ft/day as computed from the flow equation.

   b) The effective porosity n of lava formations is assumed to be 0.10.

   c) The ocean water to be disposed is assumed to be relatively free of solids, contaminants and entrained air.

2. Shallow Trench Disposal at Roadway towards HOST Park

For shallow trench disposal at the roadway towards HOST Park, it is assumed that the trench would be 5 feet wide and 5 feet or 10 feet wide and 10 feet deep with the trench bottom close to the groundwater level due to the low ground elevation at the site. It is anticipated that the half-cylinder shaped plume analysis would be relevant for this site.

Total disposal quantity equation for the half-cylinder shaped plume is:

$$Q = \frac{k\pi\ s\, x}{\ln\left(\frac{r_e}{r_o}\right)} \tag{1}$$

where,
Q = the total disposal quantity = 23 mgd, 37 mgd, and 60 mgd
k = hydraulic conductivity = 5,000 ft/day
s = injection head = 5 ft or 10 ft
x = length of trench
r_e = minimum distance from the trench to the coastline = 750 ft
r_o = half width of the trench = 2.5 ft or 5 ft

For a 5 feet wide and deep trench, solving the equation for x yields trench lengths of 225 feet, 362 feet, and 587 feet for disposal quantities of 23 mgd, 37 mgd, and 60 mgd, respectively. For a 10 feet wide and deep trench, solving the equation for x yields trench lengths of 98 feet, 158 feet, and 256 feet for disposal quantities of 23 mgd, 37 mgd, and 60 mgd, respectively. These distances should be multiplied by an appropriate factor of safety for design.

3. Shallow Trench Disposal Within the NELH Laboratory Compound

For shallow trench disposal within the laboratory compound, it is assumed that the trench would be either 5 feet wide and 5 feet deep or 10 feet wide and 10 feet deep with the trench bottom close to the groundwater level due to the low ground elevation at the site. It is anticipated that the half-cylinder shaped plume analysis would be relevant for this site.

For a 5 feet wide and deep trench, solving equation 1 for x yields a trench length of 144 feet for a disposal quantity of 23 mgd. For a 10 feet wide and deep trench, solving the equation for x yields a trench length of 59 feet. This distance should be multiplied by an appropriate factor of safety for design.

4. Deep Well Disposal.

The feasibility of ocean water disposal by wells was examined by using the Theis non-equilibrium equation:

$$S = \frac{Q}{4\pi T}\int_u^{\infty} \frac{e^{-u}}{U}\,du \tag{2}$$

where,
s = drawdown or build up of water level in a well
Q = disposal rate
T = coefficient of transmissibility
$U = r^2 S/4Tt$

where,
S = coefficient of storage
t = time since disposal started
r = distance from well

A computer program, consisting of a solution of the Theis non-equilibrium equation modified to include the interference effects from multiple wells, was applied to study the hydraulics of disposal by wells.

The following hydraulic properties were used for the [illegible] formation: the coefficient of transmissibility (T), 3,740,000 gpd/foot (for K = 5,000 [illegible]), effective aquifer thickness in well vicinity of 100 feet); the coefficient of storage [illegible] 0.1.

5. Shallow Trench Disposal.

The feasibility of ocean water disposal by shallow trenches were also examined by modeling the trenches as shallow wells and using the Theis non-equilibrium equation.

The ocean boundary was modeled using image pumping wells located equidistant from and on the opposite side of the ocean boundary.

The ocean boundary was modeled using image pumping wells located equidistant from and on the opposite side of the ocean boundary. For the model, the injection zone was assumed to be a confined aquifer and the ocean boundary assumed to be the contact zone of the injection zone with the ocean floor.

6. Residence Time Computation for Enlarging Sphere Model

Point disposal of a volume per unit time is expressed as:

$$Q \quad dt = \frac{4 \cdot n \cdot \pi (r+dr)^3}{3} - \frac{4 \cdot n \cdot \pi \cdot r^3}{3} \tag{6}$$

where, Q = constant rate of disposal
r = distance from point of disposal
n = affective porosity = 0.10
t = residence time

Eliminating the higher degree differentials give:

$$Q \cdot dt = 4 \cdot n \cdot \pi \cdot r^2 \cdot dr \tag{7}$$

and by integration,

$$r = \left(\frac{3 \cdot Q \cdot t}{4 \pi n}\right)^{1/3} \tag{8}$$

or

$$t = \frac{4 \cdot n \cdot \pi \cdot r^3}{3 \cdot Q} \tag{9}$$

7. Residence Time Computation for Enlarging Cylinder Model

The plume formed is envisioned to be an ever enlarging cylinder. The governing equation is:

$$r = (Q \cdot t/n \cdot \pi \cdot z)^{1/2} \tag{10}$$

or

$$t = \frac{n \cdot z \cdot \pi \cdot r^2}{Q} \tag{11}$$

where, n = effective porosity = 0.10
z = aquifer thickness, for anisotrophy of 5 horizontal to 1 vertical, z would be 150 feet for a flow distance of 750 feet to the shoreline.
π = 3.1416
r = distance to shoreline
Q = constant rate of disposal

ADDENDUM
DRAFT ENVIRONMENTAL ASSESSMENT AND SUPPLEMENTAL EIS
HYDROLOGICAL SECTION
MODIFICATION OF PROPOSED ACTION TO PERMIT ALTERNATIVE
METHODS OF SEAWATER RETURN FLOW DISPOSAL AT NELH
KEAHOLE, NORTH KONA, HAWAII

ON-LAND OCEAN WATER DISPOSAL

Three possible schemes of on-land disposal were previously studied. The disposal schemes examined involved possible combinations of shallow trench and deep well disposal. The disposal schemes examined were:

- Disposal of OTEC discharges by deep wells, and disposal of mariculture discharges in a shallow trench along the existing road towards HOST Park.
- Disposal of OTEC and/or mariculture discharges in a shallow trench along the existing road towards HOST Park.
- Disposal of OTEC discharges in a shallow trench within the NELH laboratory compound and disposal of mariculture discharges in a shallow trench along the existing road towards HOST Park.

We understand that the location of the shallow trench within the NELH compound has been shifted to that indicated on the Plot Plan, Plate A1. Modeling has been conducted to reanalyze the effects of discharge at this new location.

The hydraulic and environmental impacts of the disposal schemes were evaluated by means of analytical computer modeling. The basic hydraulic parameters such as coefficient of storage, coefficient of transmissibility, porosity, hydraulic conductivity, and transmissive flux were obtained from published data on the basaltic aquifer in the Keahole region.

EFFECTS OF ON-LAND OCEAN WATER DISPOSAL

The disposal of OTEC discharges (16,100 gpm) in a shallow trench within the NELH laboratory compound was modeled using an anlytical computer model based on the Theis non-equilibrium equation. Boundary conditions were set

based on shoreline geometry. Keohole point is formed by a confluence of an approximate north-south and an east-west shoreline. Based on this, and because disposal would occur close to the shoreline (within approximately 250 feet of the shoreline at the closest point) the disposal was modeled using three image well points, in accordance with the theory of images, to model the two perpendicular ocean boundaries.

For the above modeling, we calculate that 80 percent of the discharge would occur over a horizontal distance of 4,100 feet along the shoreline, an average of 4,500 gpd per foot. Assuming that the flow was distributed evenly between the 0- and -50-foot bathymetric contour would result in an average of 4.5 gpd per square foot of ocean bottom in this zone.

Discharge would be greater in offshore areas closest to the discharge trench. At these locations, the flow would be approximately 6.6 gpd per square foot.

Minimum residence times were calculated using an expanding sphere and expanding cylinder model. Because of the proximity of the shoreline, minimum residence times will range from 1 to 2 days.

The proximity of the proposed discharge to the shoreline and the location on a point (Keahole) limits the effects on the groundwater table. The land configuration results in much less groundwater flow occurring under the site (due to the groundwater divergence caused by the presence of a point of land), and the presence of two ocean boundaries in near proximity to the discharge locations results in relatively rapid migration of discharges to the coastlines.

The primary effect caused by disposal in shallow trenches would be the disruption and displacement of the existing brackish water lens. The lens is unsuitable for groundwater development, but apparently is the source of water for some stands of kiawe trees located north of Keahole Point. Trees that have deep root systems that reach the groundwater level probably would not survive the displacement of the brackish water lens by the saline ocean water plume.

The disposal by trenches would displace the existing groundwater flow in the immediate vicinity of Keahole Point. A flow net showing the flow pattern for the discharge analyzed is presented on Plate A2.

The brackish water lens also is the source of water for some anchialine ponds in the vicinity of Wawahiwaa Point approximately 2 miles south of the proposed ocean water disposal area of the NELH site. These ponds are not within the projected disposal plume for NELH discharge.

The effect of discharge of the ocean water return into the ocean is being analyzed separately. The rate of discharge per unit area is much greater for the trench discharge than for the deep injection well, particularly for the trench within NELH. However, the ocean water return would be nearly indistinguishable from the ocean water it is merging with.

DESIGN CONSIDERATIONS

For the relocated trench within the NELH laboratory compound, the proposed disposal trench orientation is roughly perpendicular to and approximately 250 feet from the shoreline at the closest point. For disposal of the anticipated projected quantity of ocean water return of 16,100 gpm from OTEC activities, the theoretical trench dimensions could be 5 feet wide, 5 feet deep, and 193 feet long. A 10-foot wide by 10-foot deep trench would require a theoretical trench length of 79 feet.

Our previous recommendations regarding doubling the length of the trench for design purposes and monitoring of the performance of the trench would apply.

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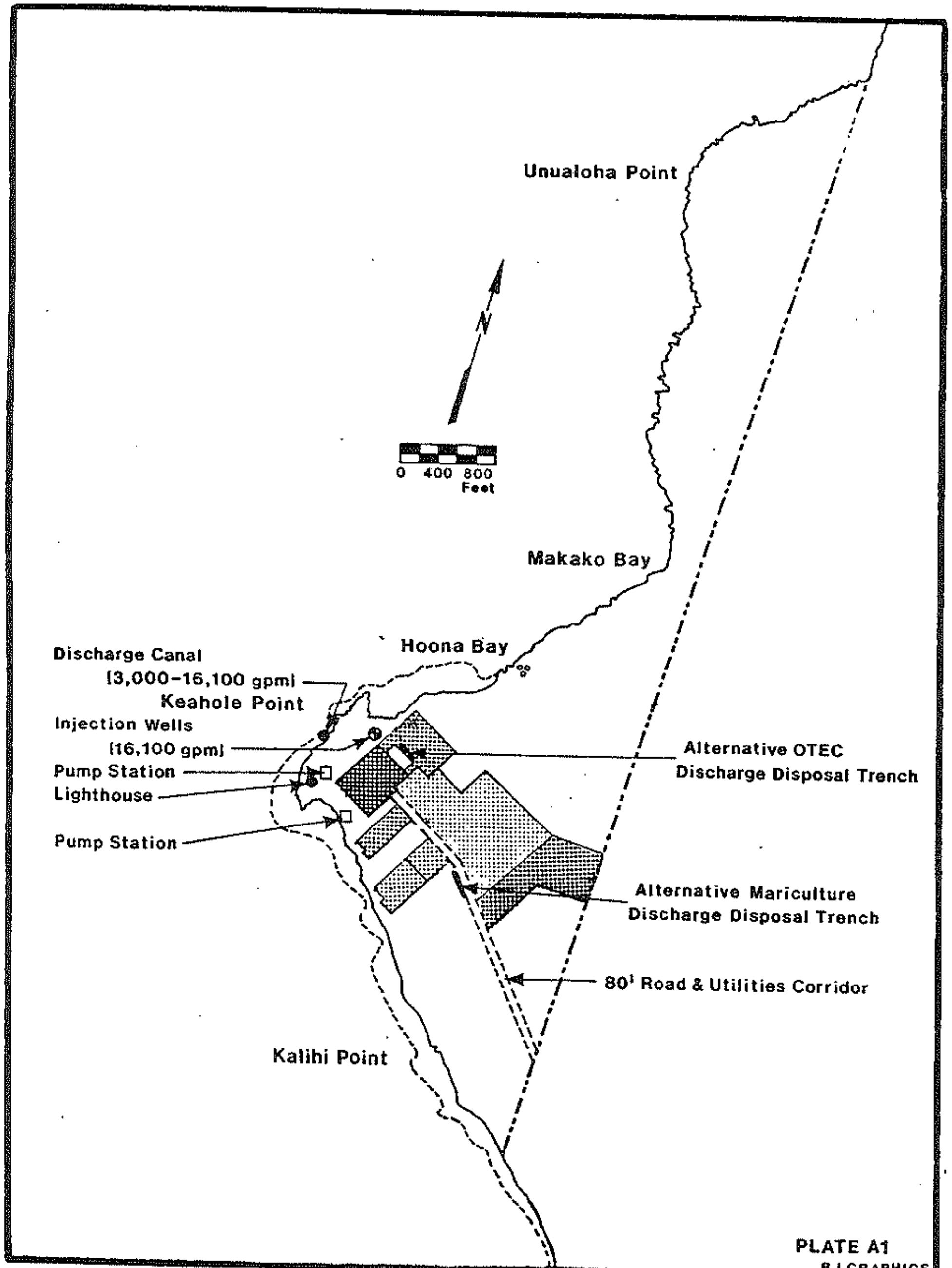
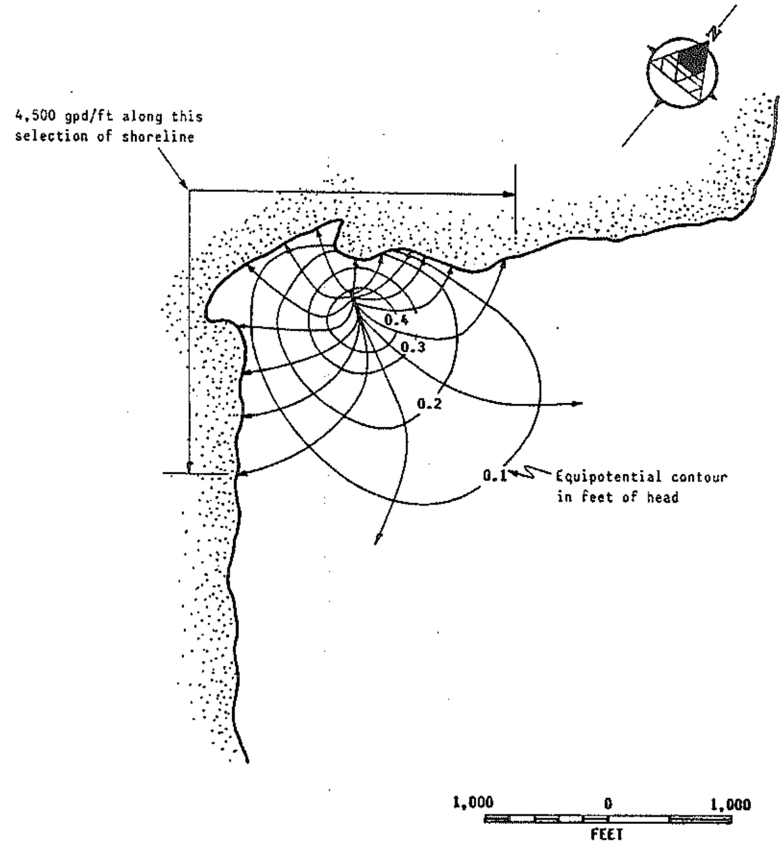


PLATE A1
BJ GRAPHICS



FLOW NET

DISCHARGE TO ALTERNATIVE DISPOSAL TRENCH WITHIN NELH

(16,100 GPM)

PLATE A2
DAMES & MOORE

ADDENDUM II
DRAFT ENVIRONMENTAL ASSESSMENT AND SUPPLEMENTAL EIS
HYDROLOGICAL SECTION
MODIFICATION OF PROPOSED ACTION TO PERMIT ALTERNATIVE
METHODS OF SEAWATER RETURN FLOW DISPOSAL AT NELH
KEAHOLE, NORTH KONA, HAWAII

ON-LAND OCEAN WATER DISPOSAL

Four possible schemes of on-land disposal were previously studied. The disposal schemes examined involved possible combinations of shallow trench and deep well disposal. The disposal schemes examined were:

- Disposal of OTEC discharges by deep wells, and disposal of mariculture discharges in a shallow trench along the existing road towards HOST Park.
- Disposal of OTEC and/or mariculture discharges in a shallow trench along the existing road towards HOST Park.
- Disposal of OTEC discharges in a shallow trench within the NELH laboratory compound and disposal of mariculture discharges in a shallow trench along the existing road towards HOST Park.
- Disposal of OTEC discharges in a shallow trench at an alternative location within the NELH laboratory compound and disposal of mariculture discharges in a shallow trench along the existing road towards HOST Park.

We understand that the preferred location of the trench along the existing road towards HOST Park has been shifted to that indicated on the Plot Plan, Plate B1. Modeling has been conducted to reanalyze the effects of discharge at this new location. Modeling has also been conducted to analyze the effects of simultaneous discharge at trenches within NELH and along the road towards HOST Park, at the locations indicated on the Plot Plan, Plate B1.

The hydraulic and environmental impacts of the disposal schemes were evaluated by means of analytical computer modeling. The basic hydraulic parameters such as coefficient of storage, coefficient of transmissibility, porosity, hydraulic conductivity, and transmissive flux were obtained from published data on the basaltic aquifer in the Keahole region.

EFFECTS OF ON-LAND OCEAN WATER DISPOSAL

The disposal of OTEC and mariculture discharges were modeled using an analytical computer model based on the Theis non-equilibrium equation. Boundary conditions were set based on shoreline geometry. Keohole point is formed by a confluence of an approximate north-south and an east-west shoreline. Based on this, and because disposal would occur relatively close to the shoreline (within approximately 250 feet of the shoreline at the closest point to the discharge trench within NELH, and within approximately 900 feet of the shoreline at the closest point to the discharge trench along the road to HOST Park) the disposal was modeled using image well points, in accordance with the theory of images, to model the two perpendicular ocean boundaries. For the case of mariculture discharges only, three image well points were used. For the case of combined OTEC and mariculture discharges, a total of six image well points were used, three for each discharge.

<u>Mariculture Discharges</u> - For the above modeling, we calculate that 76 percent of the discharge would occur over a horizontal distance of 6,200 feet along the shoreline, an average of 4,600 gpd per foot. Assuming that the flow was distributed evenly between the 0- and -200-foot bathymetric contour would result in an average of 1.2 gpd per square foot of ocean bottom in this zone.

Discharge would be greater in offshore areas closest to the discharge trench. At these locations, the flow would be approximately 2.6 gpd per square foot, for a distance of 1200 feet along the shoreline approximately parallel to the proposed trench.

Minimum residence times were calculated using an expanding sphere and expanding cylinder model. Minimum residence times will range from 9 to 61 days.

The proximity of the proposed discharge to the shoreline and the location on a point (Keahole) limits the effects on the groundwater table. The land configuration results in much less groundwater flow occurring under the site (due to the groundwater divergence caused by the presence of a point of land), and the presence of two ocean boundaries in near proximity to the discharge locations results in relatively rapid migration of discharges to the coastlines.

The primary effect caused by disposal in shallow trenches would be the disruption and displacement of the existing brackish water lens. The lens is unsuitable for groundwater development, but apparently is the source of water for some stands of kiawe trees located north of Keahole Point. Trees that have deep root systems that reach the groundwater level probably would not survive the displacement of the brackish water lens by the saline ocean water plume.

The disposal by trenches would displace the existing groundwater flow in the immediate vicinity of Keahole Point. A flow net showing the flow pattern for the discharge analyzed is presented on Plate B2.

The brackish water lens also is the source of water for some anchialine ponds in the vicinity of Wawahiwaa Point approximately 2 miles south of the proposed ocean water disposal area of the NELH site. These ponds are not within the projected disposal plume for NELH discharge.

The effect of discharge of the ocean water return into the ocean is being analyzed separately. The effect of dilution of the ocean water return within the receiving water column, however, is discussed in a later section of this report addendum. The rate of discharge per unit area is much greater for the trench discharge than for the deep injection well, particularly for the trench within NELH. However, the ocean water return would be nearly indistinguishable from the ocean water it is merging with.

Combined OTEC and Mariculture Discharges - For the above modeling, we calculate that 76 percent of the discharge would occur over a horizontal distance of 5,900 feet along the shoreline, an average of 7,800 gpd per foot. Assuming that the flow was, on the average, distributed evenly between the 0- and -150-foot bathymetric contour would result in an average of 2.8 gpd per square foot of ocean bottom in this zone.

Minimum residence times calculated separately for the OTEC and Mariculture Discharges would apply.

The proximity of the proposed discharge to the shoreline and the location on a point (Keahole) limits the effects on the groundwater table. The land configuration results in much less groundwater flow occurring under the site (due to the groundwater divergence caused by the presence of a point of land), and the presence of two ocean boundaries in near proximity to the discharge locations results in relatively rapid migration of discharges to the coastlines.

The primary effect caused by disposal in shallow trenches would be the disruption and displacement of the existing brackish water lens. The lens is unsuitable for groundwater development, but apparently is the source of water for some stands of kiawe trees located north of Keahole Point. Trees that have deep root systems that reach the groundwater level probably would not survive the displacement of the brackish water lens by the saline ocean water plume.

The disposal by trenches would displace the existing groundwater flow in the immediate vicinity of Keahole Point. A flow net showing the flow pattern for the discharge analyzed is presented on Plate B3.

The brackish water lens also is the source of water for some anchialine ponds in the vicinity of Wawahiwaa Point approximately 2 miles south of the proposed ocean water disposal area of the NELH site. These ponds are not within the projected disposal plume for NELH discharge.

The effect of discharge of the ocean water return into the ocean is being analyzed separately. The effect of dilution of the ocean water return within the receiving water column, however, is discussed in a later section of this report addendum. The rate of discharge per unit area is much greater for the trench discharge than for the deep injection well, particularly for the trench within NELH. However, the ocean water return would be nearly indistinguishable from the ocean water it is merging with.

DESIGN CONSIDERATIONS

For the relocated trench along the road to HOST Park, the proposed disposal trench orientation is roughly parallel to and approximately 900 feet from the shoreline at the closest point. For disposal of the anticipated projected quantity of ocean water return of 25,900 gpm from mariculture activities, the theoretical trench dimensions could be 5 feet wide, 5 feet

deep, and 374 feet long. A 10-foot wide by 10-foot deep trench would require a theoretical trench length of 165 feet.

Our previous recommendations regarding doubling the length of the trench for design purposes and monitoring of the performance of the trench would apply.

CALCULATION OF DILUTION OF SEA WATER RETURN

The sea water return, as it enters the ocean through the ocean bottom, will be diluted within the water column. The water column is constantly changing due to the current, and in nearshore areas, wave action tends to introduce oxygen into the water.

The dilution factors and the reductions in dissolved oxygen were calculated for the various cases. In performing these calculations, the average depth of water column, rate of sea water return discharge through the ocean bottom, and affected area were based on the modeling. A minimum current of 0.3 meters/sec was assumed.

The ambient seawater is assumed to have a DO of 6 ppm. The sea water return is assumed to have a "worst case" DO of 0.8 ppm.

The results indicate reductions in DO ranging from .00058 to .0059 ppm, which generally do not include the positive effects of nearshore wave action on the dissolved oxygen content. The sea water return would not immediately mix with the entire water column. However, assuming initial mixture with the bottom one foot of the water column would still only result in reductions in DO of about 0.1 ppm. We therefore conclude that the effect of the reduction in DO due to the discharge of sea water return flows would be insignificant.

Results of the analysis are presented on the following table:

Case		Ave Depth/ Length of Water Column (ft)	Bottom Discharge Rate (gpd/ft^2)	Dilution Ratio+	Time for Water Column Renewal (min)	Reduction in Dissolved Oxygen (ppm)
1.	Injection Wells	350/30,000	1.2	1:6,300	500	.0008
2.	Trench Discharge of OTEC flows within NELH (100' from shoreline)	25/600	26	1:1,040	10	.005*
3.	Trench discharge of OTEC flows within NELH (250' from shoreline)	25/4,100	4.5	1:880	69	.0059*
4.	Trench discharge of mariculture flows on road to HOST	100/4,300	1.9	1:8,000	72	.00064*
5.	Trench discharge of mariculture flows on road to HOST (alternate location)	100/6,200	1.2	1:8,700	103	.00058*
6.	Trench Discharge of OTEC and mari-culture flows on road to HOST	100/3,800	3.2	1:5,300	64	.00095*
7.	Combined Case 3 and Case 5 Discharges	75/5,900	2.8	1:2,900	98	.0013*

* Does not include effects of dissolved oxygen renewal due to nearshore wave action.

\+ Ratio of bottom discharge rate to water column volume/time for water column renewal.

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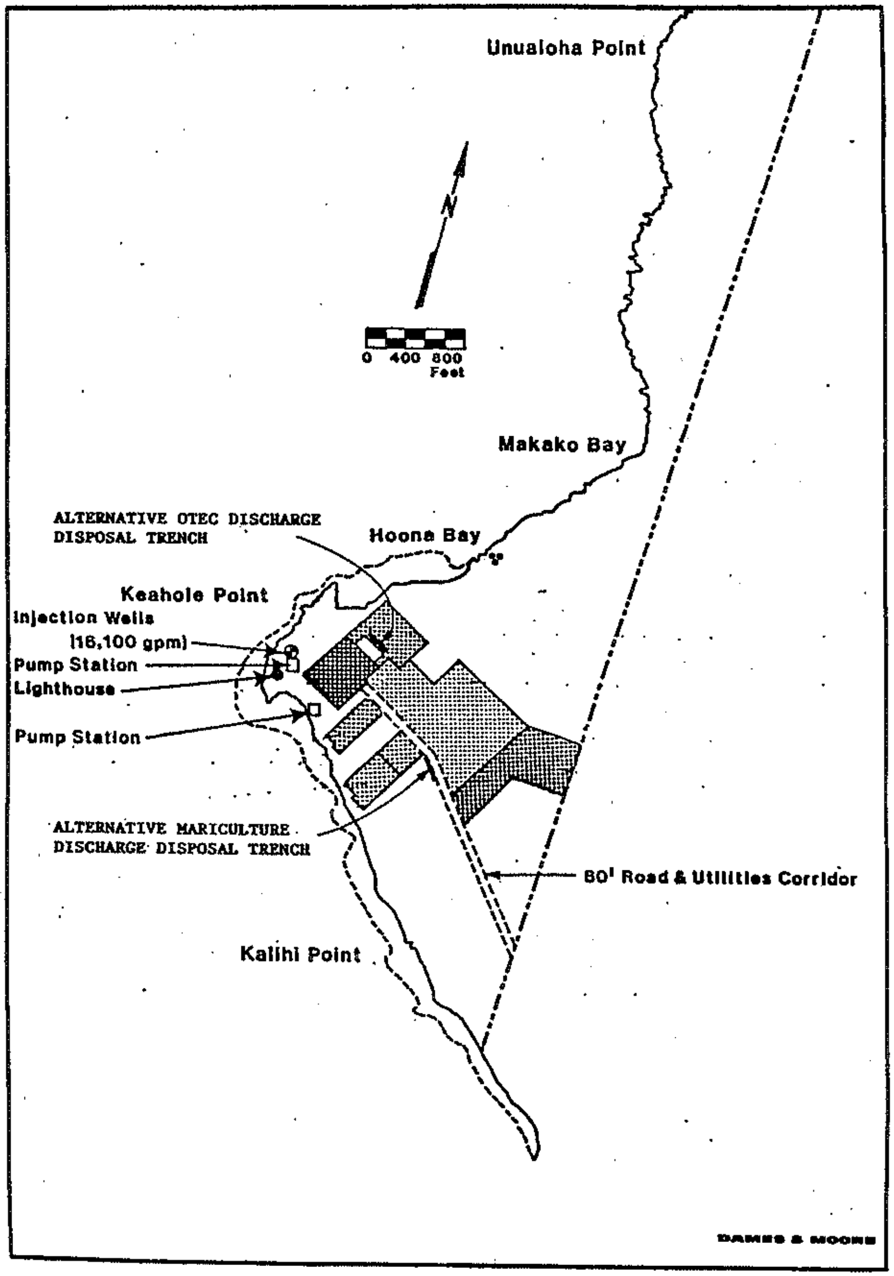
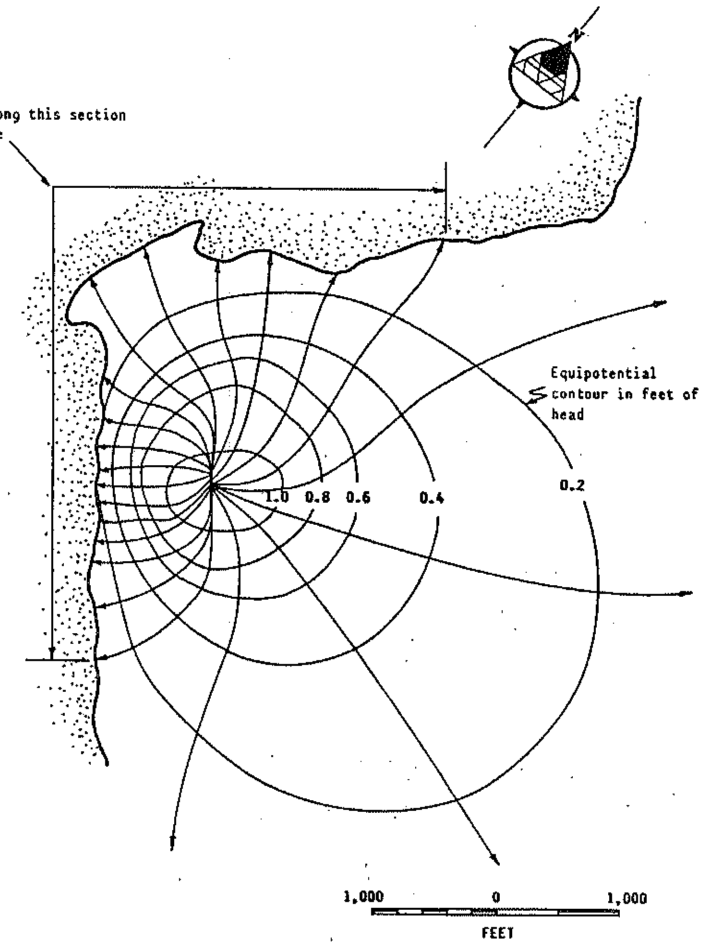
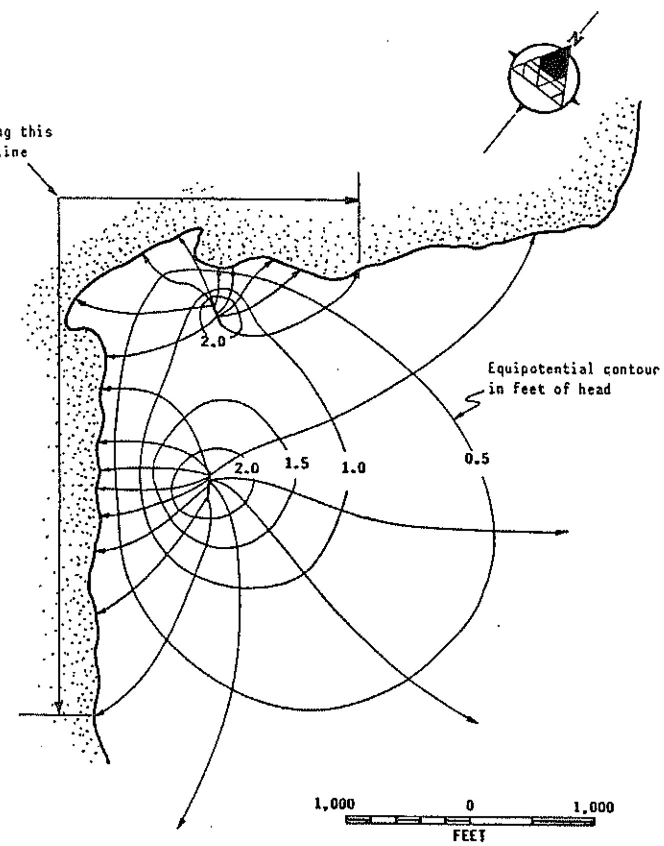




FLOW NET

DISCHARGE TO ALTERNATIVE DISPOSAL TRENCH
ON ROAD TO HOST PARK

PLATE B2
DAMES & MOORE



FLOW NET

COMBINED DISCHARGE TO DISPOSAL TRENCH LOCATIONS

PER PLATE B1

APPENDIX D

HISTORIC PRESERVATION CONCERNS AT NELH

ROSS CORDY, Ph.D.
DEPARTMENT OF LAND AND NATURAL RESOURCES

HISTORIC SITES SECTION

HISTORIC PRESERVATION CONCERNS -- NELH GENERAL PLAN

Inventory of Historic Sites

A total of 10 archaeological studies have taken place in the NELH parcel (Table 1). A Bishop Museum study (Clark 1984) summarized much of this work and concluded that all historic sites had been found -- a total of 24. The State's Historic Sites Section agrees with this conclusion and has recently conducted fieldchecks of many of these sites (Cordy 1986). Table 2 lists the sites and briefly describes them. Map 1 locates them.

The NELH parcel cuts across two traditional land units (ahupua'a), Kalaoa 4 and 5. Current findings suggest that a small prehistoric population settled Kalaoa 5 about A.D. 1500 and gradually expanded into Kalaoa 4 by A.D. 1600. The archaeological remains of the permanent dwelling sites are small clusters of pavings, platforms and enclosures found at sites D15-11, -12, -13, -14, -15 and D16-5, -6 and -12. These include remains of dwellings and work areas. These sites are small in area and contain shallow deposits. Archaeological population estimates based on these sites suggest that about 50 people lived in these ahupua'a at European Contact.

Other prehistoric sites present are two short-term or temporary occupation sites, caves D15-24 and -25. Also, prehistoric trails linked the permanent dwellings to their inland agricultural fields near today's Mamalahoa Highway. Remnants of trails are present near the Queen Kaahumanu Highway, and some of the trails found in NELH's parcel may be prehistoric.

Beginning in the mid-1800s, most of the population of the Keahole area of North Kona shifted their permanent residences inland among the agricultural fields, and permanent coastal housing was generally abandoned. An interesting exception is the cluster of high-walled enclosures and platforms between the NELH lab and the 1801 lava flow (D16-6 through -11). These are historic dwellings, but little is known about their age or why they were here. Trails (D16-14, -15, -16, -17) and shelter caves in NELH undoubtedly date to this period too.

The present condition of these NELH sites is fairly good. Some caves (D15-25, -26) were partly looted before 1975, and the filled crevices were looted between 1984 and 1986.

again, fortunately, these crevices proved not to be historic sites.) Waves and vehicles have caused some damage at D15-13. But, generally, the NELH sites are intact.

Significance

The significance of these sites has been assessed in consultation with the State's Historic Sites Section. Table 3 presents the assessments. All the sites still contain signficant information on the prehistory of this area. We still need to carefully evaluate the age of these sites to study settlement and population growth, to evaluate the patterning of remains to identify former activities at these sites and their locations, to evaluate food remains to determine exploitation patterns, and to better understand settlement in the late 1800s. These questions are important not just for understanding the Keahole Point area's history but also that of Kona and Hawaii Island in general.

Additionally, it has been agreed that 1 site and a set of 6 sites are also significant as excellent examples of types of sites within the North Kona region. Site D15-12 is a prehistoric permanent dwelling site which includes a nicely walled enclosure with an internal house platform and with external work structures, at least one petroglyph, and salt pans. Sites D16-6 through -11 are a complex of historic period (mid-1800s to early 1900s) dwellings and larger structures, including two canoe-houses and a modified anchialine pond.

Potential Impacts

Several impacts to these historic sites are expected in future development. First, as land is leased to prospective firms, land alteration and potential destruction will likely occur. Also, pipeline expansion to service NELH and HOST Park will likely occur, again with potential site destruction. Second, as the NELH/HOST shoreline is opened up and improved with parking and restroom facilities, increased recreational use may lead to inadvertent damage and littering at many of the sites. Toilet paper and some refuse already are present in some sites. Third, greater access might lead to site looting although recent studies by the Historic Sites Section indicate that looting at the coastal sites has generally not occurrred in this area since 1975, despite greater access. In sum, adverse impacts could well occur to all NELH's historic sites.

Mitigation Plans

Mitigation plans have been developed by NELH in consultation with the State's Historic Sites Section, and some have already been put into effect.

First, the 7 sites in the two site groupings that are significant as examples of types have been set aside for preservation. These are sites D15-12 and D16-6 through -11. These sites are in "no build" areas, and buffers to prevent direct and indirect damage have been determined in consultation with the Historic Sites Section. In the case of D15-12, the buffer will be marked with low posts. These sites will also have interpretive signs prepared by the Historic Sites Section. Public access to these sites will be maintained.

Second, the remaining 17 sites, those significant solely for their information content, will be protected until archeological data recovery occurs. Many of these sites may be protected permanently by choice of the leasees -- as an option to data recovery. To ensure protection, the borders of the accessible sites have been marked in company with Historic Sites Section staff and will be surveyed in on base maps, so planners, potential leasees and construction teams will know their locations. Litter problems are anticipated to be reduced by placement of trash cans at various locations along the shore and by the construction of restrooms in the HOST Park. The possibility of looting is expected to be reduced by closing off the NELH access road at night, by periodic patrol of the shore, and by public participation in notifying facility staff of such problems.

Archaeological data recovery plans have been prepared in detail by the Historic Sites Section, based on a review of prior work (e.g., Clark 1984) and fieldchecks. These plans are summarized in Table 4. These plans will be followed when archaeological data recovery is to occur.

It is recognized that an important part of archaeological data recovery is to ensure that the work is done correctly. To ensure this is done, each time data recovery is to occur, the Historic Sites Section and the County of Hawaii's Planning Department will review and approve the detailed scope of work, verify the satisfactory conclusion of fieldwork, and review and approve the final archaeological report.

Last, if new historic sites are discovered, such as hidden caves, these will be protected until the sites are documented, their significance is assessed and appropriate mitigation plans are developed in consultation with the Historic Sites Section and the County of Hawaii's Planning Department.

Table 1

References for Prior Archaeological Studies at the NELH Parcel

1. Reinecke, John 1930. Survey of Sites on West Hawaii. Bishop Museum Manuscript. On file, Historic Sites Section. [1930 Survey]

2. Ching, Francis Jr. and Deborah Cluff, Thomas Riley 1968-69. Preliminary Report of Archaeological Surface Survey & Salvage Operations at Keahole, North Kona, Hawaii Island. Section II Keahole Point Airport & Kailua-Kawaihae Road. Manuscript H-50. On file, Historic Sites Section. [1968-69 Survey]

3. Rosendahl, Paul and Patrick Kirch 1975. Archaeological Reconnaissance Survey of the Ke-ahole Point Natural Energy Laboratory Site, North Kona, Hawaii Island. Bishop Museum Manuscript 111775. On file, Historic Sites Section (H-81). [1975 Survey]

4. Cordy, Ross 1975. Scale maps of sites analyzed for Ph.D. work, with dates and interpretations. On file, Bishop Museum & Historic Sites Section. [1975 Survey w/excavations & dates]
   ------ 1978. A Study of Prehistoric Social Change: The Development of Complex Societies in the Hawaiian Islands. Ph.D. thesis, University of Hawaii. [Same 1975 study]
   ------ 1981. <u>A Study of Prehistoric Social Change: The Development of Complex Societies in the Hawaiian Islands.</u> New York, Academic Press. [Same 1975 study]

5. Rosendahl, Paul 1976. Additional Archaeological Reconnaissance Survey at the Ke-ahole Point Natural Energy Laboratory Site, North Kona, Hawaii Island. Bishop Museum Manuscript #111775 Appendix. On file, Historic Sites Section (H-81). [1976 survey]

6. Rogers-Jourdane, Elaine 1978. Archaeological Reconnaissance Survey of NELH Facilities Area at Keahole Point, North Kona, Hawaii. Bishop Museum Manuscript #061378. On file, Historic Sites Section (H-82). [1978 survey]

7. Rosendahl, Paul 1980. Intensive Archaeological Survey and Salvage Excavations at the Natural Energy Laboratory Hawaii (NELH) Site, Ke-ahole Point, North Kona, Hawaii Island: Final Report. Paul H. Rosendahl Company Manuscript 2-123179. On file, Historic Sites Section (H-81). [1978 survey w/excavations and dates]

8. Clark, Stephan 1984. An Archaeological Reconnaissance of Natural Energy Laboratory Hawaii (NELH) Property, Keahole Point, North Kona, Hawai'i. Bishop Museum Manuscript 110784. On file, Historic Sites Section H-439). [1984 survey & summary of prior work]

9. Cordy, Ross 1985. Working Paper 1. Hawaii Island Archaeology: Ooma & Kalaoa Ahupua'a, Kekaha, North Kona. Manuscript. On file, Historic Sites Section. [Summary of prior work]

10. Cordy, Ross 1986. Field Check of Some Sites in the NELH Property. Kalaoa 5 Ahupua'a, Keahole Point, North Kona, Hawaii. Manuscript. On file, Historic Sites Section. [1986 fieldcheck]

All these reports are on file at the Historic Sites Section, Dept. of Land & Natural Resources, State of Hawaii. The public may consult these reports at that office.

Table 2

List of Sites in the NELH Parcel

Site	Function	Nature
Kalaoa 4 -- North of NELH Lab (13 sites)		
D16-5	Permanent Dwelling	Enclosure with papamu
D16-6	Permanent Dwelling	Enclosure with internal enclosure & external platform
D16-7	Permanent Dwelling	Long, narrow enclosure & 2 platforms
D16-8	Permanent Dwelling	2-sided enclosure with cement foundation
D16-9	Permanent Dwelling	Long, narrow enclosure, C-shaped enclosure, modified anchialine pond
D16-10	Unknown	Enclosure
D16-11	Permanent Dwelling	Enclosure
D16-12	Permanent Dwelling	Enclosure, terrace
D16-13	Short-term occupa.	Cave
D16-14	Trail	Opihi-shell lined
D16-15	Trail	Opihi-shell lined
D16-16	Trail	Stepping stone
D16-17	Trail	Opihi-shell lined
Kalaoa 5 -- South of the NELH Lab (11 sites)		
D15-11	Permanent Dwelling	4 enclosures
D15-12	Permanent Dwelling	Enclosure, 2 platforms
D15-13	Permanent Dwelling	Platform
D15-14	Permanent Dwelling	Platform, 2 enclosures
D15-15	Permanent Dwelling	10 features = 2 enclosures, platform, 2 caves, 2 pools, etc.
D15-21	Unknown	8+ filled crevices*
D15-22	Unknown	Filled crevice*
D15-23	Unknown	Small platform, enclosure
D15-24	Short-term occupa.	Cave, C-shaped enclosure
D15-25	Short-term occupa.	Cave, platform
D15-26	Unknown	Stone cairn

*A 1986 fieldcheck indicates that these may not be historic sites (Cordy 1986). This is being further evaluated.

Table 3

Significance Determinations of the NELH Sites

Site	Information Content	Example of Site Type
Kalaoa 4 -- North of the NELH Lab		
D16-5	x	
D16-6	x	x
D16-7	x	x
D16-8	x	x
D16-9	x	x
D16-10	x	x
D16-11	x	x
D16-12	x	
D16-13	x	
D16-14	x	
D16-15	x	
D16-16	x	
D16-17	x	
Kalaoa 5		
D15-11	x	
D15-12	x	x
D15-13	x	
D15-14	x	
D15-15	x	
D15-21*	x	
D15-22*	x	
D15-23	x	
D15-24	x	
D15-25	x	
D15-26	x	

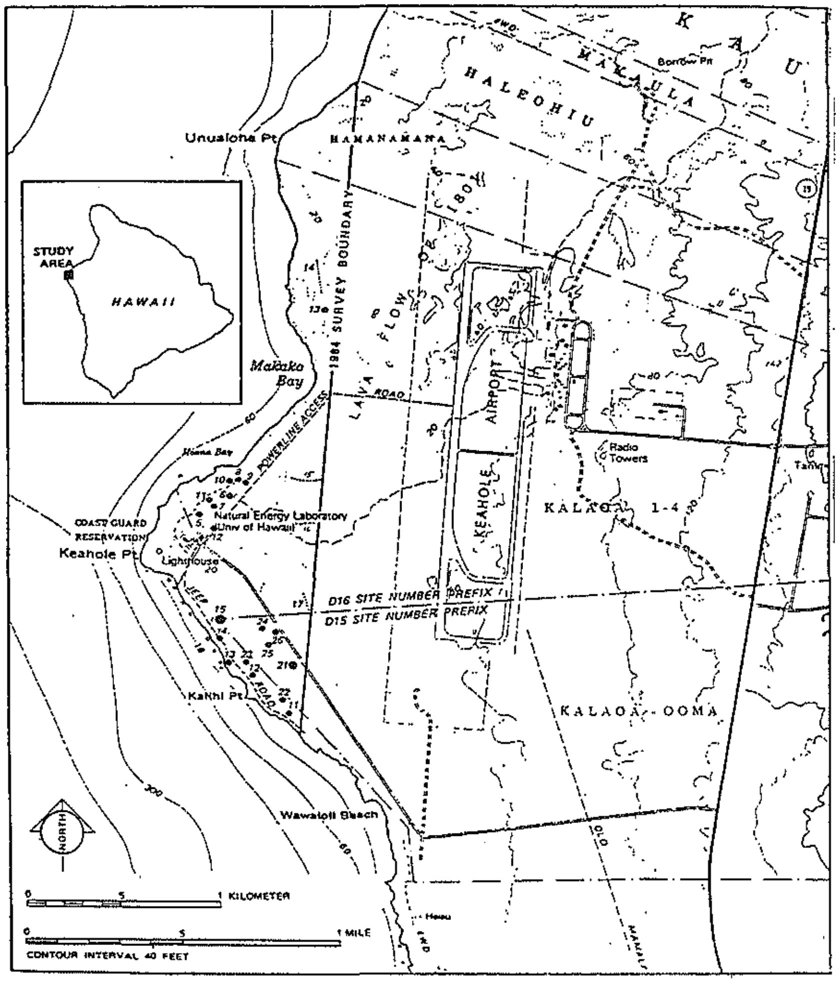
*These sites are filled crevices. 1986 fieldchecks (Cordy 1986) looked at many filled crevices and found none that were cultural sites. The remaining crevices will be checked, and if they also prove to be natural, these two sites will no longer be considered historic sites.

Table 4

Summary of Archaeological Data Recovery Tasks for NELH Sites

Site	Field Tasks		Post-Field Tasks	
	Mapping	Excavation*	Lab	Interpretation
Kalaoa 4 -- North of the NELH Lab				
D16-5		x	x	x
D16-12		x	x	x
D16-13		x	x	x
D16-14	x			x
D16-15	x			x
D16-16	x			x
D16-17	x			x
Kalaoa 5 -- South of the NELH Lab				
D15-11		x	x	x
D15-13		x	x	x
D15-14		x	x	x
D15-15	x	x	x	x
D15-21	Special problems**			
D15-22	Special problems			
D15-23		x	x	x
D15-24		x	x	x
D15-25		x	x	x
D15-26		x	x	x

* Surface collection will also be important besides excavation, and in sites with minimal deposits, surface collection will be critical.
** These sites need to be verified whether they are cultural or natural.



Map 1. Historic Sites in the NELH Parcel (Clark 1984).

APPENDIX E

IMPACTS OF OPEN CYCLE OTEC AND MARICULTURE DISCHARGES FROM THE NATURAL ENERGY LABORATORY OF HAWAII ON NEARBY ANCHIALINE PONDS

GK & ASSOCIATES

APPENDIX E

IMPACTS OF OPEN CYCLE OTEC AND MARICULTURE DISCHARGES FROM THE NATURAL ENERGY LABORATORY OF HAWAII ON NEARBY ANCHIALINE PONDS

GK & ASSOCIATES

December 7, 1986

INTRODUCTION

Anchialine ponds are land-locked brackish water pools that display tidal fluctuations and that harbor a distinctive assemblage of organisms, some of which are found nowhere else. Anchialine pond organisms fall into two classes, i.e., epigeal and hypogeal species (sensu Maciolek, 1983). The epigeal fauna is comprised of species that require the well-illuminated (sunlit) part of the anchialine system. Most of these species are found in other Hawaiian habitats albeit individuals from anchialine systems frequently show ecotype (morphological) variations. The hypogeal organisms occur not only in the illuminated part of the system, but also in the interconnected watertable below. These species are primarily decapod crustaceans, some of which are known only from the anchialine biotope.

Anchialine ponds are restricted to highly porous substrates such as recent lavas or limestone adjacent to the sea. These habitats have been reported from a number of localities globally, but the largest known number of these pools are found in the geologically young lavas along the Kona, Hawaii coast. The Kona coast has in recent years undergone considerable growth; resort development and road construction have made much of the shoreline of the South Kohala and North Kona districts readily accessible. Brock (1985) estimated that the total statewide anchialine pond resource was 600-650 ponds; of this total at least 75% or about 465 ponds were situated in these two districts.

With greater accessibility and coastal development, the Kona anchialine pond resource has been threatened. One resort development at Waikoloa filled more than 135 ponds in late 1985 (U.S. Army Corps of Eng., 1985). Perhaps just as destructive as this direct loss of habitat by infilling is the introduction of exotic fish to these ponds by man. Several exotic fish species (tilapia and topminnows) are utilized by fishermen as live bait; with greater coastal accessibility fishermen have introduced their hardy, euryhaline baitfish into these shoreline anchialine ponds. The exotic fish prey on the native crustacean fauna resulting in hypogeal shrimp species avoiding pools harboring exotic fishes. These exotic fish species are able to complete their lifecycles in the anchialine habitat making their introduction a probable permanent feature of the system. Once introduced to a single pond in a system, these exotic fishes rapidly colonize adjacent pools. Other than a preserve of about 65 ponds at Waikoloa, recent fieldwork (Ziemann, 1985; Brock, unpublished; M. Lee, U.S. Army Corps of

Engineers, pers. comm.) suggests that some ponds in every major anchialine pond complex in the South Kohala-North Kona districts have been invaded by these exotic fishes. Only isolated or individual ponds remain unaltered.

PROJECT AREA ANCHIALINE PONDS

The first inventory of Kona coast ponds by Maciolek and Brock (1974) noted the presence of nine anchialine ponds in the boundaries of the combined NELH/HOST Park project area. Three of these ponds are situated north of the NELH facility and six were located to the south, along Wawaloli Beach. The latter have not been located in recent surveys.

In their study, Maciolek and Brock (1974) found one of the three NELH ponds to be less than 10 square meters in surface area while the two adjacent pools were between 10 and 100 square meters. Depths were shallow (0.5 m), pond bottoms rocky with some sand and sediment, and salinities ranged between 7 and 8 ppt. Algae and plants present included the encrusting carbonate alga, _Schizothrix coricola_; the alga, _Rhizoclonium_ sp.; and the aquatic flowering plant, _Ruppia maritima_. In the vicinity of the ponds were kiawe (_Prosopis pallida_), naupaka (_Scaevola taccada_), fountain grass (_Pennisetum setaceum_), pohuehue (_Ipomoea pes-caprae_) and pickleweed (_Bacopa_ sp.). Fauna inventoried in these ponds included an unidentified oligochaete, the snails _Assiminea_ sp. and _Melania_ sp., the limpet _Theodoxus cariosa_ in one pond, opaeula (_Halocaridina rubra_) in one pond, and opae'o'haa (_Macrobrachium grandimanus_) present in two of the three ponds.

Ziemann (1985) examined ponds in the vicinity of NELH and noted five bodies of water. It is suspected that coralline rubble washed ashore and into these ponds by storm surf may have subdivided them temporarily creating additional pools. These rubble barriers have subsequently broken down leaving the three pool complex at high tide (see below). In any case, Ziemann (1985) found higher salinities ranging from 10 to 11 ppt. Shoreline vegetation present included the sedge _Cladium_ sp., fountain grass, pickleweed, pohuehue, Indian pluchea (_Pluchea indica_), naupaka, akulikuli (_Sesuvium portulacastrum_), and kiawe. In the ponds, Ziemann (1985) noted the alga _Enteromorpha_ sp., the snail _Melania_ sp., opaeula in two ponds only and opae'o'haa in one pond. All species were noted as being abundant.

In September, 1986, GK & Associates examined the NELH ponds. Three ponds were located, suggesting that rubble seen by Ziemann in 1985 had broken down. Further evidence for this was seen at high tide on 27 September, 1986, when a very shallow surface interconnection between two of the ponds was observed. The more northerly situated pond of the pair presently has a surface area of about 20 square meters and is about 38 meters inland of the ocean. The basin is rocky (Plate 1), attaining a maximum depth of about 46 cm. Salinity in this pool was 8 ppt. Deeper portions of this pond harbor growths of the green filamentous alga _Cladophora_ sp. (Plate 2) and a large snail population (_Melania_ sp.). Neither fish nor shrimp were observed in this pond.

The more southerly adjoining pond is slightly deeper (about 75 cm; see Plate 3). A single fish, possibly an aholehole (*Kuhlia sandvicensis*; Plate 4) and the crab *Metopograpsus thunkar* were observed. This pond has a surface area of about 11 square meters at high tide. Opaeula (*H. rubra*) were seen in one partially isolated portion of this pond. Plate 5 shows the interconnection and water exchange between these two basins at high tide. A third area of this pond is a nearly isolated circular depression about 1.2 m in diameter and 0.75 m deep which also harbors opaeula (Plate 6). In the two depressions where *H. rubra* are present, the flora is dominated by the typical anchialine pond cyanophyte (*Schizothrix* and *Lyngbya*) community.

The third pond is located approximately 30 m south of the above ponds. This pool has a surface area of about 70 square meters at high tide and a maximum depth of one meter (high tide on 27 September 1986 was about +73 cm). This pond is situated beneath a fringing canopy of kiawe and around it are naupaka and pickleweed (Plate 7). This pond is slightly seaward of the two open ponds; as a consequence surface salinity was slightly higher (10 ppt). No fish or shrimp were observed in this pond.

ADJACENT ANCHIALINE POND RESOURCES

Anchialine ponds are found along the coast both to the north and south of the NELH/HOST Park boundaries. Approximately 5 km north of the NELH ponds, Maciolek and Brock (1974) noted the presence of two anchialine ponds at Mahaiula; further north (Makalawena) others exist. About 1.8 km south of Wawaloli Beach, in the Kohanaiki parcel, are a large number of anchialine ponds. Maciolek and Brock (1974) identified the Kohanaiki ponds as having exceptional (biological and geomorphological) value. These authors noted the presence of at least 30 ponds, but made no attempt to sample all of the pools in the area. Ziemann (1985) and OI Consultants, Inc. (1986) sampled and mapped all of the ponds in the Kohanaiki parcel bringing the total number up to approximately 60 pools. In the years intervening between the 1972 and 1985-86 surveys, many of the Kohanaiki anchialine ponds have been invaded by exotic fishes, thus changing their biological characteristics. This degradation has been greatest on ponds situated around and to the north of Wawahiwaa Point (i.e., closest to the HOST Park/NELH site). To the south many ponds retain their native fauna and original natural character. Potential impacts to the Kohanaiki anchialine ponds due to development were addressed in the modeling and analysis done for the previous HOST Park/NELH FEIS as well as in OI Consultants, Inc. (1986).

IMPACTS ON ANCHIALINE PONDS IN THE PROJECT AREA

Of the optional methods of disposal of waters from NELH, injection wells or a canal would not significantly impact the ponds. Disposal of the waste waters of NELH (and the HOST Park) into trenches would displace the groundwater beneath the existing anchialine ponds at NELH. The natural groundwater lens beneath Keahole Point occurs as an unconsolidated lens of mixohaline (5 ppt) water approximately 38 m thick and has a flow rate averaging 2-5 mgd/mile. At maximum

development, the volume of water disposed of via trench would be 60 mgd. Dilution of the discharge by groundwater would be insignificant. The aquifer surrounding Keahole Point is expected to experience reduced temperatures, increased salinity, increased solute concentrations, and greater localized groundwater head. Because of the extent of the resultant altered groundwater plume, it does not appear to be possible to mitigate this impact by changing the locations of trenches; rather, if mitigation is necessary, either an alternative to the disposal trenches could be implemented or new habitat could be created outside of the zone of impact. Alternatives to the trench disposal method are more expensive (injection wells, ocean outfalls) and may have greater overall negative impacts on nearby marine communities and NELH operations (canal).

There is very little credible biological information on anchialine flora and fauna. What is known has been summarized by Brock (1985). Hence, with little "hard" data conclusions regarding significance of impacts are "best guesses" based on qualitative and observational (field) information. The expected impacts on the anchialine biota with the implementation of the project are discussed below.

Salinity

With trench disposal, groundwater salinities in the areas of anchialine ponds are expected to rise from the present condition (6-12 ppt) to something close to normal seawater (i.e., 35-36 ppt). Little is known about the salinity tolerances of anchialine species, however, many of the common epigeal forms are invaders from marine or estuarine habitats (e.g., *Theodoxus cariosa*, *Metopograpsus thunkar*, *Palaemon debilis*, *Kuhlia sandvicensis* and probably the cyanophyte mat--*Schizothrix-Lyngbya*). Other epigeal species are usually freshwater forms; these include *Cladophora* sp., *Melania* sp., *Macrobrachium grandimanus* (adults only--larvae enter the sea), and pond insect larvae (midges, dragonfly nymphs and mosquito larvae, etc.). It is expected that those forms derived from freshwater habitats would be unable to cope with high salinities and would disappear from ponds in the project area. These species include *M. grandimanus*, *Melania* sp. and *Cladophora* sp.; none of these species are restricted to the anchialine habitat.

Obligate anchialine species (hypogeal species) that have been seen in the NELH ponds include *H. rubra* and *Metabetaeus lohena*. *M. lohena* has been found in salinities from 2 to 36 ppt; most commonly, however, this species and *H. rubra* are found in waters with salinities between 2 and 30 ppt. However, Brock (unpublished) has maintained *H. rubra* in the laboratory in seawater (36 ppt) for several months with no noticable negative effects. In the field in deeper water exposures or when wind stress and mixing are low, vertical stratification of temperature and salinity will frequently occur. Both *M. lohena* and *H. rubra* move through these gradients with impunity, implying euryhalinity. Taken together, these observations suggest that negative impacts due to salinity increases may be non-existent for adults of the known obligate anchialine species present in the NELH ponds. Nothing may be said about potential impacts associated with increased salinity on the fecundity or survival of juvenile stages of these species.

Temperature

With the proposed trench disposal operation, the temperature of the groundwater could decrease to 19°C. Ziemann (1985) reported temperatures in nearby ponds to be between 21 and 31°C. Brock (1985) noted that M. lohena and H. rubra are usually found in waters with temperatures between 22 and 30°C.

Lower temperatures will reduce physiological and metabolic rates and processes. The long-term impacts of a thermal alteration to anchialine organisms are unknown, but colder water could affect reproductive success. The altered thermal regime resulting from trench disposal would probably be near the lower thermal limits of many species. The lowest temperature recorded in an anchialine pond was 19°C (Maciolek and Brock, 1974); fauna present in this pond included H. rubra, M. grandimanus and M. thunkar. Thus, the most common and characteristic anchialine species can live at the lowest anticipated discharge water temperature. In most cases discharge temperatures would be higher than 19°C due to higher than minimal warm water temperatures and warming subsequent to passage through the OTEC experimental module.

Oxygen

Discharges from OC OTEC experiments may be degassed. If the discharge is not reoxygenated, many of the anchialine species in the ponds situated on the project site may disappear. There is some evidence to suggest that some of the rare hypogeal shrimp species are able to live in very low (about 0.3 ppm) oxygenated waters (Kensley and Williams, 1986). These rare hypogeal forms are known from only one water exposure on Hawaii Island more than 80 km away. None of the anchialine species present in the NELH ponds are known to co-occur with the above rare forms.

Reoxygenation of the disposal waters is strongly recommended.

Nutrients

The concentrations of inorganic plant nutrients (e.g., nitrate, nitrite, phosphate, ammonium, silicate) are expected to increase in the groundwaters due high cold water concentrations, cell lysis and mariculture discharges. Nutrient loading may stimulate benthic algal and phytoplankton communities. Brock and Norris (1986) found no detectable biological response by anchialine pond organisms to significant man-induced nutrient loading in a large system of ponds over a nine-year period. In their study, nutrient levels increased by 360% for nitrates (to 65 µM/l), 320% for phosphates (to 3.71 uM/l) and 100% for ammonium (to 1.01 µM/l). Algae and shoreline plants with roots reaching the watertable strip the nutrients as the water passes seaward through the anchialine system. Uptake by algae is not however manifested by large increases in algal standing crops; rather these

authors attribute the lack of response by benthic algae or phytoplankton to be related to the grazing pressure exerted by herbivores (H. rubra and Melania sp.), thus maintaining the dominant cyanophyte mat community. Additionally, they suggest that phytoplankton response could be limited by short water residence times.

Nutrient concentrations in insular groundwaters are quite variable and frequently high, particularly for nitrates. Johannes (1980) reported groundwater nitrate levels between 115 and 380 µM/l from Perth, Australia. Marsh (1977) noted nitrate levels in Agana, Guam groundwater at 178 µM/l and Kay et al. (1977) found Kona groundwater nitrate levels to range between 29 and 91 µM/l.

Anchialine ponds appear to naturally exist under a highly variable nutrient regime imposed by groundwater. This suggests that if the anchialine community is intact, it can function normally under some level of loading.

Mariculture Chemical Additives

Without adequate knowledge of the nature of these discharges, their concentrations at the disposal trench and subsequent dilution, little can be said beyond what is given in Appendix B. In general, chemicals and waste products in concentrations that would be harmful to nearshore marine organisms would also probably have negative impacts on the anchialine biota. It is recommended that discharges of known toxic materials be prohibited and regulations enforced. Furthermore, discharges should be monitored on a schedule as provided in Appendix B.

Groundwater Head

The point disposal of large quantities of water would create a localized elevation (or head) of the groundwater. These changes in groundwater head are given on equipotential contour charts in Appendix C; they show a maximal local elevation greater than 30 cm. This localized rise in the groundwater could lead to the creation of new water exposures at any location where depressions in the lava field are deep enough to intersect the elevated watertable. If environmental conditions permit the existence of anchialine biota in the altered watertable, the newly created ponds should be rapidly colonized.

There are numerous documented occasions where holes have been cut through the lava and into the watertable for a variety of purposes. If left exposed, these man-made ponds are usually colonized by H. rubra within a few days to weeks. Many other anchialine species require longer periods for colonization; rates are probably related to pond location and isolation from sources of immigration (established ponds). The creation of anchialine habitat may serve as a means of mitigation. At Waikoloa one developer is digging and creating anchialine habitat to replace natural habitat destroyed during construction (U.S. Army Corps of Eng., 1985). Present plans at NELH do not include filling or otherwise physically altering any of the ponds so no habitat would be lost. Presumably this would mean that no replacement habitat would be necessary. However, if the proposed trench discharges do negatively impact the groundwater and the NELH ponds, then habitat creation may be a viable option.

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Plate 1. Portion of northernmost exposed anchialine pond at NELH.

Plate 2. Deeper portion of northernmost exposed anchialine pond at NELH showing filamentous green algae.

Plate 3. Southernmost exposed anchialine pond at NELH. Central portion contained fish but the small pool at lower center and the semi-isolated portion at the top contain the endemic *opaeula*.

Plate 4. Fish and filamentous green algae in deep section of southernmost exposed anchialine pond at NELH.

Plate 5. Sill separating portions of southernmost exposed anchialine pond at NELH containing fish or shrimp. Note floating green algae where fish are present.

Plate 6. *Opaeula* and cyanophyte mat in semi-isolated basin at NELH.

Plate 7. Covered anchialine pond at NELH.

APPENDIX F

COST ESTIMATE DATA - PROPOSED DISPOSAL
FACILITIES EXPANSION AT NELH

DAMES & MOORE

Dames & Moore

1144 10th Avenue, Suite 200
Honolulu, Hawaii 96816
(808) 735-3585
Cable Address: DAMEMORE

December 18, 1986
03014-119-11

R. M. Towill Corporation
677 Ala Moana Boulevard, Suite 1016
Honolulu, Hawaii 96813

Attention: Mr. Bud Villemont

Gentlemen:

Revised Cost Estimate Data
Proposed Disposal Facilities
Expansion of the NELH
Keahole, North Kona, Hawaii

Revised cost estimate data for the various disposal schemes are presented in this letter. These estimates are based on design considerations as discussed in the draft EIS, and discussions with contractors. Revised costs for alternate trench locations within the NELH compound and on the road to HOST Park are included.

Deep Well Disposal

Large diameter deep disposal wells have been used successfully in Hawaii to dispose of large quantities of treated industrial wastewater. For the OTEC activities, a disposal requirement of 23 mgd, it is estimated that 4 wells (2 primary and 2 backup) would be needed. The wells would be located immediately makai of the NELH laboratory. The wells would be drilled approximately 18 to 24 inches in diameter, 400 feet deep, and spaced at least 100 feet apart. For costing purposes, we have assumed the wells would be cased with 18" OD solid casing from 0 to 300 feet to limit discharge to a depth below 300 feet, and with 18-inch open hole from 300 to 400 feet. The wells may need to be deepened if low permeability zones are encounteed which reduce capacity. It is estimated that each well could handle about 11.5 mgd (8,000 gpm). Therefore, for a 23 mgd operation, only 2 of the 4 wells will be operating. The extra wells are standby capacity for planned maintenance, or in the case of 1 or more wells becoming inoperative due to clogging. The piping system and well head design would require careful engineering for smooth operation and ease of maintenance.

For the above well, we have obtained a quotation of $148,000 per well from Roscoe Moss Co. The total cost for 4 wells would be $592,000.

These wells would be designed for only the 16,100 gpm OTEC discharge, and a trench disposal scheme would still be necessary to handle mariculture discharges.

Shallow Surface Trench Disposal

Proposed locations of shallow surface trench disposal are along the roadway alignment from NELH towards the proposed HOST park and within the boundary of the NELH facility. Previously, planning was for trench excavation and replacement with a perforated pipe and large boulder backfill. This would not enable maintenance of the trench, but the end of the trench would be designed to enable extension should clogging occur or if additional capacity is required during the phased development of NELH activities. For the purpose of obtaining a quotation, we assumed the trench cross section depicted on Attachment 1.

We now understand that filling the trench with crushed lava or gravel is desired, to achieve better filtration of the discharge. This would incur the additional cost of the crushed lava or gravel. The crushed lava or gravel should not be so fine as to restrict the disposal capacity of the trench. Approximately #2 size gravel or larger is recommended, and the quantity of fine materials less than #200 should be limited to no more than 3% by weight.

For the roadway towards the proposed HOST park, the initially proposed disposal trench orientation was roughly parallel to and approximately 750 feet from the shoreline. The ground elevation in the area is approximately 10 feet above sea level. For disposal of the anticipated quantity of ocean water (23 mgd) from OTEC activities, the theoretical trench dimensions would be 5 feet wide, 5 feet deep, and 225 feet long. For planning purposes, it would be prudent to allow for twice the theoretical trench length. The extra trench length would provide an allowance for non-homogeneity of the hydrogeologic characteristics of the proposed disposal area subsurface materials and to mitigate silting and clogging problems that may occur in the initial start up stage. The trench should also be designed to allow for extension, if additional capacity is required or to replace clogged areas.

The performance of the disposal trench should be monitored to collect operation and maintenance data for subsequent phases of the expansion program. Assuming that the technical parameters used in the theoretical computations can be validated by the actual performance, the disposal trench can then be incrementally extended to handle more disposal quantity as NELH facilities expand. Theoretically, a 362-foot disposal trench 5 feet wide by 5 feet deep could handle the projected additional disposal quantity of 37 mgd from mariculture operations. Therefore, for the total proposed additional ocean water outflow of 60 mgd, the theoretical trench dimensions could be 5 feet wide, 5 feet deep, and 587 feet long.

The available length of the disposal area is more than 2,000 feet. The length of the trench, however, can be shortened by digging a deeper trench. A 10-foot wide by 10-foot deep trench would require theoretical trench lengths of 98 feet, 158 feet, and 256 feet, for disposal quantities of 23, 37, and 60 mgd, respectively, without allowing for any safety factors.

For the alternative trench location the disposal trench orientation is roughly parallel to and approximately 900 feet from the shoreline at the closest point. The theoretical trench lengths would be 232 feet, 374 feet, and 606 feet for the 5 x 5 trench; and would be 101, 165, and 264 feet for the 10 x 10 trench, for disposal quantities of 23, 37, and 60 mgd, respectively, without allowing for any safety factors. The above discussions regarding increasing the design length and monitoring the performance of the trench would apply.

For the trench within the NELH laboratory compound, the proposed disposal trench orientation is roughly parallel to and approximately 100 feet from the shoreline. For disposal of the anticipated projected quantity of ocean water of 23 mgd from the OTEC activities, the theoretical trench dimensions could be 5 feet wide, 5 feet deep, and 144 feet long. A 10-foot wide by 10-foot deep trench would require a theoretical trench length of 59 feet. The above discussions regarding increasing the design length and monitoring the performance of the trench would apply.

For the alternate trench within the NELH laboratory compound, the proposed disposal trench orientation is roughly perpendicular to and approximately 250 feet from the shoreline at the closest point. The theoretical trench dimensions could be 5 feet wide, 5 ft deep, and 193 feet long. A 10-foot wide by 10-foot deep trench would require a theoretical trench length of 79 feet. The above discussions regarding increasing the design length and monitoring the performance of the trench would apply.

We have obtained, from Isemoto Construction, a cost estimate of $160/ft for the 5 ft x 5 ft trench. This would be reduced to $135/ft if the trench is 600 feet or longer.

For the 10x10 feet trench, a cost estimate of $245/ft was quoted. This would be reduced to $210 ft if the trench is 600 feet or longer.

To the above costs, we added material costs of approximately $10/per cubic yard of trench for backfill with crushed lava or gravel.

A research trench within NELH has been recommended. Such a trench would be approximately 5 ft x 5 ft x 45 ft long.

Cost estimates for the various schemes are tabulated on Table 1:

TABLE 1

DISPOSAL TRENCH COSTS

Location	Size (ft)	Discharge (gpm)	Length (ft)	Cost ($)
Existing Road to HOST Park	5 x 5	16,100	450	76,000
		25,900	724	104,400
		42,000	1,174	169,400
	10 x 10	16,100	196	55,300
		25,900	316	89,100
		42,000	512	144,400
Existing Road to HOST Park (alternate location)	5 x 5	16,100	464	78,500
		25,900	748	107,900
		42,000	1,212	174,800
	10 x 10	16,100	202	57,000
		25,900	330	93,100
		42,000	528	148,900
Within NELH	5 x 5	16,100	288	48,700
	10 x 10	16,100	118	33,300
Within NELH (alternate location)	5 x 5	16,100	386	65,300
	10 x 10	16,100	158	44,600
Research Trench	5 x 5	5,000	90	15,200

Canal Disposal

The canal option was determined to be unfeasible as NPDES permit requirements could not be met. This option is therefore not included in this cost analysis.

Cost Comparisons

Comparisons for some of the various possible alternatives are presented below:

Alternative 1:	
OTEC discharge (16,100 gpm) via deep wells	$ 592,000
Mariculture discharge (25,900 gpm) via trench on existing road to HOST Park	89,100
	$ 681,100
Alternative 2:	
OTEC discharge (16,100 gpm) via trench within NELH	$ 33,300
Mariculture discharge (25,900 gpm) via trench on existing road to HOST Park	89,100
	$ 122,400
Alternative 3:	
OTEC and mariculture discharge (42,000 gpm) via trench on existing road to HOST Park	$ 144,400
Alternative 4:	
OTEC discharge (16,100 gpm) via alternative trench within NELH	$ 44,600
Mariculture discharge (25,900 gpm) via alternative trench on existing road to HOST Park	93,100
	$ 137,700

Alternative 1, 2, and 4 would minimize pumping costs, while Alternative 3 would incur high pumping costs to move OTEC discharges to the road leading to the HOST Park.

Alternative 1 would incur periodic well maintenance costs.

- oOo -

If there are any questions regarding this letter, please do not hesitate to contact the undersigned.

Yours very truly,

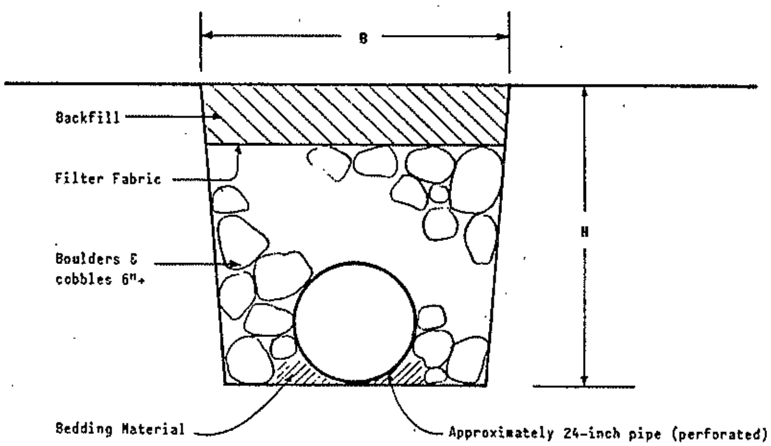
DAMES & MOORE

Masanobu R. Fujioka, P.E.
Principal-in-Charge

MRF:mo(3588A/306A:03014-119-11)

Attachment 1 - Disposal Trench Cross Section

cc: MCM Planning
Attention: Ms. Marilyn Metz



B = H = 5 or 10 feet

DISPOSAL TRENCH CROSS SECTION

DAMES & MOORE

APPENDIX G

COMMENTS AND RESPONSES ON THE DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT

APPENDIX G

COMMENTS AND RESPONSES ON THE DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT

The following agencies reviewed the draft Supplemental Environmental Impact Statement and acknowledged the fact in writing. Those who made substantive comments concerning the proposed action, as indicated by an asterisk (*) in the following list, received written responses to their concerns. Their letters, together with responses to their comments, are reproduced on the following pages of this Appendix.

Federal Agencies

Department of Agriculture, Soil Conservation Service
*Department of the Army, U.S. Army Engineer District
Department of Commerce, National Oceanic and Atmospheric Administration
- *National Marine Fisheries Service

Department of the Interior
- *Fish and Wildlife Service
- Geological Survey, Water Resources Division

Department of the Navy
Department of Transportation
- Federal Aviation Administration
- *U.S. Coast Guard

State Agencies

Department of Accounting and General Services
Department of Agriculture
Department of Defense
Hawaii Housing Authority
*Department of Health
Office of Environmental Quality Control
*Department of Land and Natural Resources
Department of Planning and Economic Development
Department of Transportation
University of Hawaii at Manoa
- * Department of Oceanography
- * Environmental Center
- Water Resources Research Center

County of Hawaii

Department of Public Works
*Department of Research and Development
*Department of Water Supply
*Planning Department

DEPARTMENT OF THE ARMY
U. S. ARMY ENGINEER DISTRICT, HONOLULU
BUILDING 230
FT. SHAFTER, HAWAII 96858

REPLY TO
ATTENTION OF:

January 21, 1987

RECEIVED
JAN 26 1987
NELH

Mr. Jack P. Huizingh, Executive Director
Natural Energy Laboratory of Hawaii
220 S. King St., Suite 1280
Honolulu, Hawaii 96813

Dear Mr. Huizingh:

Thank you for the opportunity to review and comment on the draft supplemental EIS to Permit Alternative Methods of Seawater Return Flow Disposal at the Natural Energy Laboratory of Hawaii, Keahole, Hawaii. The following comments are offered:

a. A Department of the Army permit is not required for the trench, injection well or pond alternatives. A copy of the final supplemental EIS should be sent to the Operations Branch.

b. According to the Flood Insurance Rate Map prepared by the Federal Insurance Administration (Encl), the property (TMK: 7-3-43:42) is located in an area of Zone VE designation. Zone VE is subject to flooding from the 100-year tsunami flood. The approximate 100-year tsunami elevation near the shoreline is 6 feet mean sea level.

Sincerely,

Kisuk Cheung
Chief, Engineering Division

Enclosure

D E

NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

HAWAII COUNTY,
HAWAII

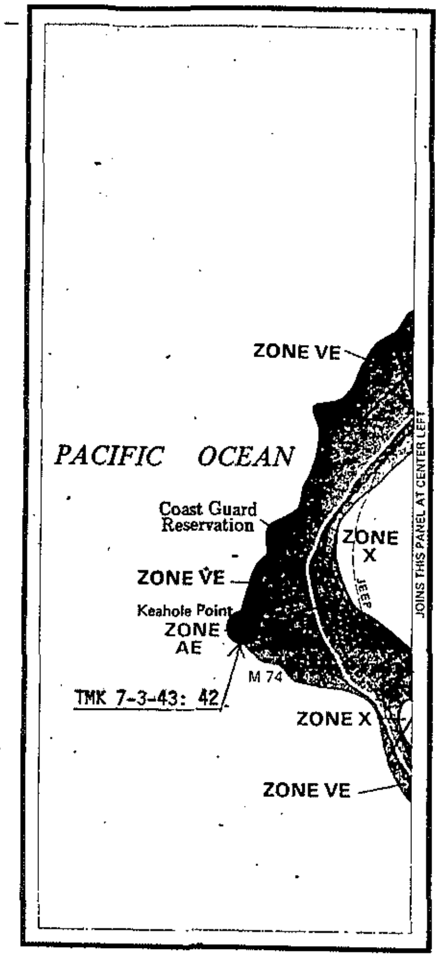
PANEL 681 OF 1900
(SEE MAP INDEX FOR PANELS NOT PRINTED)

PRELIMINARY
MICHAEL BAKER, JR., INC.

PANEL LOCATION

COMMUNITY-PANEL NUMBER
155166 0681 C
MAP REVISED:
SEP 3 0 1986

Federal Emergency Management Agency



INSET H

The Natural Energy Laboratory of Hawaii

February 19, 1987

Mr. Kisuk Cheung, Chief
Engineering Division
Department of the Army
U.S. Army Engineer District
Building 230
Fort Shafter, Hawaii 96858

Dear Mr. Cheung:

Subject: Draft Supplemental EIS (dSEIS) to Permit Alternative Methods of Seawater Return Flow Disposal at the Natural Energy Laboratory of Hawaii, Keahole, North Kona, Hawaii.

Thank you for commenting on the subject dSEIS. A copy of the Final SEIS will be sent to the Operations Branch. The flood insurance and tsunami information that you provided was presented in the original EIS for HOST Park and NELH (1985), therefore it was not repeated in the supplement.

Best regards,

Jack P. Huizingh
Executive Director

cc: DAGS
R.M. Towill

☒ 220 South King Street, Suite 1280 • Honolulu, HI 96813 • (808) 548-7017
☐ P.O. Box 1749 • Kailua-Kona, HI 96745 • (808) 329-7341
☐ P.O. 2 • Pa 96778 965-9

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region • Western Pacific Program Office
2570 Dole St. • Honolulu, Hawaii 96822-2396

February 5, 1987 F/SWR1:JJN

Director
Office of Environmental Quality Control
465 South King Street, Room 104
Honolulu, Hawaii 96813

RECEIVED
FEB 06 1987
NELH

Dear Sir:

Subject: Draft Supplemental Environmental Impact Statement (DSEIS) to Permit Alternative Methods of Seawater Return Flow Disposal at the Natural Energy Laboratory of Hawaii (NELH).

The National Marine Fisheries Service (NMFS) has reviewed the subject DSEIS for a modification of the original proposed method of seawater return flow disposal at the Natural Energy Laboratory of Hawaii (NELH). We offer the following comments for your consideration in preparing the final SEIS.

General Comments

As stated in our letter to NELH of August 30, 1986, which responded to the Preparation Notice for the subject DSEIS, NMFS was involved in the development of the original EIS for the subject project, the final of which was accepted by the Governor in September 1985. We understand that, subsequently, the U.S. Department of Energy (DOE) learned that because of Federal budget cuts it would be unable to fund the proposed expansion of OTEC facilities at NELH to the level they had originally proposed. The mixed-water discharge pipe that was to be used to dispose of the 16,100 gpm of seawater that will be used in forthcoming OTEC experiments will not be funded. Alternative disposal methods for this seawater, including direct disposal via canal, trenches and deep injection wells (and/or a combination thereof), have been investigated.

We understand that DOE and the State of Hawaii have entered into a cooperative cost-sharing agreement to provide the required ocean water for two projects, NELH and Hawaii Ocean Science and Technology (HOST) Park, with one seawater system. The disposal facility recommended in the subject DSEIS for discharge of OTEC experimental seawater is via a shallow trench located within the NELH compound. The disposal facility recommended for return of seawater from HOST Park mariculture operations is another trench located south of NELH and approximately 900 feet from the shoreline. The two trench systems would eventually receive approximately 42,000 gpm of seawater return flow.

NMFS feels the subject document adequately describes potential impacts on the coastline marine environment and anchialine ponds from the proposed OTEC and mariculture seawater return flow discharges. We agree that potential adverse impacts from discharge into a shallow trench may be substantial, particularly for mariculture seawater return flows with concentrations of nutrients, waste products and chemicals. Our major concern is the long term impact of this discharge on the nearshore waters and marine biota off Keahole, an area presently in near pristine condition.

In light of the above, NMFS considers the monitoring program to be the most critical element of the seawater disposal project. We have been in contact with the consultant during development of the proposed monitoring program (Appendix B of DSEIS) and feel, if carried out properly, it should protect the natural ecosystems present in coastal waters. Our major concern is that both facilities plan to gradually increase volumes of sea water to be used. This may make it difficult to detect impacts, particularly to nearshore biota which may acclimate or in some cases gradually disappear. The major question then becomes at what point are existing discharges halted and alternate methods employed?

Finally, if disposal of OTEC and mariculture waters via shallow trench is the selected alternative, NMFS recommends the trenches be set back the maximum distance possible from the shoreline at Keahole. This will allow greater initial dilution of seawater return flow in the receiving waters.

Sincerely yours,

Doyle E. Gates

Doyle E. Gates
Administrator

cc: F/SWR, Terminal Is., CA
F/M4, Washington, D.C.
EPA, Region 9, (P-5)
FWS, Honolulu
Hawaii State Div. of Aquatic Resources
NELH (Attn. Mr. Jack Huizingh)
MCM Planning (Attn: Ms. Marilyn Metz)

The Natural Energy Laboratory of Hawaii

February 19, 1987

Mr. Doyle E. Gates, Administrator
U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii 96822-2396

Dear Mr. Gates:

Subject: Draft Supplemental EIS (dSEIS) to Permit Alternative Methods of Seawater Return Flow Disposal at the Natural Energy Laboratory of Hawaii, Keahole, North Kona, Hawaii.

Thank you for commenting on the subject dSEIS. We also consider the water quality monitoring program to be a critical element in this project as well as the overall development of NELH and the Keahole Point area. We anticipate that the monitoring program will not be finalized until concerns expressed in comments on the subject dSEIS are evaluated and, where appropriate, incorporated in the program. We appreciate the cooperation of NMFS in developing this program and look forward to continuing coordination and cooperation as it is finalized, implemented, and the results evaluated. We hope that your staff will assist us in setting thresholds which will indicate when alternative methods of disposal should be employed.

In response to your final comment, the trenches will be set back as far as possible within operational constraints.

Best regards,

Jack P. Huizingh
Executive Director

cc: DAGS
R.M. Towill

☒ 220 South King Street, Suite 1280 • Honolulu, HI 96813 • (808) 548-7017
☐ P.O. Box 174[illegible] [illegible]a-Kon[illegible] [illegible]745 • ([illegible]) [illegible]-7341
☐ [illegible]ox 217[illegible] [illegible] HI [illegible] (808) [illegible]

United States Department of the Interior

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

RECEIVED
FEB 1 1987
ES NELH
Room 6307
FEB 11 1987

Director
Office of Environmental Quality Control
465 South King Street, Room 104
Honolulu, Hawaii 96813

Re: Draft Supplemental EIS to Permit Alternative Methods of Seawater Return Flow Disposal at the Natural Energy Laboratory of Hawaii

Dear Director:

We have completed our review of the subject document and offer the following comments for your consideration. As stated in our previous correspondence of August 23, 1986, the Service is concerned about long-term adverse effects of the proposed action upon anchialine ponds and hypogeal, crevicular habitats for native crustaceans in the vicinity of Keahole Point.

General Comments

The Service believes that the document adequately describes the physicochemical consequences of OTEC and mariculture seawater return flows upon basal groundwater and seawater quality. We concur that the discharges of OTEC and mariculture effluent into shallow trenches may lead to significant adverse impacts upon anchialine pond and hypogeal ecosystems in the project area. It is unfortunate that no new "credible" scientific information about the structure or function of the anchialine pond ecosystems that will be directly impacted by the effluents was developed as part of the overall research program at the Natural Energy Laboratory of Hawaii (NELH).

In light of the potential for extensive impact (particularly from mariculture effluents) to these unique wetland habitats and their characteristic biota, the Service feels that strict application of the proposed monitoring program must be pursued. Moreover, specific mitigation measures should be employed if anchialine ecosystems are shown to be adversely affected. Alternative mitigation measures may include creation of new ponds, pre-discharge treatment of effluent, and/or alternative discharge locations or methods.

We are concerned that as facilities are placed "on line" at NELH and effluent discharges increase incrementally, chemical and biological impacts may be difficult to quantify. As the National Marine Fisheries Service has indicated, at what point would ongoing discharges be halted and alternative measures employed? To what regulatory agency will NELH be accountable? Will NELH assume responsibility in taking the necessary corrective actions, or will individual facilities within HOST Park be forced to negotiate separately with resource agencies to achieve mitigation?

Specific Comments

The description of anchialine ponds on page III-23 of the document fails to include at least five additional ponds which are known to occur along Wawaoli Beach, south of Keahole Point. These ponds have been recently observed by Service biologists and another marine scientist. These and other ponds south of the project area (but north of "Pine Trees") should be described in this section of the EIS since they may be affected by altered groundwater levels and water quality. Their location should also be mapped in the EIS.

These issues need to be resolved in the final EIS. The Service offers its assistance in reaching a practical solution to the problem of identifying appropriate mitigation for the loss of anchialine pond resources.

Sincerely yours,

[signature]
for Ernest Kosaka
Project Leader
Environmental Services

cc: RD, FWS, Portland, OR (AFWE)
NMFS-WPPO
EPA, San Francisco
DLNR
DAR
✓NELH (Mr. Jack Huizingh)
MCM Planning (Ms. Marilyn Metz)

February 24, 1987

Mr. Ernest Kosaka, Project Leader
Environmental Services
United States Department of the Interior
Fish and Wildlife Service
P.O. Box 50167
Honolulu, Hawaii 96850

Dear Mr. Kosaka:

Subject: Draft Supplemental EIS (dSEIS) to Permit Alternative Methods of Seawater Return Flow Disposal at the Natural Energy Laboratory of Hawaii

Thank you for commenting on the subject dSEIS. In answer to your specific concerns:

General Comments

We anticipate that the monitoring program will not be finalized until concerns expressed in comments on the subject dSEIS are evaluated and, where appropriate, incorporated in the program. It is anticipated that standards for some discharge components (e.g. permissible nutrient levels, etc.) will be predetermined in consultation with NMFS, FWS, DOH, DLNR and the County of Hawaii Planning Department. When these levels are exceeded, as determined from the results of the monitoring program, the activity in its present form would have to cease. Both NELH and HOST Park have provisions in their agreements and development rules that allow them to enter the individual operator's property and monitor discharges on-site if a problem is identified by the monitoring program.

It is recognized that some components from the aquacultural discharges may indeed be very difficult to quantify and to predetermine toxic levels. The rules governing NELH and HOST Park require each new tenant to disclose the constituents of his discharge water. Biological and chemical monitoring will occur at the on-site monitoring wells and the anchialine ponds. It is proposed that if significant changes in the biota are noted, the tenant(s) discharging these substances would be required to halt the activity until appropriate mitigating measures are instituted.

The monitoring program is planned to be a joint undertaking of NELH and HOST Park. In addition, a comprehensive, coordinated water quality monitoring program, which includes developments to the north and south of NELH/HOST Park, is presently being developed. Conditions on the CDUA for the area, the U.S. Army Corps of Engineers permit, and most likely the amended SMA for NELH require monitoring. The U.S.

☐ 220 South King Street, Suite 1280 • Honolulu, HI 96813 • (808) 548-7017
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☐ F 2172 • HI 967)8) 96

The Natural Energy Laboratory of Hawaii

DOE and the State Department of Health also have an interest in the results of the program.

We appreciate the cooperation of the Fish and Wildlife Service in developing this program and look forward to continuing coordination and cooperation as it is finalized, implemented, and the results evaluated. We hope that your staff will assist us in setting standards and developing review procedures.

NELH and HOST Park are separate entities. The disposal trenches at NELH are its responsiblity; those on HOST Park are the responsibility of HOST Park management. Tenants of each are the responsibility of the respective facility. Individuals will negotiate with resources agencies through their respective facility managers.

Specific Comments:

The anchialine ponds inland of Wawaloli Beach are shown on the attached map. They are located off-site of both NELH and HOST Park on DOT Keahole airport property, therefore, they were not located in previous reconnaissance of the NELH and HOST Park sites by the U.S. Army Corps of Engineers biologist. Seven ponds were located and sampled on January 8, 1987 (after the dSEIS was filed). At they time they were located it was near low tide and at that time two of the ponds were only damp depressions with little water. All of the above located ponds are situated in the pahoehoe flow that covers the entire Wawaloli Beach area. Details of these ponds are given below following the number in on the attached map:

o Pond 1 - is located in a Christmas berry (*Schinus terebenthifolius*) patch adjacent to the NELH access road. At the time of sampling (low tide) this pond was a damp depression with no aquatic organisms present. The pond appears to have a surface area of less than 1 sq. m at high tide; the NELH roadway appears to have partially covered this pond.

o Pond 2 - lies in a large Christmas berry patch (the perimeter of which is shown as a dashed line on the attached map) about 60m SE of Pond 1. Pond 2 is about 3.5m in diameter, filled with leaf litter and has an apprent maximum depth of 20 cm at low tide. Despite considerable observation, no crustaceans were found in this pond; it is suspected that cryptic predatory fish (possibly *Awaous genivittatus*, *A. stamineus* or *Eleotris sandwicensis*) may have been present thus keeping the abundance of red shrimp low.

o Pond 3 - has been highly modified, probably long ago to serve as a bathing pool. The diameter of this pond is about 2m; the benthic community of this pond is dominated by the orange encrusting alga, *Schizothrix* sp. Crustaceans seen in this pond include the endemic red

The Natural Energy Laboratory of Hawaii

shrimp or opaeula (Halocaridina rubra) and the native prawn or opae'oehaa (Macrobrachium grandimanus).

o Pond 4 - is located about 5m from Pond 3. As with the previous pond, walls of this water body have been modified so that it may have been used as a well or bathing pool. Again, Schizothrix sp. is present as is opaeula (H. rubra). No other macroinvertebrates were seen in this pond.

o Pond 5 - is located about 20m north of the Christmas berry thicket. This pool is about 2m in diameter and motile biota present include Halocaridina rubra, Macrobrachium grandimanus and a small red unidentified amphipod species.

o Pond 6 - is about 2m mauka (inland) of Pond 5 and was just a damp depression at the time of sampling. No aquatic species were seen.

o Pond 7 - is about 6m NW of Pond 5 and is about 1.25m in diameter and 10 cm in depth. Species present include the alga Schizothrix sp. and the shrimp Halocaridina rubra.

We will request permission from DOT to include these ponds in our monitoring program. Publication of your letter in the Final SEIS will serve to incorporate the above description and attached map into the document.

Discharges from NELH are not anticipated to impact the ponds at Kohana-iki. Impacts of discharges from HOST Park were discussed in the original EIS which is incorporated by reference into this supplement. Please refer to pages IV-44 and IV-45 of the draft SEIS and page 3 of Appendix E for summary descriptions of the Kohana-iki ponds. The studies concerning these ponds are appropriately referenced and the reader is directed to these sources for further information on these bodies of water.

With the concern for on-site anchialine ponds, an alternative strategy would be the creation of new anchialine habitat elsewhere as a mitigative measure. It should be remembered, however, that these anchialine habitats are short-lived in a geological sense. Their occurrence in areas of recent volcanism lends support to this hypothesis; anchialine ponds may be created when lava flows approach the sea, first covering existing ponds and in some cases creating new ponds at the sea-shoreline interface. Possibly the 1852 lava flow that created Keahole Point covered many more ponds than it created.

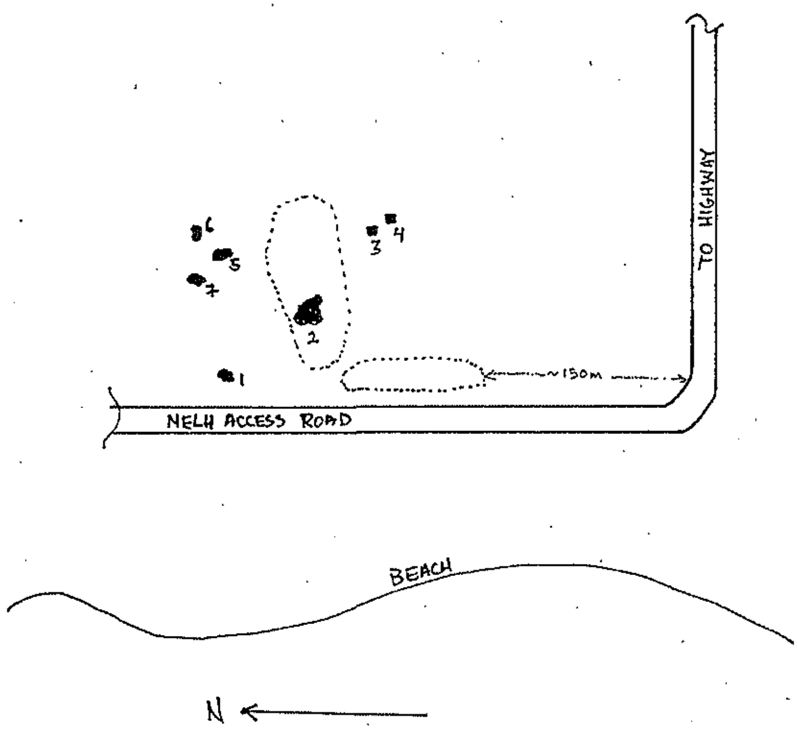
The Natural Energy Laboratory of Hawaii

We will be contacting your staff for assistance in implementing the water quality monitoring program.

Best regards,

Jack P. Huizingh
Executive Director

cc: National Marine Fisheries Service
Corps of Engineers, PODCO



TO HIGHWAY
6
5
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3
4
1
~150m
NELH ACCESS ROAD
BEACH
N

U.S. Department of Transportation
United States Coast Guard

Commander (dpl)
Fourteenth Coast Guard District

Prince Kalanianaole Federal Building
300 Ala Moana Blvd.
Honolulu, Hawaii 96850
Phone: (808) 541-2077

16475.2/4-87
Serial No. 7/059
9 February 1987

RECEIVED
FEB 13 1987
NELH

Letitia N. Uyehara, Director
Office of Environmental Quality Control
State of Hawaii
465 South King Street, Room 104
Honolulu, Hawaii 96813

Re: Draft Supplemental EIS, Natural Energy Laboratory of Hawaii (NELH) Seawater Return Flow Disposal

Dear Ms. Uyehara:

We have reviewed the subject document, which focuses on various land disposal options at Keahole Point such as trenches, canals, and deep injections wells. Since these various options appear to be located on or adjacent to Coast Guard property, and involve volumes ranging from 16,100 to 42,000 gallons per minute, we have the following comments:

(1) Any such actions occurring on our property would require either a modification to the existing Coast Guard - NELH license [enclosure (1)] or establishment of a new one;

(2) We would require detailed engineering plans to determine if the proposed action was consistent with our use of the property. We would also appreciate such plans for any action located adjacent to our property.

Thank you for the opportunity to comment on this document.

Sincerely,

J. F. MILBRAND
Commander, U. S. Coast Guard
District Planning Officer
Fourteenth Coast Guard District
By direction of the
District Commander

Copy: NELH
MCM Planning

REVOCABLE LICENSE

Property Location: Keahole Pt, Hawaii

License No. DTCG-Z71114-86-RP-008L
(Supersedes License No. DTCG-Z71114-83-RP-004L)

WHEREAS, this agreement is made and entered into by and between the United States of America, acting by and through the Commander, Fourteenth Coast Guard District, 300 Ala Moana, Honolulu, Hawaii 96850-4892 (hereinafter called the LICENSOR), and the State of Hawaii, acting herein by and through the Natural Energy Laboratory of Hawaii, 220 South King Street, Suite 1280, Honolulu, Hawaii 96813 (hereinafter called the LICENSEE; and

WHEREAS, LICENSEE has requested permission to locate a temporary generator plant and special test monitoring equipment on U.S. Coast Guard property at Keahole Point, Hawaii, for the purpose of conducting research in ocean biofouling of small heat exchanger tubes at Keahole Point; and

WHEREAS, the granting of such permission is deemed to be in the public interest and will not substantially injure the interests of the United States in the property hereby affected.

NOW THEREFORE pursuant to the authority contained in Section 93(o), Title 14, United States Code, a non-exclusive revocable license is hereby granted for the use of the Coast Guard Keahole Point, a portion of the property as indicated in Natural Energy Laboratory drawing dated 11/24/75 attached hereto and made a part hereof for the purpose stated in paragraph 2 above, together with the necessary rights of ingress and egress and subject to the following terms and conditions:

A. This license shall be effective from 1 January 1986 to 31 December 1989, and may be revoked by the LICENSOR with or without cause upon thirty (30) days written notice to the LICENSEE.

B. The license may be renewed for an additional period upon sixty (60) days written notice from its expiration date requested by the LICENSEE and at the option of the LICENSOR.

C. LICENSEE is not to be considered as acquiring hereunder any permanent interest of whatever nature in the property of the United States hereby affected.

D. No substantial alteration, addition, betterment or improvement of existing premises or facilities, or construction of any type improvements shall be made without the prior written approval of the Commander, Fourteenth Coast Guard District. All construction in connection with the research project is considered as temporary construction.

E. The use of said premises shall be on a non-interfering basis with Coast Guard operations and without expense to the United States, and be subject to such limitations, rules, regulations, or directions as the LICENSOR may, from time to time, prescribe in writing.

F. LICENSOR makes no representations, expressed or implied, as to the adequacy or safety of the licensed premises for the proposed use, and LICENSEE has the continuing and sole responsibility for insuring that the licensed areas are safe for their intended use.

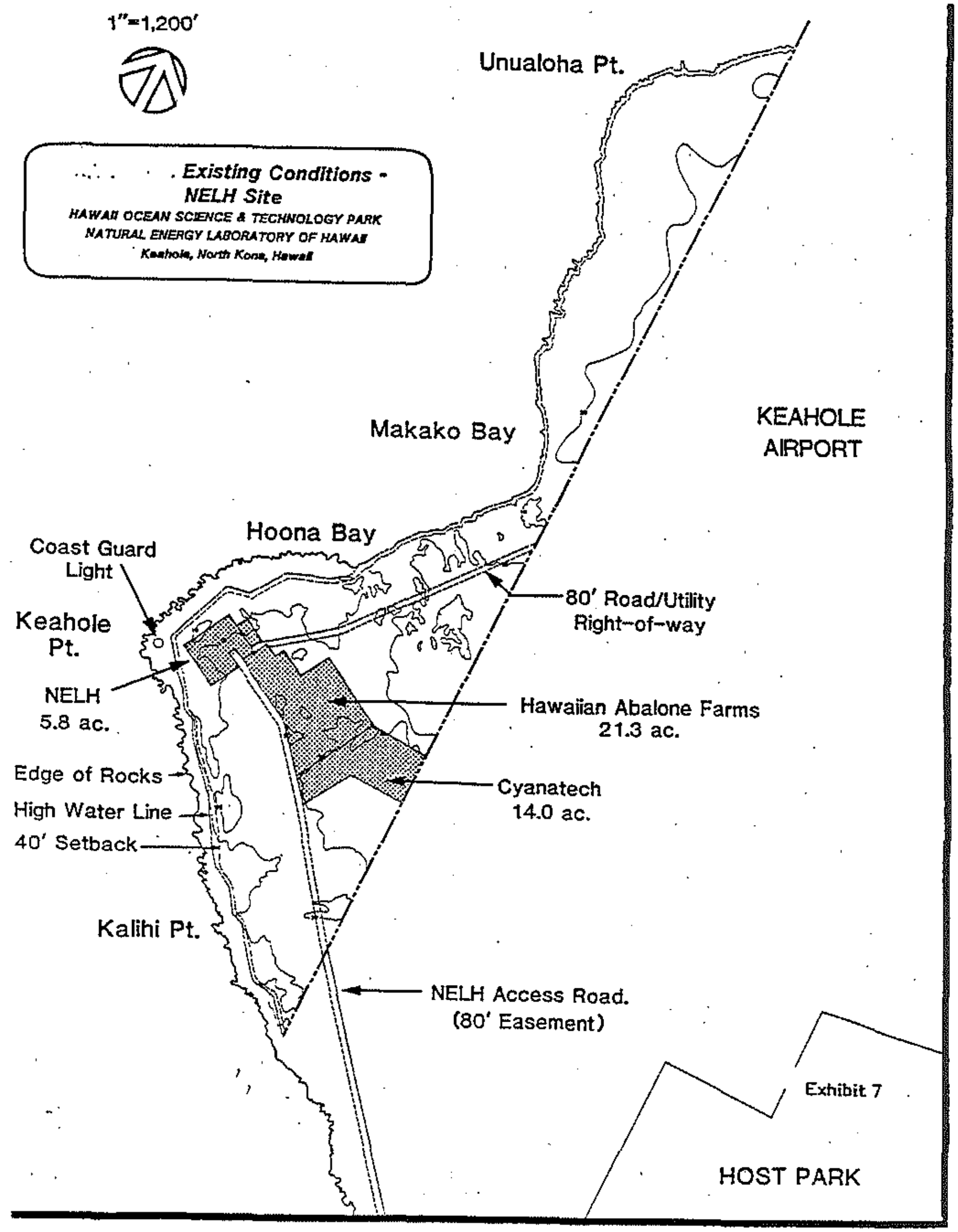
G. The LICENSEE shall keep the property under its control in a clean and orderly condition, free from trash and refuse and shall assume the responsibility for the licensed area.

H. This license shall be neither assignable nor transferable by the LICENSEE and LICENSEE shall not authorize any use of the property by others, except as stated in this license.

I. LICENSEE shall be responsible for any damage that may be caused to the LICENSOR's property incident to the use of the area and shall promptly repair or replace, to the satisfaction of the LICENSOR, any property damaged or destroyed, or in lieu of such repair or replacement the LICENSEE shall, if required by the LICENSOR, pay to the United States of America a sum determined by the Commander, Fourteenth Coast Guard District to be sufficient in amount for the loss sustained.

J. In the event that injury or death occurs to any person or loss, destruction or damage occurs to any property of the LICENSEE, its agents or employees, or others who may be on said premises at their invitation or the invitation of anyone of them in connection with the use of the area, occasioned in whole or in part by the acts or omissions of the LICENSEE, the LICENSEE shall assume all liability therefor and will indemnify and save harmless the United States Coast Guard, its officers, agents or employees from any liability and all such claims to the maximum extent allowed under the Federal Tort Claims Act, as amended (28 U.S.C. Sections 2671-2680).

K. It is a condition of this license that no person in the United States shall, on the grounds of race, sex, color or national origin, be excluded from participation in, or denied the benefits of, or be otherwise subjected to discrimination in the



use of the premises. The United States Coast Guard reserves the right to revoke and cancel this license in the event of breach of such non-discrimination condition during the period of the license.

L. Upon revocation, expiration or surrender of this license, LICENSEE shall vacate the premises or facilities before the expiration or revocation of this license and shall remove all alterations, additions, bettements and improvements made or installed and restore the premises or facilities to the same or as good condition as existed on the date of the initial entry or original license, reasonable wear and tear excepted. If removal and restoration are not accomplished within 30 days of the revocation, expiration, or surrender of this license, LICENSOR may effect removal and restoration at the expense of the LICENSEE and without liability to LICENSOR for any damage.

IN WITNESS WHEREOF, the parties hereunto have subscribed their names this date below:

UNITED STATES OF AMERICA	NATURAL ENERGY LABORATORY OF HAWAII
By R. K. JONES, CDR, USCG By direction	By Jack P. Huizingh
Chief, Comptroller Division Official Title	Executive Director Official Title
14th Coast Guard District 300 Ala Moana Boulevard Honolulu, Hawaii 96850-4982 Address	220 S King Street Suite 1280 Honolulu, Hawaii 96813 Address
10/28/85 Date	11/13/85 Date

The Natural Energy Laboratory of Hawaii

February 19, 1987

Commander J.F. Milbrand
U.S. Coast Guard
District Planning Officer
Fourteenth Coast Guard District
300 Ala Moana Boulevard
Honolulu, Hawaii 96850

Dear Commander Milbrand:

Subject: Draft Supplemental EIS (dSEIS) to Permit Alternative Methods of Seawater Return Flow Disposal at the Natural Energy Laboratory of Hawaii, Keahole, North Kona, Hawaii.

Thank you for commenting on the subject dSEIS. In answer to your specific concerns:

1. At the present time, it is not anticipated that the proposed disposal facilities will be located on Coast Guard property. If, in the future, such an action does take place, NELH will request modification to the existing license or will apply for a new one.

2. Because the disposal facility will be located adjacent to your facility, we have informed the Department of Accounting and General Services (the Project Manager) and R.M. Towill Corporation (the Project Engineers) of your request to review the plans.

Best regards,

Jack P. Huizingh
Executive Director

CC: DAGS
R.M. Towill

☒ 220 South King Street, Suite 1280 • Honolulu, HI 96813 • (808) 548-7017
☐ P.O. Box 1749 • Kailua-Kona, HI 96745 • (808) 329-7341
☐ P.O. Box 2172 • Pahoa, HI 96778 • (808) 965-9690

JOHN WAIHEE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF HEALTH
P. O. BOX 3378
HONOLULU, HAWAII 96801

John C. Lewin, M.D.
DIRECTOR OF HEALTH

RECEIVED
JAN 30 1987
NELH

In reply, please refer to:
EPHSD

January 23, 1987

MEMORANDUM

To: Director, Office of Environmental Quality Control

From: Director of Health

Subject: Draft Supplemental EIS to Permit Alternative Methods of Seawater Return Flow Disposal at the Natural Energy Laboratory of Hawaii, Keahole, North Kona, Hawaii

Thank you for allowing us to review and comment on the subject project.

The comments in our letter and memorandum which are contained in Part VII.B. of the Draft Supplemental EIS document (dated April 25, 1985, August 21, 1985, March 4, 1986 and August 18, 1986, still apply.

JOHN C. LEWIN, M.D.

cc: Mr. Jack P. Huizingh ✓
Ms. Marilyn Metz
DHO, Hawaii

The Natural Energy Laboratory of Hawaii

February 19, 1987

John C. Lewin, M.D., Director
State Department of Health
P.O. Box 3378
Honolulu, Hawaii 96801

Dear Dr. Lewin:

Subject: Draft Supplemental EIS (dSEIS) to Permit Alternative Methods of Seawater Return Flow Disposal at the Natural Energy Laboratory of Hawaii, Keahole, North Kona, Hawaii.

Thank you for commenting on the subject dSEIS. We recognize the need to coordinate with the Department of Health should any of the conditions mentioned in your previous correspondence apply.

Best regards,

Jack P. Huizingh
Executive Director

cc: DAGS
R.M. Towill

220 South King Street, Suite 1280 • Honolulu, HI 96813 • (808) 548-7017
P.O. B[illegible] • Kail[illegible] HI 967[illegible] • (808) 32[illegible]
P.O. B[illegible] • Pah[illegible]

JOHN WAIHEE
GOVERNOR OF HAWAII

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

WILLIAM W. PATY
BOARD OF LAND & NATURAL RESOURCES
LIBERT K. LANDGRAF
DEPUTY TO THE CHAIRMAN

DIVISIONS:
AQUACULTURE DEVELOPMENT PROGRAM
AQUATIC RESOURCES
CONSERVATION AND RESOURCES ENFORCEMENT
CONVEYANCES
FORESTRY AND WILDLIFE
LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

FILE NO.: HA-1862
DOC. NO.: 2506B

FEB 18 1987

RECEIVED
FEB 20 1987
NELH

Honorable John C. Lewin, Director
Department of Health
1250 Punchbowl Street
Honolulu, Hawaii 96813

Dear Dr. Lewin:

SUBJECT: Draft Supplemental Environmental Impact Statement (DSEIS) - Development Plan for the Hawaii Ocean Science & Technology Park and Proposed Expansion of the Natural Energy Laboratory of Hawaii: Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at the Natural Energy Laboratory of Hawaii (NELH)

We have completed our review of this subject document and offer the following comments:

Historic Sites

NELH, HOST Park, and their planners have worked closely with our office on general planning for this area.

The SEIS correctly covers the known sites in the area and their significance (II:16-19), likely effects (IV:53,54), and the mitigation plan worked out with our office, which also considered input from other agencies and individuals on EIS and planning steps (IV:53,54; App.D). We agree that the mitigation plan with its preservation and data recovery elements and with its verification check for proper execution by our office and the County Planning Department will change any adverse effects to "no adverse effects".

Recreation

There are no significant recreation concerns as long as nearshore water quality is monitored and recreation needs considered in evaluating alternative means of discharging water.

Aquatic Resources

The Draft Supplemental EIS has provided considerable information on the anticipated impacts and mitigation measures proposed for the initial seawater disposal of 3,000/5,000 gpm. However, due to the uniqueness of this project and the large amount of discharge proposed for the future, a monitoring program should be made a requirement, not only to detect nutrient load, dissolved oxygen variations, and chemical additives, but to assess impacts on the brackish groundwater and associated anchialine ponds.

Groundwater

We note that groundwater monitoring has been included in the Final EIS. Our concerns have been addressed.

We appreciate the opportunity to comment on this document.

Very truly yours,

WmWPaty

WILLIAM W. PATY, Chairperson
Board of Land and Natural Resources

cc: Mr. Jack P. Huizingh
Ms. Marilynn Metz

The Natural Energy Laboratory of Hawaii

February 20, 1987

Mr. William W. Paty, Chairperson
Board of Land and Natural Resources
P.O. Box 621
Honolulu, Hawaii 96809

Dear Mr. Paty:

Subject: Draft Supplemental Environmental Impact Statement (dSEIS) - Alternative Methods of Seawater Return Flow Disposal at NELH

Thank you for reviewing and commenting on the subject dSEIS. We will continue to work closely with your Historic Sites section to minimize adverse impacts to historic resources on the NELH property. Recreation needs will also be considered in evaluating means of discharging water. We also agree that the monitoring program is an important component of all methods of seawater return flow disposal employed at NELH. We look forward to continuing cooperation and coordination with your staff during the implementation and monitoring phases of these important projects at NELH.

Best regards,

Jack P. Huizingh
Executive Director

cc: DAGS
R.M. Towill

☐ 220 South King Street, Suite 1280 • Honolulu, HI 96813 • (808) 548-7017
☐ P.O. Box 1749 • Kailua-Kona, HI 96745 • (808) 329-7341
☐ P.C 72 • P 9677 965-S

University of Hawaii at Manoa

Department of Oceanography
Division of Natural Sciences
1000 Pope Road • Honolulu, Hawaii 96822
Telephone: (808) 948-7633 • Cable Address: UNIHAW

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NELH

January 15, 1987

Director Office of Environmental
Quality Control
465 South King Street, Room 104
Honolulu, Hawaii 96813

Dear Sir:

I am responding to the Draft Supplemental EIS to Permit Alternative Methods of Seawater Return Flow Disposal at the Natural Energy Laboratory of Hawaii. Two major concerns seem to be the low oxygen levels and high nutrient concentrations in the effluent water from the 165 KW demonstration plant. I gather (p. V) that the discharge will amount to 16,100 gpm = 23.2 mgd.

I am concerned first of all because Table 4-1 (p. IV-5), which lists the characteristics of the effluent, is unnecessarily ambiguous and contains one obvious error. Because I know approximately what the characteristics of deep ocean water are, it is clear to me that the concentrations of $NO_2 + NO_3$ and PO_4 in Table 4-1 are supposed to be in units of N and P, respectively. However, the table does not make this fact clear. The ambiguity arises because, for example, water which contains 93 micrograms per liter of phosphate phosphorus contains about 285 micrograms per liter of phosphate. The difference arises of course because phosphorus has an atomic weight of about 31, while phosphate has a molecular weight of 95.

In any case it is true that the nitrite plus nitrate nitrogen concentration in deep ocean water is about 554 micrograms per liter. However, the corresponding phosphate phosphorus concentration is about 93 micrograms per liter, not 930 as stated in the table. This error has been carried through into the calculation of the phosphate phosphorus concentration in the 1:1.5 mix. Clearly it is impossible for the TP concentration to be 93 micrograms per liter and the phosphate phosphorus concentration to be 930 micrograms per liter.

Now in fact there is a simple way to remove the nutrients in the wastewater, add oxygen to the water, and produce a feedstock for biofuels production all at the same time. The trick is to use

the effluent water to grow seaweeds. The seaweeds will assimilate the nitrogen and phosphorus, produce oxygen (at least during the day), and can be digested to produce alcohol or methane. In fact the summary (p. V) lists macroalgae as one potentially useful mariculture product. It seems ironic that no one apparently considered using the macroalgae to treat the wastewater and produce a biofuels feedstock.

How much land area would be required to treat the wastewater? We have 23.2 mgd = 88×10^6 liters per day of effluent containing 223 micrograms per liter of nitrite plus nitrate N. Hence we have about $(88 \times 10^6)(223 \times 10^{-6}) = 19{,}624$ g N per day = 20 kg N per day or about 44 lbs. of N per day to remove. Now seaweed grown in culture will produce about 20 g $m^{-2}d^{-1}$ of ash-free dry weight, of which about half or 10 g $m^{-2}d^{-1}$ is carbon. The C:N ratio in macroalgae is about 16 by weight [Atkinson and Smith, Limnology and Oceanography 23: 568 - 574 (1983)]. Therefore seaweeds will remove about $10/16 = 0.625$ g $m^{-2}d^{-1}$ of N. Hence the area required for the seaweeds to remove 20 kg of N per day would be $(20{,}000)/(0.625) = 32{,}000\ m^2 = 3.2$ ha or about eight acres. Given the fact that the NELH facility covers 322 acres (Summary, p. iv), I should think that setting aside eight acres for treatment of the effluent would not be a problem. Furthermore, I think production of biofuels feedstocks through growth of macroalgae should be an integral part of the system in the first place. After all, OTEC produces only electricity. If liquid fuels could be produced as a by-product, the whole operation would be much more useful from an energy standpoint.

Sincerely,

Edward Laws

Edward A. Laws
Professor

EAL:tt

cc: Mr. Jack Huizingh, NELH
Ms. Marilyn Metz, MCM Planning
Patrick Takahashi, HNEI

The Natural Energy Laboratory of Hawaii

February 19, 1987

Professor Edward A. Laws
Department of Oceanography
1000 Pope Road
University of Hawaii at Manoa
Honolulu, Hawaii 96822

Dear Professor Laws:

Subject: Draft Supplemental EIS (dSEIS) to Permit Alternative Methods of Seawater Return Flow Disposal at the Natural Energy Laboratory of Hawaii, Keahole, North Kona, Hawaii.

Thank you for commenting on the subject dSEIS. The following responses to your specific concerns have been prepared in consultation with Oceanit Laboratories, Inc.

Comment #1, page 1

"... Table 4-1 (p. IV-5) ... contains one obvious error ... concentrations of NO2 + NO3 and PO4 in Table 4-1 are supposed to be in units of N and P, respectively. However, this table does not make this fact clear. The ambiguity arises because, for example, water which contains 93 micrograms per liter of phosphate phosphorus contains about 285 micrograms per liter of phosphate. The difference arises of course because phosphorus has an atomic weight of about 31, while phosphate has a molecular weight of 95."

Response to comment #1

Thank you for pointing this out. Table 4-1 will be modified in the Final SEIS.

Comment #2, page 1

"In any case it is true that the nitrite plus nitrate nitrogen concentration in deep ocean water is about 554 micrograms per liter. However, the corresponding phosphate phosphorus concentration is about 93 micrograms per liter, not 930 as stated in the table.

The Natural Energy Laboratory of Hawaii

Thank you for pointing out this error. Please note the following changes in Table 4-1, page IV-5 which will appear in the final SEIS.

	Cold Seawater	Warm Seawater	1:1.5 mix
PO4 (µg-P/L)	93.0	4.7	40.0
TP (µg-P/L)	94.0	10.9	44.1

Although there was an error in the amount of phosphorus calculated in the discharge, the qualitative analysis and results remain the same.

Comment #3, page 2

" ... It seems ironic that no one apparently considered using the macroalgae to treat the wastewater and produce biofuels feedstock."

Response to comment #3

Although we did not consider the production of biofuels, we did consider using macro or microalgae to remove nutrients and add oxygen to the discharged seawater. Over recent months, a researcher from UHM has been conducting tests using algae to strip the nutrients from NELH discharge seawater. The next phase of his experiment is to investigate the use of algae which would have commercial value. Biofuel production could be investigated as a possible alternative with the hope that products would prove to be of economic significance.

Comment #4, page 2

"How much land area would be required to treat the wastewater? ... Given the fact that the NELH facility covers 322 acres, I should think that setting aside eight acres for treatment of the effluent would not be a problem."

Response to comment #4

The location of a single 8 acre site to be set aside for this purpose is important in order to insure the operational feasibility of the facility and its tenants since most of the suitable sites are also highly desirable for other mariculture activities with known higher returns on investment. The NELH master plan has designated several centrally located smaller sites for general service uses. Several users are also reviewing ways in which the cold seawater can be used several times before final discharge and as mentioned previously, researchers are conducting experiments to better treat and use the discharged seawater for commercial ends. As you note, OTEC power

The Natural Energy Laboratory of Hawaii

plants may be generating electricity using considerable volumes of water at relatively high costs. The more by-products that can be produced, the more feasible OTEC can be.

Best regards,

Jack P. Huizingh
Executive Director

cc: DAGS
R.M. Towill

University of Hawaii at Manoa

Environmental Center
Crawford 317 • 2550 Campus Road
Honolulu, Hawaii 96822
Telephone (808) 948-7361

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February 9, 1987

Director
Office of Environmental Quality Control
465 South King Street, Room 104
Honolulu, Hawaii 96813

Dear Sir/Madam:

Draft Supplemental Environmental Impact Statement
Alternative Methods of Seawater Return Flow Disposal
Natural Energy Laboratory of Hawaii
Keahole, North Kona, Hawaii

The above cited document addresses the potential environmental impacts related to alternative methods for discharging seawater return flows at the Natural Energy Laboratory of Hawaii (NELH) at Keahole, Hawaii. This review was prepared with the assistance of Keith Chave and Frank Sansone, Oceanography; Michael Graves, Anthropology; Hans Krock, Ocean Engineering; Frank Peterson, Geology and Geophysics; Alison Kay, Zoology; and Walington Yee, Environmental Center.

At full development, the proposed discharge, estimated to be 100,000 GPM, will be the largest in the State of Hawaii and comparable in volume to that discharged through municipal sewers of the City and County of Honolulu. The initial 16,000 GPM will approximate the volume of sewage discharge of the entire county of Hawaii. The quality of the aquaculture effluent, however, is not precisely given, and will vary with the organisms produced and the chemicals added during their culture. The primary concern of our reviewers is that the proposed plan to discharge seawater return flows laden with aquaculture waste, from the aquaculture farms at NELH and HOST parks, into land based trenches may affect the class AA coastal waters off Keahole, Hawaii and the surface intake waters of NELH-HOST.

General Comments

For the most part the draft SEIS adequately addresses many of the more general issues of concern. However, there are several critical points that either were omitted from consideration or were incorrectly interpreted. These issues are discussed in the following paragraphs.

Seawater Return Flow IV-3

Clogging is a factor that is not fully addressed and that may be quite important, especially in the injection well alternative. More attention should be given to this potential problem and the trench designed to allow de-clogging should it be neccessary. Related to clogging, is the unrecognized fact that although reaeration of the disposal waters may be highly desirable for various environmental reasons, if reaeration is done before disposal, this process will greatly increase the possibility of clogging by gas bubbles.

The disposal via a trench system for the 16,000 gpm operation may not have a significant environmental effect, however, we are concerned about the effects of the very large-scale disposal of up to 100,000 gpm described as the ultimate goal at this site. Before such large expansion is allowed, a subsequent Environmental Assessment should be required, using data collected during the initial disposal operations, to evaluate the actual operational environmental effects. Will resources be made availabe to build an alternate means of disposal if the trenches prove to be detrimental to the environment?

Mariculture Seawater Return Flows IV-26

Nutrients and biocides in the discharge waters, such as those occuring at certain aquaculture farms on Oahu, can be expected to be an issue at NELH/HOST when aquaculture operations are implemented. We note in the SEIS, (p.vii), that, "The nature of all [discharges] should be reported and investigated prior to introduction into the discharge system as it may impact the resident epifauna". Given the experience with existing aquaculture developments both on Oahu and at NELH, it does not seem likely that future aquaculture operators will abide with the stipulations of this sentence unless some legally binding enforcement provisions are instituted. In light of economic pressures on aquaculture operators for the concealment of proprietary culturing techniques, enforcement procedures to insure that discharge characteristics are adequately reported will need to be established.

Cummulative Impacts IV-40.

The discussion of the effects of the proposed discharge on the anchialine ponds at Kohana-Iki, (p.IV-44-45), states that the time required for disposal waters to reach the anchialine ponds is estimated at 10-30 years. It should be recognized that, if this is the case, by the time any adverse effects are observed it will be too late to mitigate the effects. Even if disposal was stopped immmediately, some 10-30 years of disposal waters would still be in the ground and a significant part of this would be continuing to move into the ponds.

Alternatives IV-49

The environmentally and technically sound alternative of an outfall pipe or pipes discharging in the vicinity of, or below, the thermocline was not seriously considered solely on economic arguments. Since a properly designed outfall system would comply with environmental laws and would be unlikely to result in any significant detrimental impact to the coastal waters, the lack of a thorough exploration of this alternative and finding a sound environmental reason for rejection is a serious deficiency in the SEIS. Significant cost savings by co-deployment with the cold water pipe, or other such alternatives, also needs to be addressed.

The benefits of a pipe dischage at depth, of the NELH and HOST park wastewaters, include:

a) Positive and reliable vertical separation of discharge waters from both the warm water and cold water intakes. This would eliminate recycling of any aquaculture disease organisms and chemical contaminants.

b) Discharge of the wastewater to a layer in the water column with similar nutrient concentrations, similar dissolved oxygen levels, and similar density. This means that ambient water quality characteristics would not be significantly affected.

c) Discharge to an area where the benthic and water column biological communities are already adapted to low oxygen conditions.

Alternatively, an argument can be made for a pipe discharge to the lower portion of the photic zone but away from the delicate coastal benthic community. Here the nutrients in the discharge would enhance the biological productivity of a portion of the ocean off Kona. Such an alternative would require more study of the dynamics of the density profile, of the horizontal transport and the photic zone as well as some exploration of pelagic trophic dynamics with respect to nutrients. The conduct of these studies should be considered prior to expansion of the permitted flows from the proposed 16,000 gpm to the 100,000 gpm figure predicted. The alternative recommended in the draft supplemental EIS involves discharge by means of a trench or trenches. Although some discussion of concentrated discharge via lava tubes or other high permeability areas is included in several areas of the EIS, the actual assessment of potential environmental impact appears to have been done on the basis of calculations described in Appendix C and elsewhere which consider uniform flow and average conditions. We believe that the assumptions made in these calculations and in the subsequent interpretations present a number of difficulties. These include:

a)Infrared photos and geological evidence clearly indicate that localized areas of concentrated discharges can be expected. Therefore, the assumption of uniform permeability seems incorrect. Determining the locations and sizes of these "point" discharges is essential in evaluating the possible environmental effects and in the design of any monitoring program.

b)Allthough identified as "worst case" conditions the assumption of current speed and mixing that were used are in fact very close to average conditions. The most immediate environmental impact that can be expected from the proposed discharge is low oxygen stress on the benthos. The time required for a significantly detrimental response to such a stress is tens of minutes to a few hours. The actual "worse case" assumptions should therefore be based on minimum mixing and transport conditions at the bottom on the basis of tens of minutes to a

this long and the available current records for this area also show frequent episodes of virtually no current. Under these actual circumstances the more dense discharge water exiting at several concentration points seaward of the discharge trench, can be expected to pool in depressions and flow downhill in a layer along the bottom. This would be very detrimental to the benthic community. In contrast, domestic wastewater discharges mix with the surrounding seawater even under calm conditions because of the buoyancy.

c) There is some discussion of re-oxygenation of the wastewater before discharge. This would work for the open-cycle OTEC experiment discharges because of the very low reduced organic content. However, the discharges from the aquaculture facilities will contain a considerably higher concentration of oxygen demanding material. Bacterial breakdown of this material in the trench and during passage through the ground, even after an initial dose of oxygen before discharge, will likely result in the discharge of low oxygen waters to the nearshore ocean bottom.

<u>Appendix B</u>

There is insufficient discussion of the need for biological monitoring and the procedures that will be followed. We are particularly concerned with the suggested semi-annual, frequency of the biological monitoring schedule. Affected organisms are likely to mature in much less than 6 months, therefore to estimate the effects of the discharge on the ecosystem at Keahole, monthly transect sampling would be more appropriate. Coastal areas subject to the higher nutrient seawater return flows are likely to experience an increase in the development of algal turf and in particular <u>Ulva</u>. This may lead to an increase in the sea urchin, <u>Echinometra</u>. Experience at other aquaculture farms in the state suggests that monitoring for escapees is also needed.

<u>Appendix E</u>

We note also that on page 6 of Appendix E (Impacts on Anchialine Ponds), the author recommends that "discharges of known toxic materials should be prohibited". Compliance with this recommendation would not be feasible given the list of Herbicides, Selective Toxicants, and Disinfectants cited, (p.IV-27), as necessary for successful aquaculture farm operations.

It is likely that the oxidation of organic material from aquaculture activites will lead to the development of hypoxic and/or anoxic conditions within the disposal trench and the surrounding water-saturated rocks. These conditions are likely to affect hypogeal anchialine organisms living within the brackish/marine watertable. Related to this is the likely development of bacterial slime in the rock surrounding the discharge trench (particularly in the case of the aquaculture discharge); this type of biofouling is commonly seen around sewage injection wells, and could result in the clogging of the proposed trench system.

Miscellaneous comments

We have not attempted to correct or cite the typographical errors in the draft. A couple of the more serious errors however include: the contents of table A-1 (p. A-37), this data is out of date and wrong; Table A-2 (p. A-37) is not referenced in the text, it disagrees with Table A-1 enormously, and it is not likely based on reference 25; Table 2 (p. A-58) represents the input to the mariculture facility not the discharge.

We appreciate the opportunity to contribute comments during the review period of this draft supplemental EIS and look forward to your response.

Sincerely,

Jacquelin N. Miller

Jacquelin N. Miller
Acting Associate Director

cc Stephen Lau
Jack P. Huizingh
Marilyn Metz
Keith Chave
Frank Sansone
Hans Krock
Frank Peterson
Walington Yee
Pamela Bahnsen

The Natural Energy Laboratory of Hawaii

February 20, 1987

Jacquelin N. Miller
Acting Associate Director
Environmental Center
University of Hawaii at Manoa
2550 Campus Road
Honolulu, Hawaii 96822

Dear Ms. Miller:

Subject: Draft Supplemental EIS (dSEIS) to Permit Alternative Methods of Seawater Return Flow Disposal at the Natural Energy Laboratory of Hawaii, Keahole, North Kona, Hawaii.

Thank you for reviewing and commenting on the subject dSEIS. Oceanit Laboratories, Inc., GK Associates and Dames and Moore assisted in the preparation of the responses related to their particular areas of expertise. In answer to your specific comments:

- Your letter, Page 1, Paragraph 2

"At full development, the proposed discharge, estimated to be 100,000 gpm..."

The subject SEIS specifically addresses discharge at the Natural Energy Laboratory of Hawaii (NELH). At full development of NELH the discharge is estimated to be 42,000 gpm, of which 16,100 gpm will be generated by OC OTEC and 25,900 gpm by mariculture activities. The mariculture figure is undoubtedly overstated as it is based on the relatively simplistic assumption that all of the seawater pumped to shore via all of the intake pipes proposed for NELH goes out via the trenches. It does not account for evaporation nor reuse of the water, factors that could reduce the volume of discharge.

"... The primary concern of our reviewers is that the proposed plan to discharge seawater return flows laden with aquaculture waste, from the aquaculture farms at NELH and HOST parks, into land based trenches may affect the class AA coastal waters off Keahole, Hawaii and the surface intake waters of NELH-HOST."

The reviewers' concern about possible impacts on nearshore water quality is shared by the authors of the SEIS, and this was a major focus of the SEIS. Potential impacts were identified and disclosed. We believe that the monitoring program proposed in the SEIS will provide adequate notice of unacceptable impacts. It is most important to remember that negative impacts on the surface water intake will directly affect the users themselves, so that the results of monitoring will receive close scrutiny by users as well as facility management and regulatory agency personnel.

☒ 220 South King Street, Suite 1280 • Honolulu, HI 96813 • (808) 548-7017
☐ P.O. Box 1749 • Kailua-Kona, HI 96745 • (808) 329-7341
☐ P.O. Box 2172 • Pahoa, HI 96778 • (808) 965-9699

The Natural Energy Laboratory of Hawaii

- Seawater Return Flow IV-3

"Clogging is a factor that is not fully addressed and that may be quite important, especially in the injection well alternative. More attention should be given to this potential problem and the trench designed to allow de-clogging should it be necessary."

The probable effects of clogging are discussed in the design considerations section of Appendix C (Pages C-8 to C-10). The present trench design utilizes a crushed lava or gravel backfill which filters the discharge prior to seepage into the ground. In this case, clogging may be alleviated by either replacing the fill or extending the trench. It has been recommended that design lengths of trenches be approximately twice the theoretical length required, to account for clogging effects. The ends of the trench would also be designed to enable extension should clogging occur.

"Related to clogging, is the unrecognized fact that although reaeration of the disposal waters may be highly desirable for various environmental reasons, if reaeration is done before disposal, this process will greatly increase the possibility of clogging by gas bubbles."

Clogging due to gas bubbles caused by reaeration was recognized as a potential problem, but this is basically one of engineering design of the facility. If necessary, a stilling basin could be added to allow the gas to dissolve prior to water disposal. Beyond this, liquid oxygen could be injected, although with less favorable economics. This concern is among those to be addressed during the 3,000 to 5,000 gpm heat and mass transfer experiment phase .

"The disposal via trench system for the 16,000 gpm operation may not have a significant environmental effect, however, we are concerned about the effects of the very large-scale disposal of up to 100,000 gpm described as the ultimate goal of this site."

There seems to be some confusion as to volumes and types of discharge at NELH. As stated in our response to your introductory comments, the projected total volume of discharge at NELH is 42,000 gpm. The discharge at the adjacent HOST Park, which was assessed in the previous EIS, may reach 100,000 gpm at full development.

As stated in the SEIS (Page II-6, Monitoring and Pages IV-48 & IV-49, Recommendations) initial volumes for both OC OTEC and mariculture at NELH are expected to be considerably less than the projected maximums. For OC OTEC, there will be a 3 to 4 year period of heat and mass transfer experiments at volumes of 3,000 to 5,000 gpm. During this period, extensive environmental research and monitoring will be conducted to identify any adverse impacts and develop mitigating measures. Although there is no set time frame in which maximum mariculture volumes will be reached, these discharges are also expected to be increased gradually. Initial operations at these low discharge levels will allow time to monitor the impacts and implement additional mitigation measures should they be necessary prior to increasing flow rates.

An important limiting factor for growth of mariculture discharge flows is the availability of cold seawater. At the adjacent HOST Park, discharges will not exceed 6,800 gpm (the capacity of the planned intake pipeline) for the foreseeable future. Twelve additional ocean water intake pipes will have to be deployed off of NELH and HOST Park before maximum volumes are reached. This process could take at least 5 to 10 years or more.

"Before such large expansion is allowed, a subsequent environmental assessment should be required......"

Preparation of a new EA at some future date would be redundant and no regulatory mechanism requires this. Data collected in the monitoring program will be provided directly to regulatory agencies for their review under permit conditions.

"Would resources be made available to build an alternative means of disposal if the trenches prove to be detrimental to the environment?"

If the trenches prove detrimental to the environment, the utility of the facility would be correspondingly reduced. This would be unacceptable to federal and state agencies, as well as to other facility users, and clearly an alternative means of disposal would have to be implemented. The source of funding for an alternative system has not been identified, but would depend on the nature and cause of the unacceptable impact.

• Mariculture Seawater Return Flows IV-26

"....In light of economic pressures on aquaculture operators for the concealment of proprietary culturing techniques, enforcement procedures to insure that discharge characteristics are adequately reported will need to be established."

We agree with your comment, and such provisions are being included in the facility rules and regulations. The monitoring program will detect against the more likely abuses, but again, it is important to point out that it is in the best interest of the user community to self-police its actions.

• Cumulative Impacts IV-40

"....Even if disposal was stopped immediately, some 10-30 years of disposal waters would still be in the ground and a significant part of this would be continuing to move into the ponds."

To guard against this and provide an early warning system, monitoring wells (as recommended in the previous EIS), located on both the NELH and HOST Park sites, are being constructed as part of the HOST Park first phase construction. The monitoring program developed in Appendix B includes sampling of these wells. Adverse impacts will be detected early enough so that they can be mitigated before large volumes of seawater reach the ponds.

• Alternatives IV-49

"The environmentally and technically sound alternative of an outfall pipe or pipes discharging in the vicinity of, or below, the thermocline was not seriously considered solely on economic arguments...Significant cost savings by co-deployment with the cold water pipe, or other such alternatives, also need to be addressed."

We understand the potential benefits of an outfall pipe system, and included these in our consideration of alternatives. The economics of this option are prohibitive at this time. Co-deployment with the cold-water pipe was considered by the engineers but was still too expensive given current funding levels for the project. The previous EIS assessed the originally proposed mixed-discharge pipe. Because this is a supplemental EIS, the analysis was not repeated but rather incorporated by reference.

The stated purpose of this SEIS is to assess alternatives to an outfall for OC OTEC seawater return flow disposal because funding is not available at the present time to construct the discharge pipe. The conclusion of the analysis of alternatives in the SEIS is that within available economic resources there is a solution which appears to have acceptable environmental risks. We believe the risks are minimal because of the small initial flow volumes, the monitoring program and the nature of the discharges. If adverse impacts occur as a result of disposal into trenches, additional mitigating measures will be undertaken, including reexamination of the deep-water discharge pipe. The deep-water discharge pipe was not rejected; it will remain an alternative to be considered when and if conditions warrant it.

"Alternatively, an argument can be made for a pipe discharge to the lower portion of the photic zone but away from the delicate coastal benthic community....Such an alternative would require more study of the dynamics of the density profile, of the horizontal transport and the photic zone as well as some exploration of pelagic trophic dynamics with respect to nutrients. The conduct of these studies should be considered prior to expansion of the permitted flows from the proposed 16,000 gpm to the 100,000 gpm figure predicted."

The data from the monitoring program should provide considerable insight into the trophic dynamics of the offshore pelagic environment. It is beyond the authority of either NELH or HOST Park to fund a major multi-disciplinary research program on basic nutrient cycling in the ocean.

"Although some discussion of concentrated discharge via lava tubes or other high permeability areas is included in several areas of the EIS, the actual assessment of potential environmental impact appears to have been done on the basis of calculations described in Appendix C and elsewhere which consider uniform flow and average conditions. We believe that the assumptions made in these calculations and in the subsequent interpretations present a number of difficulties. These include:

"a) Infrared photos and geological evidence clearly indicate that localized areas of concentrated discharges can be expected. Therefore, the assumption of uniform permeability seems incorrect. Determining the locations and sizes of the "point" discharges is essential in evaluating the possible environmental effects and in the design of any monitoring program."

Previous investigations made by the Water Resources Research Center of the University of Hawaii (Adams, W.H.; Peterson, F.L.; Mathur, S.P., Lepley, L.K.; Warren, C; and Hubber, R.D.; 1969. A Hydro Geophysical Survey from Kawaihaw to Kailua-Kona, Hawaii. Technical Report No. 32, Water Resources Research Center, University of Hawaii.) found no unusual groundwater conditions in the Keahole region. The infrared scan of the coastline did not show any evidence of substantial freshwater outflow.

Geologic conditions in the Keahole area are conducive to the formation of lava tubes. Dames & Moore's experience in the general area, however, has been that lava tubes which were uncovered and followed (for purposes of ground preparation for the construction of structures) have been small and have had a relatively limited extent. The results of the above referenced infrared scan do not indicate the presence of a major continuous lava tube in the vicinity.

The only known freshwater spring in the vicinity, at Wawaloli Beach, is due to the confluence of groundwater flow caused by the shoreline geometry (i.e. an embayment).

In addition, uniform permeability was not assumed in the analysis. The effect of lava tubes would be to increase anisotropy. In the expanding sphere and expanding cylinder models, the effects of

anisotropy were partially accounted for by limiting the expansion of the plume field in the vertical direction. Although the Theis non-equilibrium model assumes a uniform flow field, the assumed flow thicknesses were developed considering the effects of anisotropy.

Data from infrared photos were considered in the selection of station locations for the monitoring program.

"b) Although identified as 'worst case' conditions the assumption of current speed and mixing that were used are in fact very close to average conditions...The actual 'worse case' assumptions should therefore be based on minimum mixing and transport conditions at the bottom on the basis of tens of minutes...Under actual circumstances the more dense discharge water exiting at several concentration points seaward of the discharge trench, can be expected to pool in depressions and flow down hill in a layer along the bottom. This would be very detrimental to the benthic community."

This particular situation was explored in more detail in Appendix A, Addendum I, starting on page A-52. As a result of this investigation, it was determined that the slightly higher density discharge will cause the build-up and formation of a thin layer because there are no buoyant forces to cause initial dilution. This layer, although mathematically calculated to be an average thickness of one inch, will be slightly thicker in some areas and undetectable in other areas due to irregularities in the bottom. The formation and thickness of this layer will depend on waves and currents, which will change seasonally. The probability of turbulent mixing from these factors was calculated; monitoring the effects of the discharge on corals and marine life will serve to revise and refine our calculations.

The environmental impact analysis in the SEIS was based on analyses from both Appendix A and Appendix C. Reaeration of degassed water prior to discharge was recommended as a mitigation measure because of the potential for concentrated effects due to the density differential between the discharged water and ambient seawater which would tend to keep the discharge on the bottom. This problem was also identified and discussed in the original EIS to which the present document is a supplement.

" c) ... discharges from the aquaculture facilities will contain a considerably higher concentration of oxygen demanding material. Bacterial break down of these material in the trench and during passage through the ground, even after an initial dose of oxygen before discharge, will likely result in the discharge of low oxygen waters to the nearshore ocean bottom."

The oxygen demand of the discharge from the aquaculture facilities is expected to be higher than that of the mixed OTEC discharge. Because neither the composition of the discharges nor the efficiency of the trench system in treatment can be specified at this time, this potential cannot be dismissed. However, these effects would rapidly be detected in results from the monitoring well network and if necessary the effluent will be pretreated to the extent required to mitigate this impact.

Appendix B

"There is insufficient discussion of the need for biological monitoring and the procedures that will be followed. We are particularly concerned with the suggested semi-annual frequency of the biological monitoring schedule."

The benthic portion of the monitoring program was designed to detect impacts of a longer-term nature on significant reef fauna. The actual procedures to be followed would include standard marine biological methods such as transect and quadrat survey techniques, as well as bottom photography. These will be specified when the program is implemented. Biological sampling frequency could be increased if this appears warranted based on the results of the initial chemical monitoring. Prior to publication in the draft SEIS, the monitoring program was reviewed by staff of the State Department of Health, the U.S. Army Corps of Engineers, the National Marine Fisheries Service and the U.S. Fish and Wildlife Service.

"Experience at other aquaculture farms in the state suggests that monitoring for escapees is also needed."

The SEIS specifies that adequate containment provisions be instituted for exotic species, and this will be emphasized in the facility rules. Each user will be required to demonstrate how his facility design and intended operating procedures would insure against such releases. In many cases, the differences between the culture environments and the ambient offshore environment would preclude establishment of exotic populations. In other cases, accidental releases would provide a food subsidy for resident fish populations.

• Appendix E

" ...on Page 6 of Appendix E, the author recommends that 'discharges of known toxic materials should be prohibited.' Compliance with this recommendation would not be feasible given the list of Herbicides, Selective Toxicants, and Disinfectants cited, (p. IV-27), as necessary for successful aquaculture farm operations."

The listed substances, while effective in the concentrations normally used in mariculture operations, are not toxic in the diluted concentrations which would reach any anchialine pond. Furthermore, many of these compounds are normally applied within cultures of living organisms.

"It is likely that the oxidation of organic material from aquaculture activities will lead to the development of hypoxic and/or anoxic conditions with the disposal trench and the surrounding water-saturated rocks. These conditions are likely to affect hypogeal anchialine organisms living within the brackish/marine water table."

The discussion of the biology of the hypogeal shrimp notes that they are able to subsist on a diet of bacterial cells and tolerate very reduced oxygen concentrations. The organic matter and bacteria in the pore waters would provide a food supplement to the shrimp.

"Related to this is the likely development of bacterial slime in the rock surrounding the discharge trench (particularly in the case of the aquaculture discharge); this type of biofouling ... could result in the clogging of the proposed trench system."

Please refer to our response to your previous comment on clogging.

• Miscellaneous Comments

" ... contents of table A-1 (p. A-37), this data is out of date and wrong; Table A-2 (p. A-37) is not referenced in the text, it disagrees with Table A-1 enormously, and it is not likely based on reference 25; Table 2 (p. A-58) represents the input to the mariculture facility not the discharge."

In response to comments made regarding Table A-1: This data may be somewhat dated; however, the data comes from a very useful book entitled "The Oceans, Their Physics, Chemistry and General Biology", by Sverdrup, Johnson and Fleming, first published in 1942. More accurate data may be available today and some are included in Table A-2. This type of elemental data, however, is somewhat site specific and may vary from location to location. Tables A-1 and A-2 were included into the text to give the reader a sense of the range in values available in the literature.

Thank you for pointing out the mixed-up references in Table A-2; this will be corrected in the final SEIS. The table was created from information provided in "Distribution of Elements in Sea Water," by M.S. Quinby-Hunt and K.K. Turekian, published in The American Geophysical Union, EOS, Vol. 64, No. 14, April 5, 1983. Although it is slightly dated, the reference was intended to be used for estimating various elemental concentrations in the World's oceans. Even though elemental concentrations throughout the World's oceans are expected to depend on site specific geophysical- chemistry considerations, the numbers used in Table A-2 were determined to be acceptable for the purposes of the study.

In response to comments made regarding Table 2 (p. A-58): This table

The Natural Energy Laboratory of Hawaii

estimates the resulting discharge water quality as a result of mixing four (4) parts cold with one (1) part warm seawater. It was not intended to include the biochemical reactions resulting from specific mariculture operations, including the use of fertilizers, food supplements, antibiotics, etc.

Thank you for your comments. We hope that our response answers the questions that have been raised.

Best regards,

Jack P. Huizingh
Executive Director

cc: DAGS
R.M. Towill

DANTE K. CARPENTER, MAYOR
DENNIS M. YAMAMOTO
Director

DEPARTMENT OF RESEARCH AND DEVELOPMENT
COUNTY OF HAWAII • 34 RAINBOW DRIVE • HILO, HAWAII 96720 • TELEPHONE (808) 961-8366

January 27, 1987

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Director
Office of Environmental Quality Control
465 South King Steeet Room 104
Honolulu, HI 96813

We wish to state our position of support for the draft supplemental EIS to permit alternative methods of seawater return flow disposal at the Natural Energy Laboratory of Hawaii.

Both NELH and OTEC experiments at Keahole represent unique and valuable scientific positions in the world of ocean science. While NELH was originally designed to do basic research, recent legislation permitting commercial work has made ocean research a valuable addition to the Big Island economy. This transition to commercialization is what has attracted considerable attention and given rise to the concept of the Hawaii Ocean Science and Technology Park, an idea which should prove the value of NELH and the research conducted there. We are of the opinion that this research and the commercialization capability will have beneficial worldwide ramifications.

We favor permitting further development at NELH to allow not only expansion of facilities and capabilities but to permit observation and monitoring of the effects of the proposed actions. Because NELH is a pioneer in many aspects of ocean technology, data gathered from developments such as those proposed is not available elsewhere. Such data will add to NELH's store of information, increasing it's credence as a leader in ocean science, and permitting technology transfer in the future.

We are aware of the probable impacts which may result from permitting the proposed action, however, we feel that the benefit from the proposed action will accrue not only locally but internationally. Because of such potential, we feel that the eventual benefit will offset the probable inimical impacts over the long run.

Dennis M. Yamamoto
Director

cc: Mr. Jack Huizingh, Executive Director, NELH
Ms. Marilyn Metz, AICP, MCM Planning

The Natural Energy Laboratory of Hawaii

February 19, 1987

Mr. Dennis Yamamoto, Director
County of Hawaii
Department of Research and Development
34 Rainbow Drive
Hilo, Hawaii 96720

Dear Mr. Yamamoto:

Subject: Draft Supplemental EIS (dSEIS) to Permit Alternative Methods of Seawater Return Flow Disposal at the Natural Energy Laboratory of Hawaii, Keahole, North Kona, Hawaii.

Thank you for your letter of support for the proposed projects and disposal alternatives at NELH. We agree that the proposed monitoring program will provide data that will be of benefit both locally and internationally. Be assured that NELH will be conscientous in its responsibilities to minimize environmental impacts that could result from its operations. The facility could not exist if the pure ocean water was compromised.

Best regards,

Jack P. Huizingh
Executive Director

cc: DAGS
R.M. Towill

☒ 220 South King Street, Suite 1280 • Honolulu, HI 96813 • (808) 548-7017
☐ P.O. Box 1749 • Kailua-Kona, HI 96745 • (808) 329-7341
☐ P.O. Box, ahoa, 8 • (8)699

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DEPARTMENT OF WATER SUPPLY • COUNTY OF HAWAII

25 AUPUNI STREET • HILO, HAWAII 96720

January 14, 1987

Ms. Letitia N. Uyehara, Director
Office of Environmental Quality Control
465 South King Street, Room 104
Honolulu, HI 96813

DRAFT SUPPLEMENTAL EIS
ALTERNATIVE METHODS OF SEAWATER RETURN FLOW
DISPOSAL AT THE NATURAL ENERGY LABORATORY OF HAWAII
KEAHOLE, NORTH KONA, HAWAII

Thank you for the opportunity to comment on the subject document.

We have no objections or comments to the alternative methods of seawater return flow disposal.

However, the additional domestic water demand requirements for the expansion of the Natural Energy Laboratory of Hawaii facilities should be included.

H. William Sewake

H. William Sewake
Manager

QA/HWS

cc ✓ Mr. Jack P. Huizingh, Executive Director, NELH
Ms. Marilynn Metz, AICP, MCM Planning
Planning Department, County of Hawaii

... Water brings progress ...

The Natural Energy Laboratory of Hawaii

February 19, 1987

Mr. H. William Sewake, Manager
County of Hawaii Department of Water Supply
25 Aupuni Street
Hilo, Hawaii 96720

Dear Mr. Sewake:

Subject: Draft Supplemental EIS (dSEIS) to Permit Alternative Methods of Seawater Return Flow Disposal at the Natural Energy Laboratory of Hawaii, Keahole, North Kona, Hawaii.

Thank you for commenting on the subject dSEIS. Subsequent to the publication of the subject document, NELH has projected its additional domestic water demand resulting from expansion of the facility. These figures will be incorporated into Part II, Section C (NELH Development Plan) of the Final SEIS.

Best regards,

Jack P. Huizingh

Jack P. Huizingh,
Executive Director

cc: DAGS
R.M. Towill

☒ 220 South King Street, Suite 1280 • Honolulu, HI 96813 • (808) 548-7017
☐ P.O. Box 1749 • Kailua-Kona, HI 96745 • (808) 329-7341
☐ P.O. Box 2172 • Pahoa, HI 96778 • (808) 965-9699

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February 9, 1987

Director
Office of Environmental Quality Control
465 South King Street
Honolulu, HI 96813

Dear Sir:

Draft Supplemental EIS - HOST PARK/NELH
<u>Alternative Methods of Seawater Disposal</u>

Thank you for the opportunity to review this draft EIS. We believe the document adequately addresses the potential environmental impacts which may be encountered by the project.

HOST Park/NELH proposes a network of coastal water quality monitoring locations to determine causal relationships between discharges and impacts. In the future, this network needs to be expanded to include locations associated with other coastal developments north and south of Keahole Point. A comprehensive, coordinated water quality monitoring program needs to be developed.

Sincerely,

Albert Lono Lyman

ALBERT LONO LYMAN
Planning Director

ALL:aeb

cc: ✓NELH
MCM Planning

The Natural Energy Laboratory of Hawaii

February 29, 1987

Mr. Albert Lono Lyman, Director
County of Hawaii Planning Department
25 Aupuni Street
Hilo, Hawaii 96720

Dear Mr. Lyman:

Subject: Draft Supplemental EIS (dSEIS) to Permit Alternative Methods of Seawater Return Flow Disposal at the Natural Energy Laboratory of Hawaii, Keahole, North Kona, Hawaii.

Thank you for commenting on the subject dSEIS. We recognize the concerns of the County of Hawaii in maintaining the quality of the nearshore and onshore environment at Keahole. We agree that a comprehensive, coordinated water quality monitoring program, which includes developments to the north and south of NELH/HOST Park, needs to be developed. Appendix B, pages 33-37 of the dSEIS attempts to provide a rough outline of various parameters which might be included in such a plan. We look forward to working with you and your staff in the development of such a program.

Best regards,

Jack P. Huizingh

Jack P. Huizingh
Executive Director

cc: DAGS
R.M.Towill

☒ 220 South King Street, Suite 1280 • Honolulu, HI 96813 • (808) 548-7017
☐ P.O. Box 1749 • Kailua-Kona, HI 96745 • (808) 329-7341
☐ P.O. Box ... • Pahoa ... 778 • ... 5-9699