1998-99 Annual Report

Natural Energy Laboratory of Hawaii Authority

An attached agency of the
Department of Business, Economic Development & Tourism
STATE OF HAWAII

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Joint Message
from the Chairman of the Board and Executive Director

John Corbin

James A. Frazier

Thanks to the groundwork laid during Fiscal Years 1998 and 1999, the Natural Energy Laboratory of Hawaii Authority (NELHA) is well-positioned for a new era of growth.

The Staff and Board focused on a variety of projects to streamline operations and enhance services during the reporting period. A new Booster Pump Station was designed and built to supplement deep sea water supplies to the HOST Park area, revisions to the NELHA Administrative Rules were completed, internal species management protocols were reevaluated, planning and design for new infrastructure projects were begun, and leasing procedures, documents, and the entire lease approval process were revised to better meet the needs of tenant business startups.

Several subcommittees with Board and Staff members were formed to address master planning, leasing, and rental fee restructuring issues. The Board was able to provide creative input to the master planning process, conceiving a commercial development initiative for the highway frontage properties to support NELHA's revenue enhancement efforts. NELHA's seawater rates were re-evaluated, and lease re-opening negotiations with DLNR led to revision of the terms of NELHA's master leases.

The Hawaii State Legislature provided important support of NELHA's plans for growth by passing several items of legislation during the reporting period. Among these were an amendment to the Hawaii Revised Statutes to allow multiple retail activities on NELHA property and a total of $16 million in CIP allocations for the long anticipated completion of the NELHA seawater supply system expansion. This CIP project will add pumping capacities of up to 40,500 gpm of warm surface seawater and 28,500 gpm of deep seawater to NELHA's seawater supply system.

The resourceful NELHA Staff and Board face many new challenges in the new millennium and we look forward to doing our part to help the state realize its vision of economic diversity and sustainability.

Sincerely,

John Corbin
Chairman of the Board

James A. Frazier
Executive Director

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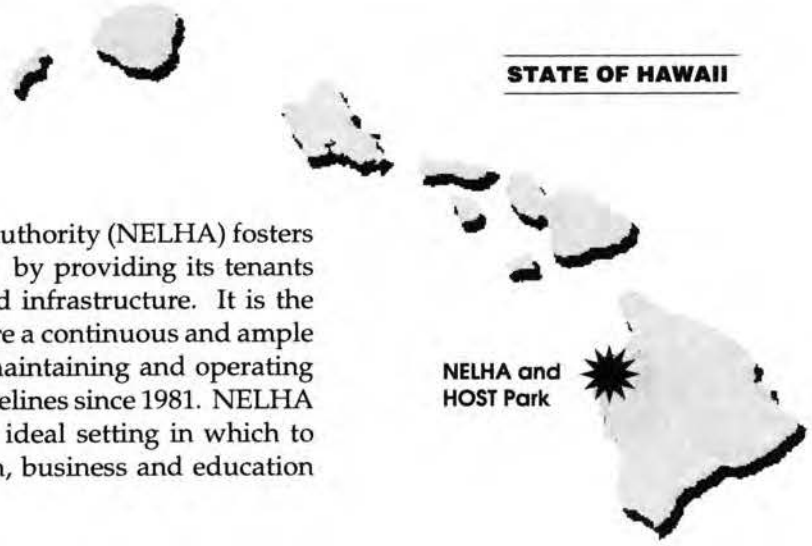
Charting a Course Towards Economic Growth

MISSION STATEMENT:

"To develop and diversify the Hawaii economy by providing resources and facilities for energy and ocean-related research, education, and commercial activities in an environmentally sound and culturally sensitive manner."

PROGRESS 1974-1999



The Natural Energy Laboratory of Hawaii Authority (NELHA) fosters economic development and diversification by providing its tenants with access to unique support facilities and infrastructure. It is the only facility in the world which brings ashore a continuous and ample supply of both warm and cold seawater, maintaining and operating the world's deepest and largest seawater pipelines since 1981. NELHA offers its existing and potential tenants an ideal setting in which to explore and develop ocean-related research, business and education ventures.

In 1974 the Hawaii State Legislature established the Natural Energy Laboratory of Hawaii (NELH) as a 322-acre research support facility for the development of alternate energy and related technologies. Research and demonstration activities quickly ensued, with studies starting offshore in 1976 and the launching of Mini-OTEC, the world's first net power-producing OTEC plant, in 1979. The first buildings were constructed in 1980 to house administration, operations, a power center, and an analytical laboratory.

Within the first decade of NELH's existence, research at Keahole revealed the tremendous commercial potential of the many innovations from science and technology. In 1984, the Hawaii State Legislature took the next logical step, melding science and business, by authorizing commercialization on state property. This made possible the blossoming of NELH as a unique and productive business incubator in the

Within the first decade of NELH's existence, research at Keahole revealed the tremendous commercial potential of the many innovations from science and technology.

The NELHA entrance from the Queen Kaahumanu Highway leads to a two-mile access road through the NELHA properties.

Unlike other government CIP projects which demand a one-way drain on tax dollars each year, those at NELHA yield measurable returns to the state.

coastal desert of Keahole. The first commercial tenant signed on in 1984 and was soon followed by other entrepreneurial interests.

Subsequently, in 1985, the Hawaii Ocean Science and Technology (HOST) Park was created on an additional 548 acres of land, designated by the Legislature for commercial expansion of the ideas spawned by NELH research. The HOST Park was initially administered by the Oahu-based High Technology Development Corporation (HTDC).

The Natural Energy Laboratory of Hawaii Authority was created by legislation in 1990 to administer both the 322-acre NELH property and the 548-acre HOST Park property. NELHA is an attached agency of the Department of Business, Economic Development and Tourism (DBEDT).

The State of Hawaii has now seen 25 years of growth and development at NELHA. What began as an innovative experiment supporting research in science and technology has yielded far more than could have been imagined in 1974. A total of 870 acres of land devoted to economic development and diversification today provides the setting for a successful work in progress. Of the 29 tenants at NELHA during the reporting period, 13 were fully commercialized, 5 were in the pre-commercial research phase, 8 were conducting research projects, and 2 were providing educational services.

The figures speak for themselves. Unlike other government CIP projects which demand a one-way drain on tax dollars each year, those at NELHA yield measurable returns to the state in terms of revenues, jobs, and economic activity. The less than $1 million of General Funds appropriated for NELHA operations annually yields approximately double that amount in taxes alone. NELHA special fund revenues continue to rise. Tenant revenues in excess of $10 million per year demonstrate the success of the innovative business enterprises, many shipping unique products to destinations outside the state of Hawaii. In addition to the 21 state positions provided by the agency itself, NELHA tenants provide livelihoods for over 160 Kona residents. Most importantly, activities generated by NELHA and its tenants provide an estimated $30-40 million per year in total economic impact, calculated using standard economic multipliers.

The following section provides a graphic summary of some of these measurements of growth. It is worthwhile to note that the overall growth of tenant revenues and jobs is primarily due to the activities of NELHA's anchor tenant, Cyanotech Corporation. The company went through a major downsizing during the reporting period to streamline operations and is currently in a new phase of reorganization and growth.

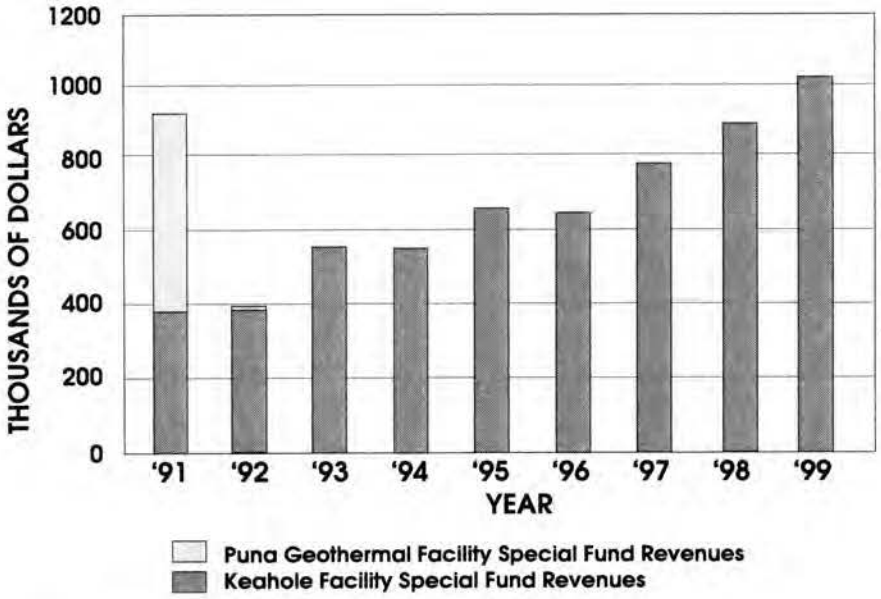


Figure 1. NELHA Special Fund Revenues (including reimbursables); NOTE: the 1991 sale of a used turbine from the Puna Geothermal Facility recovered $550,000

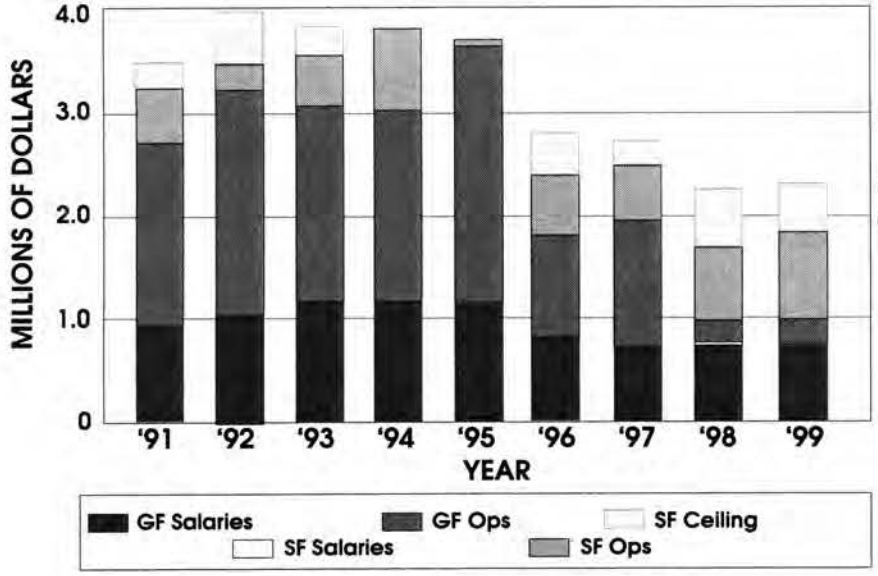


Figure 2. NELHA General Fund (GF) and Special Fund (SF) Expenditures

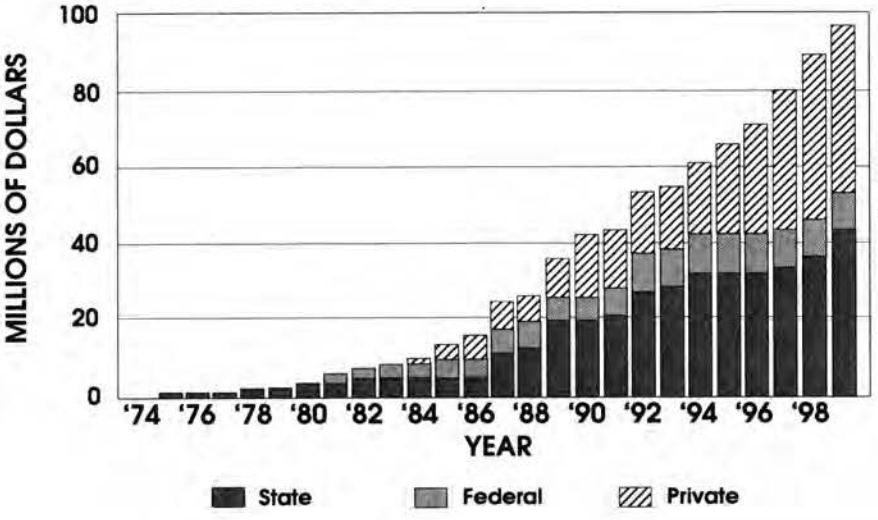


Figure 3. Cumulative Investment at NELHA by state, federal, and private sources.

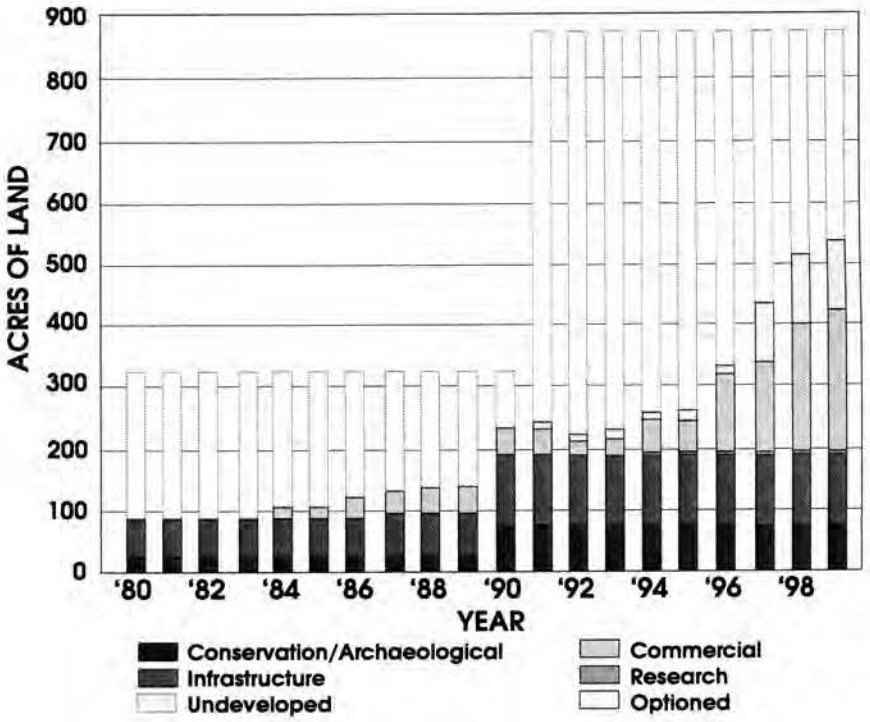


Figure 4. Land Utilization at NELHA (original NELH properties totaled 322 acres; in 1991 NELHA administratively acquired the HOST Park property, an addition of 548 acres)

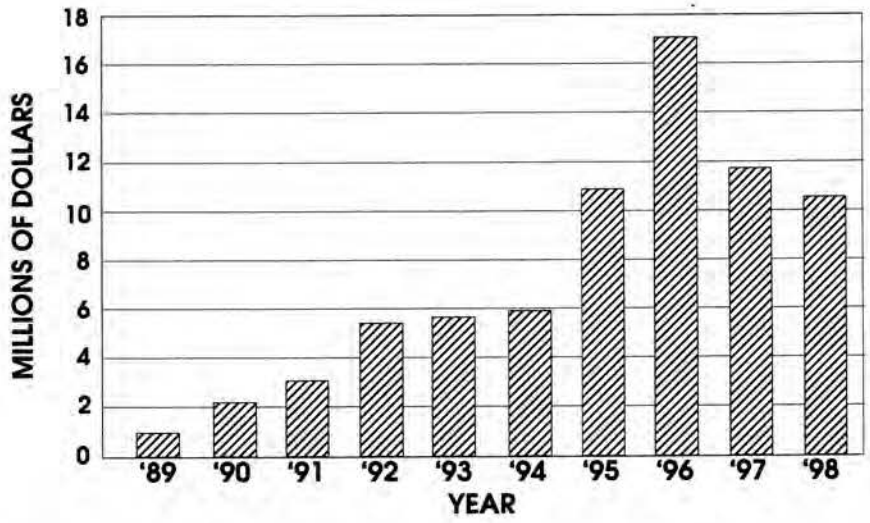


Figure 5. NELHA Tenant Revenues

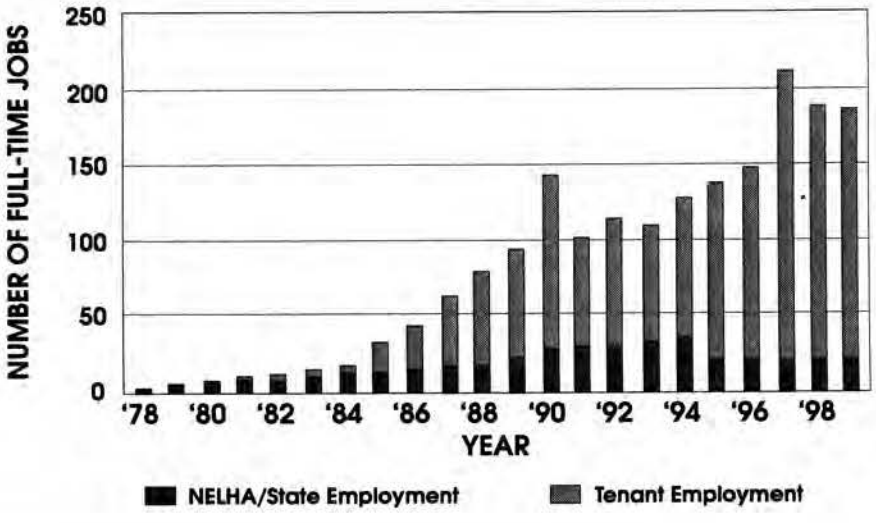


Figure 6. Employment at NELHA by NELHA/state and tenant employers.

OUTSTANDING RESOURCES

A unique complement of natural and logistical resources at Keahole Point gives NELHA a decided advantage over other locations.

• SOLAR INSOLATION is consistently high at NELHA, with the rate of incoming natural sunshine ranked above that of any other coastal site in the United States. Rainfall is also low, less than 15 inches per year, maximizing days of clear, cloudless skies.

• PROXIMITY TO AN INTERNATIONAL AIRPORT allows tenants to export fresh product directly to Asian markets, as well as those of the continental United States and other countries. The Kona International Airport at Keahole began linking Kona directly to Asia in 1997 with the addition of the appropriate supporting infrastructure. Airport expansion plans include an international terminal and a closer working relationship with NELHA and its tenant companies as traffic to the Big Island and particularly West Hawaii increases.

• LOCATION at Keahole Point is an ideal setting for an ocean science facility primarily due to its steep offshore bathymetry and narrow band of coral reef, characteristic of the geologically youthful Big Island. The steep bathymetry affords close proximity to deep ocean water, accessed within a mile from shore at Keahole Point. Contrast this to geologically older locations such as islands with more extensively developed reef systems or continental coasts where access to deep ocean water may typically be 50-100 miles from shore.

• WARM SURFACE SEAWATER (SSW) is also pumped onshore continuously, drawing from an inlet pipe located 600 feet offshore at a depth of 45 feet from the surface and 45 feet above the ocean bottom. The waters from which the NELHA SSW is drawn are rated Class AA in water quality and range in temperature from 76° to 82°F (24.5° to 27.5°C) year-'round.

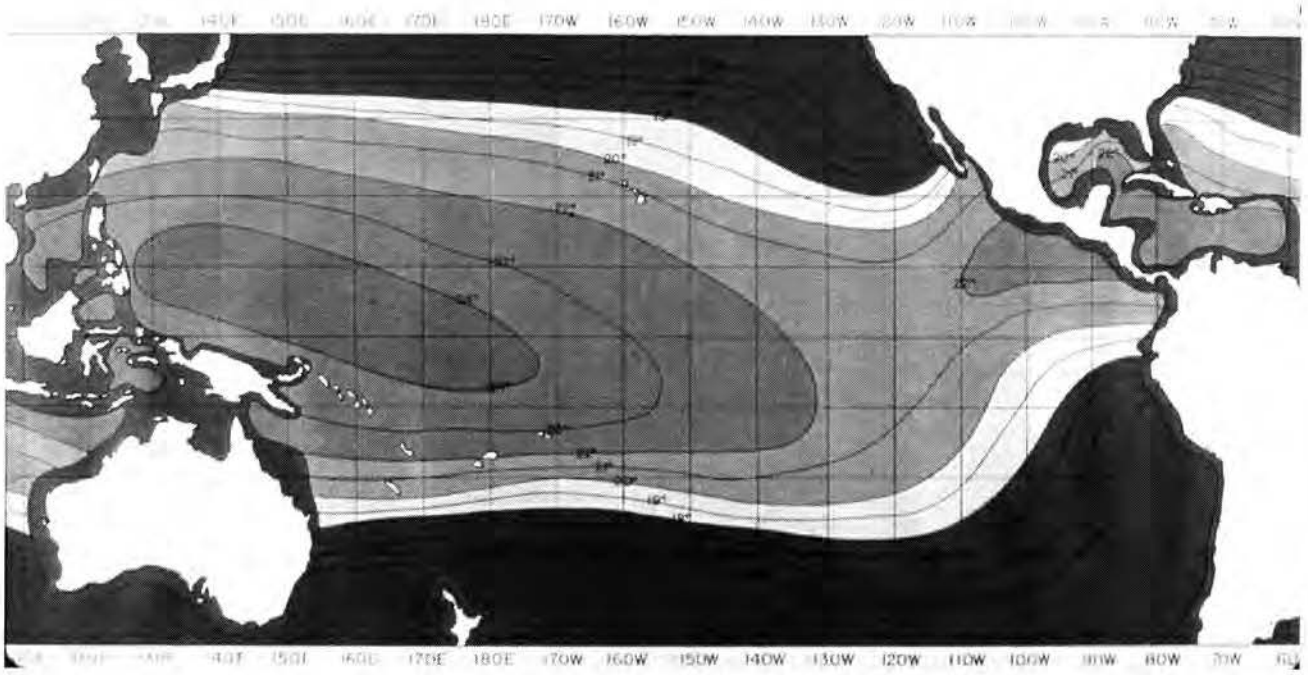
• COLD DEEP SEAWATER (DSW) is continuously pumped from 2,000 foot depths via the world's deepest cold seawater supply pipelines and is distributed onshore through the largest seawater delivery system of its kind. The DSW is drawn from chilly deep ocean water less than a mile from shore at a constant 43°F (6°C), virtually pathogen-free and rich in the inorganic nutrients essential for plant growth.

• THE LARGE TEMPERATURE DIFFERENCE BETWEEN SSW AND DSW brought onshore makes NELHA ideal for development of ocean thermal energy conversion (OTEC) technologies. Hawaii is one of the few locations in the developed world that is included in the broad band of oceanic waters in which these conditions exist, circling the globe within about 23 degrees of latitude to the north and south of the equator.

• LOCATION WITHIN A STABLE POLITICAL CLIMATE is a plus for any business venture weighing options at sites around the world. Other places in the equatorial regions where warm and cold seawater might also be accessible tend to be in politically unstable settings in developing countries. The access to both cold deep and warm surface seawater in one location, with a sufficient "delta T" to make energy produc-

The underground main NELHA pump station at Keahole Point provides warm and cold seawater to all current NELHA tenants.

A unique complement of natural and logistical resources at Keahole Point gives NELHA a decided advantage over other locations.



The gray shaded areas above and below the equator identify regions in the Pacific where "delta T" or the temperature difference between deep and surface seawaters is sufficiently great to make the OTEC concept feasible in those locations.

tion feasible through OTEC-related technologies, is not available elsewhere in a location as ideal as at Keahole.

• LOCATION WITHIN A FRIENDLY COMMUNITY is an added benefit to any business which establishes activities here. Schools, hospitals, and all the components of a highly desirable place to live are here in this community. An added plus is the Hawaiian "Aloha Spirit" which is alive and well in Kona, bringing thousands of visitors here again and again from year to year.

You might say location, location, location summarize the keys to NELHA's long term success.

NELHA has the world's deepest cold seawater pipelines, and the largest seawater delivery system.

APPLICATIONS

Deep seawater (DSW) is available for use in ocean thermal energy conversion (OTEC) projects, aquaculture, coldwater agriculture, low cost cooling, and a host of other applications. Here are some of the categories for which the precious seawater resource has been used. There are many other possible uses, some still waiting to be discovered.

• COOLING WITH DEEP OCEAN WATER is a valuable, economical application of this seawater resource at NELHA. One of the most cost-effective applications is for air conditioning since traditional methods use energy-hungry technologies. For example, NELHA has saved taxpayers up to $4,000 per month in electricity costs since it converted from traditional air conditioning systems to new ones based on cold seawater. NELHA tenants can also take advantage of this cost-saving application which, in its simplest form, uses a combination of a recycled automobile radiator and a fan, with deep cold seawater as the coolant.

This concept has excellent potential for use on a larger scale where a cluster of developments can collectively be supplied with cold deep seawater from a central supply. In some situations, freshwater can be chilled using the deep seawater in a centralized heat exchanger, then circulated to users along a closed loop, eliminating seawater-induced corrosion problems at user sites. The capital expended on such a project could be recouped over a relatively short period of time, making it extremely cost-effective.

• ALTERNATIVE ENERGY PRODUCTION from natural resources was a prime concept which inspired the creation of the Natural Energy Laboratory of Hawaii in 1974. In particular, ocean thermal energy conversion or OTEC, the use of ocean thermal differences to make electricity, had first been proposed in 1881, but it took the oil embargo of 1973-4 to catalyze political interest and commitment to support its research and development. Hawaii was an ideal setting, since it is located within the tropical band of oceanic waters where the temperature difference ("delta T") between surface and deep seawater is sufficiently large to make OTEC an economically feasible energy production method. OTEC technologies, inherently large in scale, require correspondingly large scale seawater systems such as are located at NELHA. As a result, all of the world's major OTEC research projects have been located at NELHA since 1979.

The world's first net power producing OTEC plant was constructed and floated offshore of Keahole Point in 1979. The proof-of-concept demonstration system generated up to 52 kW of electricity and was hailed as a major breakthrough in ocean energy development. This successful project was a partnership between the state government and several private companies and heralded the coming of a new wave of research and development based on cold and warm seawater resources. Since that time, the world's largest net power producing experimental plant, rated at 210 kW gross, has been built and tested at NELHA. It was preceded by a series of experiments testing components for the two main OTEC system types: closed-cycle and open-cycle OTEC. The next step in the R&D process, anticipated early in the new millennium, will be a scaling up towards commercial applications, developing pilot plant designs in the range of 1-10 MW.

• SOLAR RESOURCES--The same intense sun that warms the surface waters around Keahole Point also provides a ready source of natural energy that can be converted into usable form through the use of photovoltaics, photobioprocessors, and other solar energy-dependent technologies. NELHA's Keahole Point location and low rainfall combine to make the site ideal for research and development of all solar technologies.

• AQUACULTURE PRODUCTS were recognized, early in the development of the NELH facility, as economically profitable co-products of the energy technologies being developed here. With its unique complement of logistical and natural resources, NELHA has become recognized as a premier location for aquaculture development. NELHA's abundant supplies of cold, clean, nutrient-rich deep seawater and warm surface seawater combine with the ideal weather conditions to provide optimum growing environments. Since the aquaculture industry is the fastest growing sector of the U.S. federal agricul-

ABOVE: This modest set of pipes and simple heat exchanger supplied with deep seawater provides the "cold" source for one of NELHA's air conditioning systems.
BELOW: Aquacultured products such as high valued finfish thrive in the NELHA-based tenant facilities.

All of the world's major OTEC research projects have been located at NELHA since 1978.

These laboratory cultures of pure strains of microalgae are but a small sampling of the 30,000 cataloged species known worldwide.

ture program, aquaculture is an attractive area for business development in Hawaii.

Many of the tenants at NELHA are involved in aquaculture enterprises, growing various species of high-value marine or aquatic plants and animals. It is a relatively new industry that is growing in importance as world fisheries feel the increasing pressures of over-harvesting. There will be a greater need for alternative sources to replace or supplement the "wild" catch from the world's oceans in the future. NELHA's unique resources are very well-suited for businesses that wish to capitalize on this market potential. From tropical reef fish culture in warm Keahole seawater to Maine lobster culture in Keahole deep seawater, any combination of temperature regimes may be used to create optimum growing conditions for plants and animals at no extra cost. This results in growout system technologies that are more cost-effective than traditional chilling or warming technologies used by the industry elsewhere in the world.

MICROALGAE or microscopic plants grow extremely fast in the ideal conditions at NELHA. Over 30,000 different species have been identified worldwide, yet only a few have been commercially developed to date. Some of these are being cultured both in commercial production facilities and as experimental research ventures by businesses at NELHA. Products from microalgae include food supplements, pigments used in molecular medical tagging and cosmetic products, natural fertilizers, organic mosquitocides, cancer-inhibiting drugs, and many others. Microalgae can also be a vital link in the early stages of growout of marine animals when larvae are microscopic. Companies such as Taylor Resources, Inc. and Coast Seafoods, Inc. culture large amounts of microalgae to feed clam and oyster spat which are sent after a few months to restock growout areas located at company headquarters in the Pacific Northwest.

Many of the tenants at NELHA are involved in aquaculture enterprises, growing various species of high-value marine or aquatic plants and animals.

MACROALGAE are larger marine and aquatic plants, also known as seaweed or sea vegetables. These can be used for food, medicinal resources, and other purposes. Like microalgae, macroalgae can be grown optimally at Keahole Point, and a number of businesses at NELHA are taking advantage of this opportunity. The low rainfall rate of about 15 inches per year greatly reduces the possibility of rainfall dilution of the growing medium in land-based ponds or tanks so that they can be left open to receive the free and ample sunshine year-'round.

• MARINE BIOTECHNOLOGY holds great promise for the companies at NELHA that choose to venture into this area. Both pharmaceutical and nutraceutical products can be obtained through the mass culture of a variety of marine organisms. Through life cycle manipulation, genetic engineering, and selective breeding, the production of both plant and animal species can yield a variety of useful products for commercial applications.

A vast market potential exists for a segment of the biotechnology industry based on the production of microalgae, microscopic one-celled marine and aquatic plants. Researchers point out that microalgae are the fastest growing plants on earth, able to double their weight daily in laboratory cultures, and exceeding the average growth of trees by a factor of 100. They grow optimally when provided with the natural resources of sunlight, water, carbon dioxide and nutrients. In turn,

they can yield a vast array of high-value pharmaceutical and nutraceutical products, with applications to carbon dioxide mitigation, AIDS research, pharmaceuticals, drug discovery, food supplements, and even alternative energy. For example, a naturally occurring pigment, astaxanthin, from certain microalgae species is believed to improve health, survival and fertility in fishes, poultry and livestock. The few microalgae of the 30,000 known species that have been explored in drug discovery research have yielded compounds potentially useful in the treatment of cancer, HIV, and degenerative diseases.

Even the roughest estimates of market potential for astaxanthin are impressive. Reliable sources value the annual market at more than $185 million, growing at 8% per year. Emerging markets in poultry and livestock feeds could add another $125 million. World market price is $2,500 per kilogram. Near-term markets for microalgae products in general are estimated in excess of $3 billion per year. For the long term, some estimate these figures may exceed $10 billion per year.

Increasing efficiency is an important element of maintaining market competitiveness for commercial production based on both open pond and closed systems ("photobioreactors"). NELHA provides an ideal location for the development of these technologies, and NELHA-based companies such as Aquasearch Inc. and Cyanotech Corporation are already reaping the benefits of their research and development successes in these areas.

• COLDWATER AGRICULTURE is a new area of development in which cold deep seawater is used to cool soil temperatures to create unique microclimates in a subtropical coastal setting. Test crops at NELHA's Keahole facility have demonstrated immense potential in the manipulation of growing conditions to increase and improve yield and shorten growing times for both temperate and tropical plants. The late Hawaii State Senator Richard Matsuura used the term "blue-green revolution" to describe this new field of agriculture which combines "blue" (ocean) and "green" (agricultural) technologies. He likened it to the "green revolution" of agriculture which increased local production of land-based crops in underdeveloped countries such as India and Thailand several decades ago. Companies such as Common Heritage Corp. are capitalizing on this potential, assisting third world countries to develop sustainable coastal communities by adapting integrated seawater systems to support food, water, and energy production.

A demonstration site for "eco-turf," proposed for golf courses of the future, is prepared by burying an underground heat exchanger which will chill plant roots with deep seawater.

Near-term markets for microalgae products in general are estimated in excess of $3 billion per year.

ABOVE: Air cargo service at nearby Kona International Airport routinely takes fresh product from NELHA businesses to distant markets overseas. BELOW: Shrimp on skewers and split lobster tails are just two examples of seafood products grown at NELHA.

Over 160 Project Intitiation Packets were provided to interested parties during FY 98 and 99.

TENANT GROWTH: 29 REASONS FOR SUCCESS

Although the emphasis during the past two years at NELHA has been on streamlining, reevaluating resources, and planning for the future, interest from prospective tenants has been continuous. NELHA advertises in selected periodicals and conferences, maintains a website, and recognizes that word of mouth continues to be a valuable contributor in the marketing process. The marketing activities of other state offices supplement these efforts both here and abroad. These recruitment activities have brought many interested investors and business prospects to our door. Over 160 Project Initiation Packets were given to interested parties during FY98 and 99, and the Board entertained over a dozen formal presentations by new proposers during the reporting period.

Several new commercial projects began their pre-commercial research phases at NELHA during the reporting period. In FY98, Marine BioProducts, Inc. of Canada located their seaweed research project within the Research Compound. In FY99, Ocean Rider, Inc. relocated from Florida facilities to begin research in preparation for developing a seahorse culture facility. They cited NELHA's pristine water supply as one of the most important reasons for selecting their new location. Stockly's Aquariums, Inc. of Kona commenced work on native anchialine pond shrimp as a potential aquarium feed.

Also approved in FY98-99 and currently finalizing plans to break ground in HOST Park are EagleNet Sea Farms, Inc., which will build a commercial hatchery and nursery for California abalone, and Oceanic Institute, which will use federal and state funds to construct an aquaculture research and training center.

New research tenants during the reporting period included the "Cafe Thorium" project from the world-renowned Woods Hole Oceanographic Institution, and Marine Life Investigative Group, a community research group.

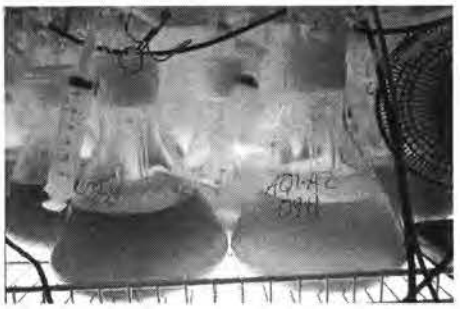
Seatech Contracting, Inc. and Cultured Technology, Inc. each chose to terminate their projects at NELHA as FY98 began, and Hawaiian Bred Tropicals and Island Traders ended their projects in early FY99. The prime real estate vacated generated immediate interest by other tenants, and each site was fully leased within a few months of vacancy.

A number of existing commercial and pre-commercial tenants worked on major site development and expansion projects during FY98-99. Coast Seafoods was provided with large seawater service connections; Pacific Harvest, Inc. doubled the size of their fish production facility; Aquasearch, Inc. completed a major expansion of their facility; and Big Island Abalone Corporation (BIAC) tripled the size of their precommercial research project as their hatchery and nursery experiments met with continued success. BIAC is also preparing to break ground in HOST Park early in the year 2000, and will be the first tenant in that section of NELHA'S technical park.

AQUASEARCH, INC. Aquasearch Inc. has been a tenant at NELHA since 1995. Specializing in marine biotechnology, it is a global leader in the development of proprietary, cost-effective, photobioreactor technology for commercial scale production of pure cultures of microalgal species, and in research and development of high-valued products derived from microalgae. Aquasearch holds several patents, including an expanded European patent for its process and equipment to grow microalgae in photobioreactors. Aquasearch's mission is to apply its AGM (Aquasearch Growth Module) photobioreactor technology to multi-billion dollar markets for natural microalgae products—pigments, proteins, sugars, fats, amino acids, vitamins and unusual bioactive compounds.

To broaden its entry into diverse markets, Aquasearch has targeted drug discovery, nutraceuticals, and animal feed additives as its primary products. Its $2.5 million Hawaii Research, Development and Production Facility, completed in January 1999 at NELHA, will focus on new product development. Laboratory scale production can be tested on the lab bench and then ramped up to fully computerized production scale in one location. The facility also incorporates open pond technology, and maintains full harvesting and processing capabilities with a variety of commercial equipment. The initial commercial product is astaxanthin, a natural red pigment which replaces synthetic colorings used in salmon, trout, and poultry feed. Cultor Ltd. of Finland, the world's second largest user of astaxanthin, is a partner in this market.

The Aquasearch staff and its Science Advisory Board include world leaders in marine bioscience, including photobiology, fluid mechanics, natural product chemistry, aquaculture, and the physiology and biochemistry of microalgae. Aquasearch is a founding member of the



ABOVE: Pure cultures of microalgae are started in small laboratory flasks under sterile conditions.
BELOW: CFO Earl Fusato and CEO Mark Huntley discuss facility expansion plans.
BOTTOM: Aquasearch's new $2.5 million research facility at completion in January 1999.

Lane Cameron shows Governor Cayetano Big Island Abalone Corporation's culture system for abalone and its fodder.

new $40 million Marine BioProducts Engineering Center (MarBEC) at the University of Hawaii, and an Industrial Affiliate of the Center for Marine Biotechnology and Biomedicine at Scripps Institution of Oceanography. These relationships leverage the company's access to facilities, expertise, and fast-breaking developments in marine biotechnology. For more information, visit Aquasearch's website at **http://www.aquasearch.com**.

BIG ISLAND ABALONE CORPORATION. The Big Island Abalone Corporation (BIAC) plans to capitalize on the world market demand for abalone and its knowledge base for abalone culture and production. The NELHA Board approved BIAC's proposal in FY97, allowing the company to commence its pre-commercial research phase in early FY 98. BIAC was able to successfully spawn and settle abalone larvae soon after receipt of their first shipment of abalone broodstock. They not only validated but improved their proprietary algae and abalone co-culture system in their research efforts during FY98-99 and have applied for patents on their technology.

To accommodate BIAC's growth and research successes, the area leased by the company in the Research Compound was tripled in size by FY99, and modifications were required to expand the nursery area to accommodate the thousands of growing abalone. These valuable organisms will be transferred to production areas for final growout in the commercial phase next year. In late 1998, Carl Demetropoulos came on board as BIAC's algologist and greatly increased algae production capabilities. Additionally, research funded by a SBIR grant was completed and plans for the next phase of development are underway.

In preparation for the company's impending commercialization in the year 2000, a sublease on a 10-acre parcel in HOST Park was obtained in FY 99, and a Right of First Refusal to Rent or Sublease was obtained for an adjacent 30 acres of land. Results from the research phase of project development have exceeded all expectations, and the outlook for large scale commercial production is excellent. The BIAC website may be accessed at: **www.bigislandabalone.com**.

BLACK PEARLS, INC. Black Pearls, Inc. (BPI) has developed the hatchery technology for black-lip pearl oysters, *Pinctada margaritifera*, to produce valuable black pearls in Hawaii and other islands in the South Pacific. Following successful hatchery development, BPI is now investigating the feasibility of commercial pearl farming in Hawaii. Working closely with the state's Aquaculture Development Program, they helped to clarify the implementation of the state's ocean leasing laws, passed by the Hawaii State Legislature in FY99.

The company has also developed a mobile quarantine hatchery system which now allows expansion of pearl farming into many islands in the Pacific. Broodstock are flown to the hatchery, spawned, and the larvae are then reared under state-approved quarantine conditions. Once the spat settle, they are flown back to the farm site. A commercial pearl farm has been established in the Marshall Islands using these mobile hatchery methods.

Black Pearls, Inc. is also working with an established pearl farm operation in the Philippines to build and operate a gold-lip pearl oyster

hatchery there. BPI also completed investigations, under a CEROS (see page 58) grant, into the use of probiotic (beneficial) bacteria to improve hatchery production. The results may lead to expanded uses of the deep seawater resource at NELHA. With CEROS support, BPI has also conducted studies investigating the applicability of nontoxic antifouling materials on ropes and lines for the aquaculture industry and the Department of Defense.

Dan Bezdek examines healthy oyster spat in Coast's nursery facilities at Keahole.

COAST SEAFOODS COMPANY. Coast Seafoods Company (CSC) is a well-established oyster company originally incorporated in 1946 in the state of Washington in the Pacific Northwest. CSC is currently the largest oyster company in the U.S. Expansion of its successful hatchery division for oyster, clam, and mussel seed was followed by establishment of a nursery at NELHA to provide an economical way to grow the bivalve spat year-'round. The organisms are shipped to Hawaii immediately after settling from the last larval stage when they are about 1 mm in size and given a "Hawaiian growout vacation" in the sunny climate, ideal for production of the microalgae cultures that are their fodder. Three and one half months later, they are shipped back to headquarters for final planting and growout in the ocean.

Construction of CSC's new Pacific oyster and Manila clam seed nursery at Keahole began in August of 1997, and the facility was operational by February 1998. First seed sales were made two months later in April. The facility is currently producing clam and oyster seed, rearing oyster larvae and producing a variety of algae for internal use and for sale as algae diet. In addition, CSC conducts ongoing research to further improve the nutritional content of the algae raised in this tropical environment and the processing techniques used for growing oyster and clam seed. Looking ahead, CSC is also considering possible development of the seed nursery into a full-scale hatchery operation.

COMMON HERITAGE CORP. Common Heritage Corp. (CHC) exists to further its mission of the "management of innovation for the benefit of the Common Heritage." To this end CHC has developed an integrated system of deep ocean water technologies and identified a state of the art "starter system" for such countries as Haiti, the Cape Verde Islands, Curacao, Mexico, and others with access to deep ocean water.

CHC developed a demonstration system for integrated use of deep ocean water, first dedicated on January 31, 1998, at NELHA. In the process of this development, CHC made significant world class breakthroughs in agriculture, accelerating the growth and increasing the productivity of hundreds of temperate and tropical plants. The late Senator Richard Matsuura, well-known for his part in agriculture's "green revolution," characterized CHC's breakthroughs as the beginning of the "blue-green revolution." The CHC facility has since become known as the birthplace of the blue-green revolution.

The integrated demonstration system employs deep ocean water sequentially to air condition the CHC office, to generate fresh water by condensation, to supplement irrigation, to generate fresh water in a development model of a desalinization device called a "hurricane tower" (patent pending), to cool a chill house and its chill boxes and food preparation area, to provide cold for the coldwater agriculture of wine grapes, to provide cold for the coldwater agriculture of a wide

ABOVE: In the background, the CHC "Hurricane Tower" extracts freshwater from seawater, while, in the foreground, deep seawater successively cools the Chillhouse and the roots of a thriving row of corn growing in the organic demonstration garden.

spectrum of agricultural crops normally grown in nontropical climates, to provide cold for coldwater agriculture of superior tropical crops, to provide cold for coldwater agriculture landscaping of the facility, to provide cold and nutrients for the aquaculture of sea vegetables, to provide cold and nutrients for the aquaculture of "fruits de mer," and to provide cold for creature comforts (water fountains, coldwater showers, field tents, and other habitat comforts). More information can be found on the CHC website at **www.aloha.com/~craven.**

CYANOTECH CORPORATION. Specializing in microalgae production at Keahole since 1984, Cyanotech Corporation is NELHA's largest and most productive tenant. The company began commercial production on five acres of land with four paddlewheel raceways and a small processing building in 1985, and added ten more acres by the following year. Today Cyanotech leases a total of 183 acres from NELHA, with 90 acres in full production and 93 acres slated for a $20 million development in the new millennium.

The well-established company produces a variety of high-value natural products from selected species of microalgae for important market applications worldwide. Cyanotech's current products include Spirulina Pacifica™, a nutrient-rich nutritional supplement, NatuRose™, a natural astaxanthin product used in the worldwide aquaculture industry; and phycobiliproteins, which are fluorescent pigments used in the immunological diagnostic market. Cyanotech is the only microalgae company in the world to have an ISO 9002 Registered Quality System and has been the world's largest producer of *Spirulina* for several years.

Cyanotech was named "Governor's Exporter of the Year" during the reporting period in the inaugural year of an annual awards program launched by Governor Ben Cayetano. The program recognized the company's role in helping to diversify the economy and create new opportunities for economic growth. State officials reported that companies like Cyanotech are part of a large group of exporters in Hawaii that generate $5.9 billion or 17% of the gross state product.

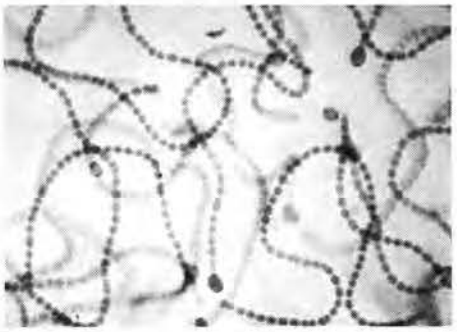
During the reporting period, Cyanotech invested $4.5 million in its Keahole site to improve production processing and to expand produc-

RIGHT: University students explored NELHA with Dr. John Craven (second from right), NELHA founder, and President of Common Heritage Corporation.

tion facilities for a new line of products. Commercial astaxanthin production reached 5,000 kg per month during FY98. In FY99 the company downsized to streamline operations as it reassessed changes in the global market. A new astaxanthin product, BioAstin™, was cleared by the U.S. Food and Drug Administration for sale into the human nutrition market. Cyanotech also reached a tentative agreement with Norsk Hydro ASA, a multi-billion dollar enterprise based in Norway and the world's largest salmon producer, for production, sales, and distribution of NatuRose™. Another landmark event was reached in July 1999 when Cyanotech become the first company in Hawaii to officially sign on as an industrial member of the University of Hawaii's new Marine BioProducts Engineering Center (MarBEC).

Currently under development are microalgae-based products that can be used in the biopesticide market and can enhance commercial production of high-valued organic compounds. Among these is a natural mosquitocide comprised of a blue-green algae and a genetically-introduced soil toxin from *Bacillus thuringinsis* var., *israelensis* (Bti). Development is also ongoing, under license from the Scripps Research Institute, of a patented aldolase catalytic antibody with potential applications in industrial synthesis of pharmaceuticals, fine chemicals and agricultural products. More information about this active marine biotechnology company can be found at **www.cyanotech.com**.

HAWAIIAN BRED TROPICALS, INC. Hawaiian Bred Tropicals completed their research in FY99, terminating their land use agreement at the end of 1998. Research on breeding techniques for popular ornamental reef fish species is of great interest to the aquarium industry as they seek to find ways to reduce pressures on natural reef populations.



ABOVE: Commercial scale production of microorganisms such as this species of chained cyanobacteria yield high value natural products.
BELOW: An aerial view of some of Cyanotech's production ponds.

ABOVE: Certified Specific Pathogen-Free broodstock is supplied to the world's shrimp hatcheries from High Health Aquaculture's NELHA facilities. BELOW: Tridacna clams, which only require clean seawater and abundant sunlight to grow, thrive in the Keahole facilities of Indo-Pacific Sea Farms.

HIGH HEALTH AQUACULTURE. High Health Aquaculture supplies certified Specific Pathogen-Free (SPF) broodstock to the world's shrimp hatcheries. They operate a first phase facility that includes basic infrastructure (water, air, electrical and security systems) and broodstock rearing tanks. A shrimp reproduction system, installed in FY96, continues to operate. The company will be pursuing commitment to a long term sublease in FY00 and will more than double the area of their current subleased area at NELHA.

The company continues to work on developing new stocks of pathogen-free shrimp. With the assistance of state biologist Dr. Jim Brock, the company has established certified SPF stocks of *P. stylirostris* and *P. vannamei* from the Oceanic Institute. The company's motto is: "Healthy shrimp are profitable shrimp."

INDO-PACIFIC SEA FARMS. Indo-Pacific Sea Farms' (IPSF) mission is to develop and commercialize innovative technologies for sustainable production of reef-dwelling organisms. IPSF's present research and development emphasis is on photosynthetic molluscs and cnidarians, primarily giant tridacnid clams and scleractinian (reef-building) corals. These photosynthetic animals derive nutrition from their association with microscopic algal symbionts called zooxanthellae.

Cultivation requirements for the plant-animal consortium are similar to those of free-living microalgae, and include ample tropical sunlight, warm surface sea water and a carefully controlled concentration of deep sea water to control temperature and supplement essential inorganic nutrients such as nitrogen and phosphorus. IPSF uses no commercial feeds and produces no seawater pollution with this novel approach. IPSF products are currently in demand in the sea food and aquarium industries and also have potential biomedical applications. The IPSF website may be accessed at **www.ipsf.com**.

ISLAND TRADERS. Using the abundant sunshine at Keahole Point, Island Traders successfully produced a popular sun-dried fish jerky at NELHA through FY 98, after which the company decided to terminate its land use agreement. The fish jerky was prepared from locally caught fish, marinated in a "hot-n-spicy" or mild teriyaki seasoning, and dehydrated with the use of specially designed solar drying units. Island Traders produced its jerky in a shorter time than standard methods and without the use of electricity.

KONA BAY OYSTER & SHRIMP CO. Kona Bay Oyster & Shrimp Company (KBOSC) produces blue shrimp as well as American and Pacific oysters. KBOSC continues development of work begun by Aquaculture Technology, Inc. investigating the commercial co-production of marine shrimp and oysters in a symbiotic system. The KBOSC system design reduces the labor required for operations while increasing product output. This makes a significant difference in projected business development and has contributed to their confidence about the future.

During the reporting period, KBOSC developed a 2.2 acre commercial growout operation and began marketing the tasty blue shrimp to local hotels. Reorganization during FY99 further advanced the company's progress and brought in a new CEO. KBOSC looks forward to opti-

mizing its current proprietary production system and is contemplating expansion into the HOST Park early in the new millennium.

KONA COLD LOBSTERS LTD. Kona Cold Lobsters Ltd. (KCL) utilizes the deep cold seawater supplied by NELHA to create a habitat for live Maine lobsters and live Dungeness crabs. KCL imports live lobsters and crabs from the natural fisheries and rejuvenates them in cold seawater holding pens for distribution throughout the Hawaiian Islands and select Asian destinations. Currently KCL services over 50 customers on five Hawaiian Islands, including supermarkets, restaurants, and resorts, meeting their specific size and quantity requirements on a daily basis.

KCL also continues to conduct aquaculture research, growing Maine lobsters with a multidisciplinary plan that includes broodstock, husbandry, nutrition, pathology and habitat design. KCL has successfully bred and raised lobsters from egg to sexual maturity for over 20 years. KCL's long range goal is to become operationally independent of the natural fishery, producing a high-quality Hawaiian-bred Maine lobster for consumer enjoyment.

MACFARMS OF HAWAII, INC. The well-established macadamia nut farm, MacFarms of Hawaii, brought a research project to NELHA in FY99 to test the efficacies of a proprietary water treatment system for irrigation of macadamia and other crops. The water treatment system has been demonstrated in other places, including Mexico, and applications to Hawaii are being tested in hopes that they might prove useful for the drought-stricken agricultural industry in Kona.

MAKAI OCEAN ENGINEERING, INC. Makai Ocean Engineering, Inc. has been an active participant in many aspects of engineering at Keahole during the development of NELHA. CEROS has funded them in FY99 to operate NELHA's experimental 50 KW closed cycle OTEC plant and gather important data on plant optimization which will be applied to future 1 MW demonstration plant design.

MARINE BIOPRODUCTS, INC. A subsidiary of Marine BioProducts International Corporation of Canada, Marine BioProducts, Inc. (MBPI) established a research facility at NELHA in FY98 to investigate the feasibility of commercial macroalgae culture in the Keahole environment. MBPI intends to be the first agar producer to offer premium specialty agar products extracted from specific strains of cultivated seaweeds utilizing its proprietary cultivation and extraction technologies.

MBPI's work at NELHA is a continuation of over 18 years of development from basic research to applied research to pilot-scale facilities. With its well-developed and proven technology platforms, MBPI is poised to enter an established global market valued in excess of $1 billion per annum.

MARINE LIFE INVESTIGATIVE GROUP. The community group, Marine Life Investigative Group, conducted a six-month project to investigate aspects of marine ornamental culture. The project operated under a private grant administered by the nonprofit Malama Kai Foundation.

ABOVE: Lobster claws from Kona Cold Lobsters Ltd. as buffet hors d'oeuvres. BELOW: Live, healthy lobsters are packed and sent daily by Kona Cold Lobsters Ltd. to destinations in Hawaii and abroad.

ABOVE: Michael Harburg of Ono Take, Inc. with tasty shiitake *mushrooms grown in rooms chilled by deep seawater at NELHA.*
BELOW: Reishi *mushroom, highly prized in both China and Japan for its immune system-enhancing properties, is a new experimental crop at Ono Take.*

OCEAN RIDER, INC. Ocean Rider, Inc. began its precommercial research project at NELHA in FY98. The company is developing proprietary breeding and growout facilities and methods for the commercial production of seahorses. Ocean Rider is targeting the ornamental fish industry, but is also considering supplying the Chinese herbal market. Commercialization of the project is anticipated for FY00.

ONO TAKE INC. Ono Take Inc. is concluding its research and development phase and is proceeding to the commercial production of *shiitake* and myco-medicinal mushrooms. Ono Take Inc.'s mission is to cultivate fruiting fungi by certifiable organic methods. Utilizing available agricultural waste, Ono Take Inc. produces highly esteemed *shiitake (Lintinula edodes)* and *reishi (Ganoderma lucidum)* mushrooms for a growing gourmet and nutraceutical market. The company's waste products are utilized as a high grade agricultural fertilizer. Working with mushroom mycelium *en masse* empowers Ono Take Inc. and the community with direct economic, ecological, and nutritional benefits. This myco-technology is a perfect example of good environmentalism, good health and good business.

PACIFIC HARVEST, INC. Pacific Harvest, Inc. (PHI) has established the largest Pacific threadfin (locally known as *moi*) aquafarm in the state at NELHA. *Moi* were so highly prized in ancient Hawaii that they were reserved for consumption only by royalty. In recent years, the natural fishery has been depleted, and commercial *moi* farming now has great market potential as a new industry for Hawaii.

In FY98-99, Pacific Harvest added four full-time positions for marine science technicians. During this year, PHI more than doubled its growout tanks, established some major markets overseas, and continued to refine more site-specific production techniques based on research and information established by the private research organization, The Oceanic Institute, and the state's Anuenue Fisheries Research Center. Area rented increased from 0.67 acres to 1.06 acres in the reporting period to accommodate the company's quick expansion. Phase I development involved installation of an intermediate growout area, including air and water supply plumbing; Phase II added production area growout tanks. Phase III of the expansion, planned for FY00, will involve further expansion of growout facilities and construction of a hatchery/nursery to provide independence from purchased juveniles.

PACIFIC INTERNATIONAL CENTER FOR HIGH TECHNOLOGY RESEARCH. PICHTR brought its open cycle OTEC demonstration project at Keahole to a conclusion in FY99. The government-funded, 210 kW facility had operated for over five years, collecting valuable data to advance the development of OTEC technologies. The physical plant was demolished in January 1999 to make room for other projects in the NELHA Research Compound.

The primary objective of the project was to acquire experience in the operation of OTEC plants for the production of electricity and desalinated water and to gather life cycle data for the major components (turbine and high speed vacuum compressors). A second objective was to continue dissemination of the acquired knowledge by publishing articles in professional journals and interacting with the general public during tours of the facility.

The experimental work was sponsored by the State of Hawaii and the Federal Department of Energy. The open-cycle OTEC plant produced up to 255 kW of electrical power, using 150 kW to operate itself, with up to 100 kW net power for other uses. It also produced 7,000 gallons of fresh (desalinated) water per day of operation. These set new world records for OTEC development. This research contributed vital new information towards the realization of future commercial applications. PICHTR also completed the construction and shakedown operation of NELHA's 50 kW closed-cycle OTEC test system (see pp. 39-41).

ROYAL HAWAIIAN SEA FARMS, INC. Royal Hawaiian Sea Farms, Inc. (RHSF) has been in business at Keahole since 1987 and commercially produces *limu*, or edible sea vegetables. Sales of these popular nutritious delicacies have consistently reached over two tons per week. A pickled *ogo* (*Gracilaria*) product is being processed under the "Waimanalo Ko-Ko" brand. In addition to *limu*, RHSF also produces salt water tilapia (*Tilapia*) and milkfish (*Chanos*). Intensive applied research is being conducted to investigate the potential of commercially producing edible sea cucumbers (*Stichopus*), the Hawaiian limpet, *opihi* (*Cellana*), and warm water abalone (*Haliotis*).

STATE UNIVERSITY OF NEW YORK MARINE SCIENCE CENTER. Dr. Jeanette Yen of the State University of New York at Stony Brook Marine Science Center has been conducting research at NELHA on the micro-processes involved in the feeding behavior of a type of deep seawater copepod. Living in all the oceans of the world, copepods are small marine crustaceans which form an important link in the oceanic food web, passing nutrients from single-celled plants (phytoplankton) to larger animals such as fish, for whom they serve as food.

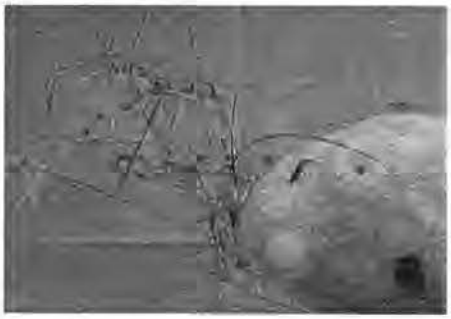
Dr. Yen's research involves the study, on a microscale, of fluid dynamics involved in copepod feeding behaviors. She relies on the supply of experimental organisms obtained by straining the incoming deep seawater supply at NELHA. Obtaining specimens by this method of collection is far simpler, more economical, less time-consuming, and less damaging to the organisms than the traditional method of collecting these types of organisms from research vessels.

STOCKLY'S AQUARIUMS, INC. Stockly's Aquariums, Inc. is conducting research on the production of the native anchialine pond shrimp, *Halocaridina rubra*. The project will determine on a small pilot scale if *H. rubra* can be economically cultured as a high quality live food for aquarium fishes and as an ornamental animal for local and export markets. Studies will determine the reproductive potential, food requirements, behavior, and optimum growing conditions for these small red shrimp. An intensive culture system is being developed that can be scaled up for commercial production.

TAYLOR RESOURCES, INC. Taylor Resources, Inc. is a family-owned and operated shellfish company with its headquarters in Shelton, Washington. Their Manila clam and Pacific oyster facility at NELHA serves as a nursery for a small but important segment of the life cycle of the popular shellfish.

The company produces the shellfish larvae in their hatchery in Washington state and sends them to Hawaii just after they have settled

ABOVE: The late Richard Hargreaves with Pacific Harvest's trademarked "Hawaiian Ali'i Moi."
BELOW: Moi *freshly harvested using deep seawater "slumber" tanks at Pacific Harvest have a longer shelf life.*



The tiny anchialine pond shrimp, Halocaridina rubra, *is being cultured by Stockly's Aquariums for both aquarium feed and as an ornamental animal.*

out of their swimming cycle. At this stage the animals are about 250 microns in size. At the NELHA facility, Taylor Resources allows the shellfish to grow up to 5 mm size on screens and in sand raceways. They are then shipped back to the Pacific Northwest for final growout.

The cold and the warm seawater provided by NELHA are utilized to achieve the exact temperatures needed for shellfish growout. The year-'round warm climate allows year-'round production of their food supply and therefore extends the growing season for the shellfish. An expansion of the Taylor Resources nursery has been underway, with goals of producing up to 400 million juvenile clams and 10 million juvenile oysters per year.

THERMAL ENERGY STORAGE, INC. Thermal Energy Storage, Inc. (TESI) of San Diego demonstrated an innovative and promising new technique for extracting freshwater from seawater at NELHA by the process of "freeze desalination." TESI aims to develop a desalination technology for initial use on California's Channel Islands.

Under a cost-sharing agreement with the Federal Bureau of Reclamation, the company conducted research on the innovative methods during FY 98. In the freeze desalination process, seawater is frozen and freshwater is obtained when the ice is melted. The key property of water which makes this possible is the crystalline lattice structure of ice molecules, too small to admit the ions of salt. When ice is formed from seawater, it is nearly pure freshwater since the salt is naturally excluded. Purity of desalinated water from initial experiments approached the low salinity levels of freshwater from the Colorado River.

Whereas freezing normally requires large amounts of energy, TESI reduces energy requirements by mixing a clathrate forming chemical with seawater cooled by 43°F deep seawater. The clathrate has a freezing point of about 45.5°F, so crystallization, or freezing, can occur with no extra input of energy.

The demonstration system at NELHA crystallized the clathrate in polyethylene heat exchangers through which deep seawater was pumped. The crystals were then melted in a separate heat exchanger warmed by surface seawater, and the clathrate former was recovered, leaving pure freshwater behind. In an operational system, the clathrate would be pumped down to chilly ocean depths and the ice crystals returned to the ocean surface via pipelines. TESI and subcontractor Makai Ocean Engineering conducted additional investigations, funded by NELHA affiliate CEROS, on the effects of deep ocean pressures on clathrate ice formation at those depths.

UNIVERSITY OF HAWAII SEA GRANT EXTENSION SERVICE. The national Sea Grant College Program supports an innovative program of research, education and extension services directed to the improved understanding, management, and use of marine resources of the state, region and nation. Sea Grant is a collaborative effort of the public and private sectors that utilizes federal, state and community support. The University of Hawaii at Manoa (UHM) has been a charter Sea Grant college since 1970. Its Sea Grant College Program in the School of Ocean and Earth Science & Technology (SOEST) maintains an Extension Service (SGES) office in West Hawaii at NELHA.

The Hawaii Sea Grant College Program serves a geographic area that includes the Hawaiian archipelago and the U.S.-affiliated Pacific islands. Sea Grant funds research in aquaculture, fisheries, shoreline processes, and education. Its Extension Service focuses on technology transfer, coastal resource management, environmental education, sustainable economic development and capacity building and training.

In the early days of NELH, it was Sea Grant that provided funding for the first aquaculture research projects which explored economically promising uses of deep seawater at Keahole. Results provided the evidence for launching the first NELH tenant businesses. Sea Grant also funded the first coldwater agriculture experiments at NELH in the 1980's, opening up further terrestrial applications using deep seawater.

Projects undertaken by the West Hawaii SGES Agent Sara Peck during the reporting period included public education outreach, proposal writing, establishment of a volunteer community coral reef monitoring group called Reef Watchers in cooperation with DLNR/Division of Aquatic Resources, development of coastal resource plans within specific communities, support of the West Hawaii Fishery Council, coordination of monthly ReefTalk public education presentations, development of education plans, curriculum and signage text for specific state parks, and support of a teens-teaching-elementary students program at NELHA called Aloha Kai which is operated at the West Hawaii Explorations Academy, another tenant at NELHA. Under a grant from MarBEC at UHM, the following projects were also completed: implementation of a summer internship program with industry partner Aquasearch Inc. and others and production of a MarBEC intern symposium, a MarBEC teacher workshop, and a marine biotechnology teachers manual.

The SGES Agent also works with NELHA staff and tenants to improve the effectiveness of community outreach, education and interpretation. Resource materials and data bases in the SGES office are available to tenants and the public upon request. Shaping the program offered in West Hawaii is the mission statement: "To raise consciousness about marine and coastal resources, build consensus, understanding and commitment to establish a sustainable resource management ethic."

UWAJIMA FISHERIES. Uwajima Fisheries, Inc. (UFI) has developed a facility for growing *hirame*, a flounder highly prized by the Japanese for *sashimi* and *sushi*. Uwajima Fisheries markets their 1.5 to 2 pound *hirame* through a Honolulu distributor who supplies the Oahu *sushi* market and is also beginning to export the product to the West Coast of the U.S. UFI manages the maturation and spawning of their broodstock for year-'round production of eggs.

UFI also utilizes the NELHA surface and cold deep seawater for the semi-intensive polyculture of marine shrimp, milkfish and the edible seaweed, *Gracilaria spp.*, also known locally as *ogo*. With this system they are able to produce high quality, superior products. UFI has also experimented with white shrimp, *P. vannamei*, utilizing a strict Specific Pathogen-Free (SPF) quarantine protocol. As a result, they are currently marketing certified SPF broodstock throughout the mainland U.S. and Central and South America. Additionally, UFI has experi-

Ryan Murashige of Uwajima Fisheries, Inc. holds a healthy specimen of the highly prized hirame, *ready to harvest for local market.*

WHEA students show Governor Ben Cayetano their award-winning electric car at NELHA in July 1998.

mented in broodstock management, spawning, larval rearing and commercial production of Pacific threadfin (*moi*) for local markets. UFI executed a long term sublease from NELHA for its 2-acre site during the reporting period, and has plans to further expand its production site in the near future.

WEST HAWAII EXPLORATIONS ACADEMY. The West Hawaii Explorations Academy (WHEA) is an integrative educational program of Konawaena High School and the state Department of Education, completing its fifth year as a NELHA tenant. Each year more than 50 students, mostly juniors and seniors, spend a full academic year at NELHA working on projects related to the resources available at Keahole Point.

Originally designed to address the needs of students who were at risk of dropping out of school, this innovative program has also attracted many college bound students. The observed success with this broad range of interests and abilities is a tribute to WHEA's talented teaching staff. WHEA infrastructure now includes the following:

- a 30′ x 30′ classroom/office constructed by the Department of Education
- a 30′ x 40′ pavilion-style shop completed with program and community resources
- approximately 600 square feet of concrete pad for student projects, including a 9600 gallon student reef tank project with a 600 gallon biofilter.

WHEA students have initiated and implemented a variety of projects to date. These include Aloha Kai presentations to elementary students (over 3000 students and 200 chaperones annually); a solar car prototype; an electric car which placed second in a statewide race of 25 entries; an environmentally friendly wastewater cleaning project using native *makaloa* grass (sponsored by a collaboration of Bishop Museum, the National Biological Service, and the Amy Greenwell Ethnobotanical Garden); a vog monitoring project; hydroponic and cold-water agriculture; and one commercial and several research aquaculture projects.

WOODS HOLE OCEANOGRAPHIC INSTITUTION: CAFE THORIUM. Researchers from Woods Hole Oceanographic Institution in Woods Hole, Massachusetts conducted a short-term research project at NELHA in March 1999 to optimize the separation and detection of naturally occurring thorium isotopes in seawater. Led by Dr. Ken Buesseler since 1989, the "Cafe Thorium" group brought their seagoing laboratory to Keahole, the second visit in the last several years.

Detection and measurement of the element thorium in seawater are being used to indirectly measure the rate of carbon, in particle form, raining from the upper 100 meters of the ocean to the seafloor. The natural radionuclide, thorium 234, produced by the decay of uranium 238, tends to "stick" to particles, many of which are organic and therefore carbon-containing. Measurements of the varying ratios of occurrence of these isotopes in the ocean can reveal information about carbon transport, which in turn will help scientists learn more about the capacity of the oceans to take up greenhouse gases such as carbon dioxide. The Cafe Thorium group's work using thorium as a tracer continues back in Massachusetts, with the data gathered at NELHA added to the growing knowledge base on ocean dynamics.

Essential Support Services

ADMINISTRATION

NELHA administrative staff provide administrative support, personnel assistance, internal management, fiscal services, leasing and tenant relations, contract management, permit processing, and marketing and outreach services. They also coordinate and implement required procedures with the Departments of Accounting and General Services, Agriculture, Land and Natural Resources, Transportation, Budget and Finance, and the Attorney General, as well as the Governor's Office, the Hawaii State Legislature, and various County and Federal agencies.

The NELHA Research Compound provides incubator facilities for the precommercial research projects of tenant business startups as well as NELHA administrative offices.

MASTER PLANNING

In the fall of 1998, NELHA retained the services of William L. Moore Planning to review and update its Master Plan and assist with development of strategies for revenue enhancement, with particular emphasis placed on the high visibility area adjacent to Queen Kaahumanu Highway. A planning charrette brought together representatives of the business community with NELHA Board and staff to brainstorm further revenue enhancement opportunities at Keahole. A 1999 report summarizes the recommendations which were made.

Lobbying efforts for needed CIP legislation were met with success, even as tough budgetary decisions were made on the legislative floor.

LEGISLATIVE SUPPORT

NELHA appreciated the support from many legislators and their staffers throughout the 19th and 20th Sessions of the Hawaii State Legislature. Lobbying efforts for needed CIP legislation were met with success, even as tough budgetary decisions were made on the legislative floor.

Section 226-D-1, Hawaii Revised Statutes, was amended to authorize NELHA to include multiple retail and commercial activities within the research and technology park. This authorization complements revenue enhancement efforts identified in NELHA's updated master planning strategy.

The Legislature appropriated $16 million in CIP funds towards planning, design, construction and equipment of a major expansion of the

Some of the NELHA Staff with Governor Ben Cayetano during a visit to the Keahole facilities.

Two views of the Wawaloli Beach Park complex maintained by NELHA staff.

NELHA seawater supply system. Two 55" diameter pipelines and an onshore seawater distribution system will provide water to the HOST Park area, as described later in this section.

Rough expenditure plans for the seawater system installation are:

Description	FY00	FY01
Plans	$30,000	$5,000
Design	60,000	10,000
Construction	1,924,000	4,995,000
Equipment	4,657,000	3,693,000
TOTAL	$6,671,000	$8,703,000

This infrastructure development complements revenue enhancement efforts identified in NELHA's updated master planning strategy, as well as expansion of research and education efforts sought through the NELHA Gateway Project and related federal funding.

In related legislation, amendments were made to Section 171-53, Hawaii Revised Statutes, to allow leasing of state submerged lands. This will pave the way for additional opportunities at NELHA for ocean-related research and commercial projects.

FEDERAL FUNDING

Through the good graces of Senator Daniel K. Inouye, NELHA also received new U.S. Department of Energy funding. Of these federal allocations, $1 million will fund pre-construction (design, planning, engineering, architecture) efforts and $1.5 million program development/construction for a new NELHA Gateway facility that will expand the research and education efforts at NELHA.

Through the good graces of Senator Daniel K. Inouye, NELHA also received new U.S. Department of Energy funding.

LAND USE

NELHA's leasing support services include the preparation and processing of short term and long term land use agreements for research, education, and commercial tenants. NELHA has the authority to use its own bridging documents for short term projects on a year to year basis. These are the Facilities Use Agreement for research projects and the Facilities Rental Agreement for commercial projects. Long term agreements use the Sublease format, modeled after NELHA's Master Lease with DLNR.

During the reporting period, NELHA staff worked closely with the Department of the Attorney General and the Land Division of DLNR to standardize the language in NELHA's land use documents. The intent is to streamline the processing of land use documentation, currently a lengthy process. To support tenant expansion planning, a new option policy was also drafted during the reporting period. The Right of First Refusal to Rent or Sublease and the True Option agreements were created to document the implementation of this policy.

Staff also worked diligently on renegotiating NELHA's master leases, working closely with the DLNR Land Division staff. Finalization of

this work is anticipated early in FY 2000. NELHA funded a third party appraisal, completed in August 1998, that aided in determination of appropriate lease rents due to the state.

MARKETING

Staff updated the NELHA general brochure, Project Initiation Packet, Rate Sheet, Option Policy summary, and Leasing summary for use with prospective tenants. Staff also produced two articles to advertise the facility, and continued to advertise in selected publications. Marketing efforts were reduced in general while the NELHA staff and Board labored on streamlining document processing, master planning, and other vital facility development concerns. Over 160 Project Initiation Packets were distributed over the reporting period in answer to inquiries by prospective tenants.

DBEDT and NELHA representatives also participated in a National Science Foundation (NSF) site review in February 1998 for the then-proposed Marine BioProducts Engineering Center (MarBEC) project in the School of Ocean and Earth Sciences and Technology at the University of Hawaii at Manoa. Approved by the NSF in FY99, MarBEC combines chemical engineering, ocean engineering and marine microbiology to support cutting edge research and development and to create a new interdisciplinary curriculum for the nation's next-generation marine biotechnology engineers. NELHA tenants Cyanotech and Aquasearch are both industry partners in the innovative center. Additional partners in the multi-disciplinary effort include other industrial firms, as well as three national laboratories (Argonne National Laboratory, Edgewood Research Development and Engineering Center, and Eastern Regional Research Center), the Bishop Museum, and DBEDT.

OUTREACH AND EDUCATION

2600 visitors in FY98 and 1900 in FY99 attended NELHA's free weekly presentations providing introductory information about the facility, its history and activities. In addition, special group visits by school and college groups, conference groups, legislators, government workers, and private visitors were also hosted by NELHA staff. Governor Ben Cayetano also paid a visit to NELHA in July of 1998. An Open House for the general public in April 1998 attracted over 400 visitors. NELHA will host an Open House in the year 2000 to celebrate the new millennium. A comprehensive description of NELHA activities may be found on its popular website, maintained by NELHA staff.

HUMAN RESOURCES

The NELHA staff consists of 21 employees with diverse skills and talents. The management staff consists of the Executive Director, Technical/Scientific Director, Administrative and Projects Manager, Operations Manager, Fiscal Officer, Leasing & Tenant Relations Specialist, and Engineering Projects Coordinator. These staff members work closely as NELHA's management team.

Other staff members provide necessary support for agency operations. Administrative support staff include the Senior Secretary, Secretary, and Account Clerk. The Scientific and Technical Section includes two

ABOVE: Students from a Waipahu High School physics class paid a special visit to NELHA to learn about applications of heat transfer.
BELOW: Executive Director Jim Frazier and visitors at the NELHA Open House event.

The Board of Directors and NELHA Staff untie the maile at a dedication ceremony for the new Booster Pump Station in October 1998.

Chemists and a Microbiologist, and the Operations Section includes two Electricians, an Engineer, two Maintenance Mechanics, a Vehicle/ Construction Equipment Mechanic, a Groundskeeper, and a General Laborer.

Together, the 21 staffers manage and maintain the 870 acres of property including the NELH and HOST Park sections of the technical park, the Wawaloli Beach Park, the Ho'ona Archaeological Preserve, and other archaeological and conservation areas located at Keahole, as well as the Puna Geothermal Facility site located south of Hilo.

The complex and dynamic nature of managing the NELHA facilities demands flexibility, resourcefulness, and constant attention to detail. Therefore NELHA continually reviews operational needs vs. staff assignments, reorganizing when necessary to ensure that it is able to meet the challenges of fulfilling its mission through the most efficient and cost-effective means possible.

NELHA employees take great pride in the facilities they care for and in the surrounding community in which they live. They are active in numerous community organizations, and participate in a variety of outreach activities with various educational groups. The annual Food Bank, United Way, and Toys for Tots drives are just a few of the charitable activities supported by the NELHA staff each year.

In FY98 Jan War, Operations Manager, was recognized by the Board of Directors for 20 years of service. Mr. War has been with NELHA since 1978 and continues to be instrumental in managing the physical plant and infrastructure at Keahole and Puna.

BOARD OF DIRECTORS

The NELHA Board of Directors is responsible for establishing policies pertaining to NELHA operations and growth, maintaining NELHA property and facilities, reviewing and approving proposals from prospective and existing tenants, and planning and coordinating the development of the NELHA site. NELHA staff provides technical assistance and develops staff recommendations to assist the Board in its decision making.

The members of the Board serve as volunteers and represent a broad range of interests. In FY98, Tom Whittemore, formerly of First Hawaiian Bank and currently a Trustee of Parker Ranch, was appointed as a new At-Large Director. Diane Quitiquit of the County Department of Research and Development was succeeded as Chairman of the Board by former Executive Director and Board member Admiral (ret.) Robert Kihune of the U.S.S. Missouri Memorial Association. Chair Kihune elected to step down in early 1999 when he was called to serve as an interim trustee of Bishop Estate, and Vice-Chair John Corbin of the Aquaculture Development Program was elected to serve out the remainder of the term. Director Quitiquit, having accepted a position with the Hawaii Tourism Authority, resigned from the Board at the end of FY99 after three years of distinguished service, and was succeeded by Raymond Carr representing the Mayor of the County of

Hawaii. Governor Cayetano appointed Barry Mizuno of Puna Geothermal Ventures to join the Board as an At-Large member at the end of FY99 after Director Steven Chu's term expired.

During the reporting period, the NELHA Board of Directors continued to work closely with the staff to provide guidance in land use and other areas of concern. They reviewed numerous proposals by new and existing tenants for a variety of projects. In FY98, several committees were formed to address specific areas of concern: the Special Review Committee regarding master planning which completed its report in August 1998, the Facilities Use and Rental Fees Committee, regarding seawater rates, rental fees, and facilities use issues, the Policy and Administration Committee, the Infrastructure Committee, and the Archaeological and Environmental Committee.

ABOVE: NELHA Ops staffer Tony Mitchell operates a backhoe to help a tenant prepare for site improvements. BELOW: Staff of the Operations Section at the site of the new Booster Pump Station they built.

OPERATIONS

The Operations Section manages the operation and maintenance of all of NELHA's facilities and equipment. Its staff is dedicated to maintaining an efficient and safe working environment, reliable services, and premium quality resources, central to the uniqueness and success of NELHA as a facility.

The most critical responsibility of the department is maintaining continuous delivery of deep and surface seawater, in addition to the electricity, freshwater and other essential services required by NELHA's diverse group of tenants. Each and every member of the Operations Section is committed to providing tenants with uninterrupted seawater supply. NELHA's ability to provide tenants with cold and warm seawater 24 hours a day, 365 days a year, is an important asset that draws many new tenants to the Keahole facility.

The Operations Section includes skilled planners, mechanics, electricians, and maintenance specialists who work cooperatively to fulfill NELHA's mission. Many of the facility improvements over the years have been completed using NELHA's internal "self help" philosophy. Staff members are encouraged to combine their initiative, talents and trades to complete projects in-house that might otherwise have a higher cost or long delivery dates if pursued through traditional means. With this approach, both time and tax dollars have been saved in the overall operations of the facility.

HOST PARK BOOSTER PUMP STATION

NELHA's primary seawater delivery systems are limited to pressures that only allow delivery of water to elevations less than about 20 feet. Expansion of tenant development into the HOST Park section of NELHA required extension of pumping capability to higher elevations. Since the present NELHA intake pipelines are more than a mile from the HOSTPark area, near the end of Keahole Point, efficient seawater supply to HOST Park will require a separate intake and pumping system located there. Such a system has been planned and designed, but the funding for its completion was unavailable until it was appropriated by the State Legislature in 1999.

In order to allow tenant expansion into the HOST Park section prior to

A crane is needed to lift the heavy concrete covers to the NELHA main pump station at Keahole Point.

With the talents and versatility of its staff, NELHA has become a world leader in the development of ocean science research and business incubator facilities.

completion of the much-anticipated HOST Park seawater supply system, NELHA staff designed and built a booster pump station which now provides moderate amounts of deep seawater to intermediate elevations in the HOST Park. Planning and design of the system were completed in June 1998, and construction began the following month. The NELHA Operations Section staff completed Phase I construction in October 1998, allowing 800 to 1,200 gallons per minute of deep seawater to be pumped to the lower elevations of the HOST Park. Five tenants are currently making plans to develop commercial expansion in HOST Park utilizing the new booster system.

The Booster Pump Station development was designed on a 3-phase schedule, timed to provide larger water volumes as tenants' needs develop. Future completion of Phase II and Phase III will allow delivery of up to 6,500 gallons per minute of deep seawater to various elevations in the HOST Park.

The NELHA staff has provided all of the labor for completion of the Booster Pump Station project, except for three small subcontracts. The project has been funded partly from the NELHA Special Fund and partly with Capital Improvement Project funds appropriated by the State Legislature.

OVERALL SEAWATER SYSTEM IMPROVEMENTS

Improvements to NELHA's existing seawater distribution system continued during FY98 and 99. Additional equipment was installed and other measures were taken to improve the efficiency and reliability of the entire system. Due to these measures and the concerted efforts of the Operations staff, the efficiency and reliability of the entire seawater system has never been greater.

A 75 HP variable frequency (speed) drive unit was purchased and installed to control NELHA's largest surface seawater pump. This expanded NELHA's warm seawater pumping capability and complemented similar measures accomplished the previous year. All of NELHA's pump stations are now fully automated, contain emergency standby pumps, and are backed up by independent diesel/electric generators. The few unscheduled outages that do occur can now be resolved within 120 minutes of alert.

The nearshore section of NELHA's 18" deep seawater pipeline required extensive maintenance and repairs during FY98, after ten years of service and a particularly severe winter swell period. Underwater inspections revealed that many of the anchoring devices installed at shallow depths eleven years ago in 1987 were severely corroded and in need of replacement.

As part of their contract to provide diving services for NELHA, Sea Engineering, Inc. was directed to replace the first eighteen hold-down assemblies securing the pipeline to the bottom and all of the bolts anchoring the offshore pump station. In addition to this work, Sea Engineering inspected all of NELHA's offshore pipelines to a depth of 80 feet.

TENANT ADDITIONS & EXPANSIONS

The Operations Section staff routinely assists new and existing tenants with work on their site development and expansion projects.

During FY98-99, full seawater and utility hookups were provided for a major research project conducted by Marine BioProducts, Inc., increased seawater service connections were provided to Coast Seafoods, and sitework and increased seawater connections were provided to Pacific Harvest, Inc. as they doubled their facility size. In addition, Operations staff assisted Aquasearch, Inc. in their recent expansion which involved construction of a new biotechnology research center, and Big Island Abalone Corporation in a series of incremental expansions of their precommercial research program.

The Operations Section also provided NELHA tenants with troubleshooting and problem-solving assistance, such as recommending control measures for a corrosion problem in Coast Seafoods large vertical turbine circulation pumps.

With the talents and versatility of its staff, NELHA has become a world leader in the development of ocean science research and business incubator facilities.

Karin Haleamau controls the timed freshwater irrigation that keeps landscaped sites green around the NELHA property.

SCIENTIFIC/TECHNICAL SECTION

The Scientific/Technical Section provides engineering support for all infrastructure development and land use at NELHA. They also provide consultation and support services to NELHA tenants on an as needed, as available basis. The scientific/technical staff also perform the sample collection, analysis, and data reporting for the environmental monitoring necessary to maintain the pristine quality of the unique natural resources of Keahole Point.

NELHA staff members plan all infrastructure development on the Keahole properties, from roads to utilities to seawater systems.

ENGINEERING

NELHA staff members plan all infrastructure development on the Keahole properties, from roads to utilities to seawater systems. Additional assistance is obtained, as needed, from experienced engineering firms in the community.

SEAWATER SYSTEMS

NELHA staff designed and constructed a Booster Pump Station, completed in October 1998, to provide cold deep seawater at the pressures needed to serve higher elevations of the HOST Park area. This new system provides up to 6,500 gallons/minute (gpm), enough to meet projected needs of expanding tenants for about the next three years.

NELHA staff also designed an Interim Surface Seawater Supply system to bring warm seawater from its current distribution in the NELH section to the HOST Park section of the technical park. Construction

ABOVE: Joe Clarkson of PICHTR explains the workings of NELHA's CC-OTEC experimental plant to a visitor. BELOW: The CC-OTEC flat plate heat exchangers are the focus of testing for this phase of the research process.

Completion of the new seawater supply system will take place during the FY00-01 biennium with funds appropriated by the1999 Legislature.

for this much needed project was begun using CIP funds appropriated by the 1998 Legislature and will service tenants planning to expand over the next two years.

NELHA staff have worked for about ten years on the development of a seawater supply system that can supply water to the range of elevations in the HOST Park. The design for two 55-inch inside diameter pipelines, one for surface seawater from 80 ft depth and the other for 38°F deep seawater from 3000 feet, was completed in 1998.

In preparation for the pipeline installation, a twin-tunneled shoreline crossing, drilled using a new, environmentally benign microtunneling technology, was completed in January 1997. It consisted of two 55-inch inside diameter tunnels extending from the bottom of a 30-foot deep sump 500 feet onshore to a break out from the seafloor 500 feet offshore at an 80-foot depth.

Completion of the new seawater supply system will take place during the FY00-01 biennium with funds appropriated by the1999 Legislature. Work will include installation of the deep water intake pipe, the surface water intake pipe, the onshore primary pump station, the HOST Park onshore distribution system, a photovoltaic power supply for the pumps, and a chilled water loop for air conditioning throughout the HOST Park.

ACCESS ROAD AND UTILITIES DESIGN

With new expansion projects in the works, NELHA is also preparing to construct additional access roads and utilities for the build-out of HOST Park. Final design of these projects will be accomplished as part of the construction contracts for their installation. NELHA has already solicited bids for installation of a 1 MW emergency generator, a necessary component of the system expansion. A Standby Capacity Agreement whereby HELCO would purchase excess power when needed may also be negotiated in conjunction with this project.

PLUG AND ABANDON HGP-A GEOTHERMAL WELL

In FY99, under the direction of the NELHA Board of Directors and the State Departments of Land and Natural Resources and Business, Economic Development and Tourism, NELHA successfully completed the plugging and abandonment of the Hawaii Geothermal Project Well-A (HGP-A). This was accomplished under budget, following a revised P&A plan that complied with the DLNR Administrative Rules. Additional Capital Improvement Project funding from the 1999 Legislature made this revised plan possible.

Management of the HGP-A geothermal well, located in the Kilauea Rift Zone of the Puna District, was originally assigned to NELHA in 1985, with formal transfer of title from the U.S. Department of Energy in 1986. The well had been drilled in 1976 and had been previously managed by the HGP-A Geothermal Development Group. A geothermal power plant, built with federal support in 1978 and upgraded with State funds in 1987, was operated commercially on the site under a contract with the Hawaii Electric Light Company from 1982-1989.

NELH developed the Puna Geothermal Facility on the 4-acre site adja-

cent to the well, located about 25 miles south of Hilo. The 2,000 square foot laboratory building and 1,400 square foot test pad provided opportunities for research, development and commercialization of alternate uses of the geothermal resource. The Community Geothermal Technology Program (CGTP), operated at the Puna Geothermal Facility by the Hawaii Energy Extension Service with funding from the U.S. Department of Energy, provided small grants that allowed local businesses to develop projects using the waste heat and/or the geothermal fluids. From 1986-1989, the CGTP supported the development of several viable businesses and received strong community support. The geothermal resources were used for projects such as palm seed germination, lumber drying, culture media steam sterilization, cloth dyeing, electro-deposition of minerals, heating of aquaculture water, art glass production, and drying of agricultural products.

The Puna Geothermal Facility successfully demonstrated that the production of electricity from the geothermal resource was technically, economically and environmentally viable. The CGTP also showed the community some of the possible side-benefits of the technology.

Drill rig looms over the PGF facility site during the plug and abandon procedures for the HGP-A well.

OCEAN THERMAL ENERGY CONVERSION (OTEC) RESEARCH AND DEVELOPMENT

Since its founding in the 1970s, NELHA has been the world's leading site for OTEC research. Considerable work has been performed at NELHA on both closed- and open-cycle OTEC systems.

CLOSED-CYCLE OTEC. Research sponsored at NELH by the U.S. Department of Energy (DOE) in the 1980's demonstrated that aluminum alloys can work well for closed-cycle OTEC heat exchangers. This work also confirmed that biofouling of the heat exchangers can be controlled with periodic injection of minute, environmentally benign concentrations of electrolytically generated chlorine. Subsequent NELHA research and development by ALCAN International, the world's largest aluminum company, investigated advanced aluminum alloys and demonstrated that "roll-bonded" aluminum heat exchangers have the potential to dramatically reduce the manufacturing cost of the large heat exchange surfaces required for closed-cycle OTEC plants.

Starting in 1989, ALCAN developed plans to build a small plant at NELHA to demonstrate the efficacy of the roll-bonded heat exchangers. Following significant changes in project structure, in 1992 NELHA received a $725K State CIP appropriation to support the purchase of equipment for the project. Shortly thereafter, ALCAN withdrew from the project because of financial constraints. In early 1994, NELHA reached agreement with the Pacific International Center for High Technology Research (PICHTR) to pool funds from the NELHA CIP appropriation ($725K), Hawaiian Electric Company ($50K) and PICHTR internal sources ($460K) to construct and operate the 50 kW plant that ALCAN had proposed. The heat exchanger panels were to be purchased from former ALCAN subsidiary, ALGOODS, Inc. of Toronto, and Makai Ocean Engineering, Inc. (MOE) of Waimanalo was contracted to provide engineering services to PICHTR for the project. Shortly after the project began, the National Defense Center of Excellence for Research in Ocean Sciences (CEROS) awarded a grant to MOE

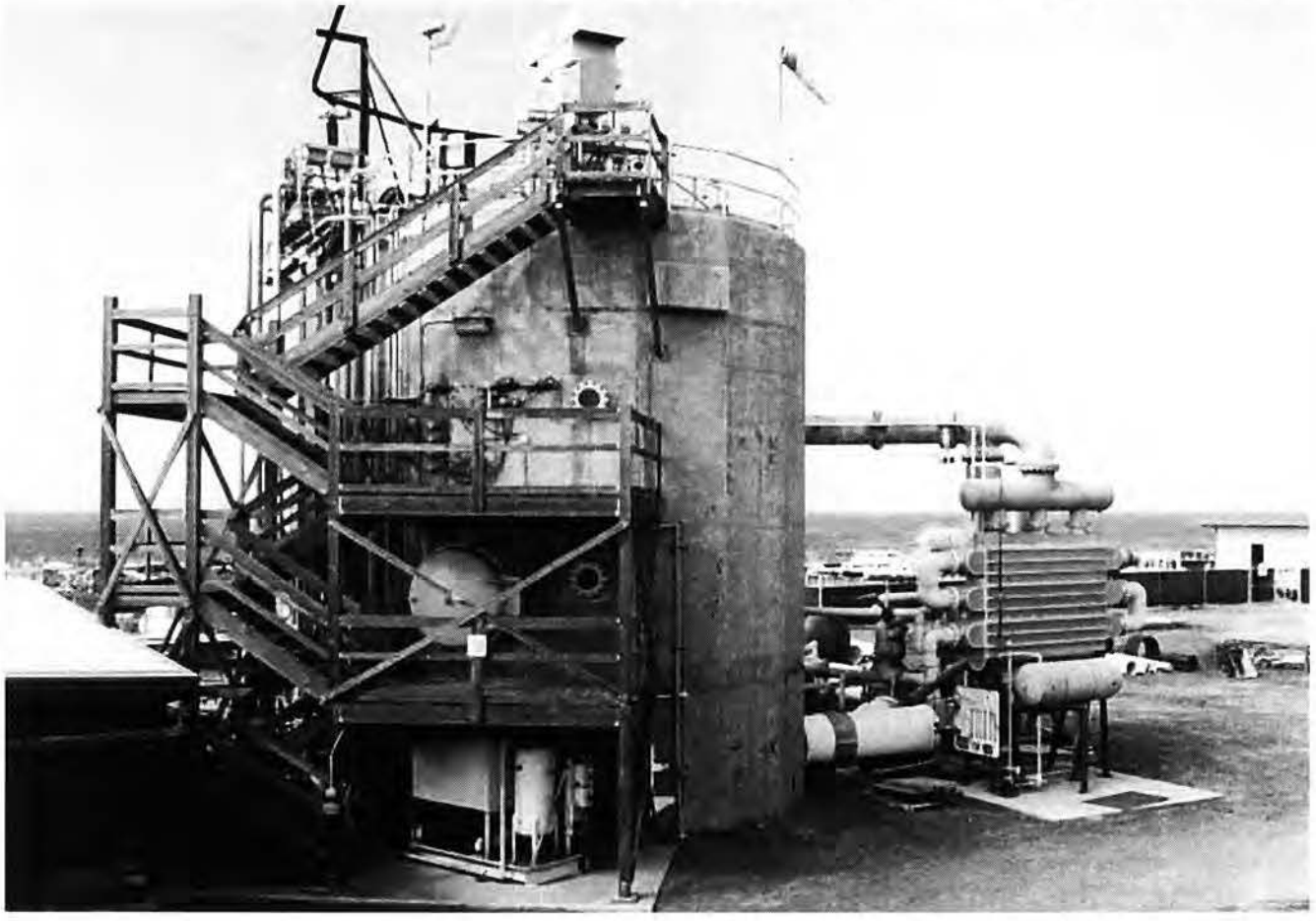
The 210 kW open cycle OTEC plant, the largest OTEC facility ever constructed, operated experimentally from1992 to 1998, providing important scientific and engineering data for future OTEC designs.

for collection and analysis of engineering data from the 50 kW plant to develop the design for a proposed 1 MW plant. $200K of this grant was earmarked for upgrading of the experimental plant and its instrumentation to facilitate the data collection.

The closed-cycle plant construction was completed and shakedown operations began in May 1996. Before the shakedown was completed, after only six weeks of operation, the heat exchangers developed ammonia leaks from corrosion of the aluminum panels. Though these panels were made of the same alloy that had been extensively tested at NELHA over several years by both DOE and ALCAN, they apparently failed because of an incompatibility between the aluminum and the "nitrile" rubber spacers that were used to separate the panels. After a year of effort aimed at identifying the source of the problem and devising schemes for refurbishing the old panels, ALGOODS agreed at the end of FY97 to re-manufacture new panels using a different spacing technique. A Supplemental Agreement to the initial contract between NELHA and PICHTR for construction of the plant was negotiated, and the plant was reconstructed by PICHTR and completed successful shakedown trials in June 1999. MOE will, with funding provided by CEROS, now conduct an abbreviated operational phase to collect data for the 1 MW design.

The 210 kW open cycle plant showing the large vacuum chamber and, on the far right, a cold seawater-cooled heat exchanger/condenser.

OPEN CYCLE OTEC. The U.S. Department of Energy funded open-cycle OTEC research at NELH beginning in about 1986. The first major DOE grant funded construction and testing of the Heat and Mass Transfer Scoping Apparatus (HMTSA). Built in 1989, the HMTSA



project provided data on the vaporization and condensation of seawater under OTEC conditions that would later be used in the design of an open-cycle plant constructed at NELHA in 1990-91. The 210 kW open cycle OTEC plant, the largest OTEC facility ever constructed, operated experimentally from 1992 to 1998, providing important scientific and engineering data for future OTEC designs. PICHTR was contracted by the DOE to carry out the design and operation of this important project.

Results from the operation of the 210 kW experimental plant included:

- validation that a large high-speed turbine works well with the 1/4 psi pressure difference available in an open-cycle system
- testing of a fluid clutch between the turbine and the generator to allow synchronization for power export
- development of magnetic bearings to support the very high rotational speeds required for efficient operation of large vacuum pumps
- production of pure, distilled water from an external surface heat exchanger, averaging 7,000 gallons per day of plant operation
- development of desalination from a direct contact heat exchanger that uses fresh water pre-chilled by deep seawater in a conventional liquid-to-liquid heat exchanger.

Funding for experimentation with the historic open-cycle plant concluded in 1997, but PICHTR obtained incremental funding from various sources to continue its maintenance and some operations throughout 1998. Following the end of project support and funding, demolition of the plant was finally accomplished in January 1999, making the site again available for other research interests.

Monica Dunse examines and identifies microbiological organisms found during routine NELHA environmental monitoring.

ANALYTICAL LABORATORY

NELHA's Analytical Laboratory collects and disseminates the information needed to protect NELHA's valuable seawater and groundwater resources. Environmental monitoring activities include sample collection, analysis, data recording, and testing of incoming and outgoing seawater, as well as groundwater and anchialine pond water and biota onshore, and benthic and midwater biota and water quality in the oceanic waters offshore. Data are also reported in compliance with regulatory requirements of other government agencies including the Department of Land and Natural Resources, the County Planning Department, the Office of Environmental Quality Control, and the Department of Health. The analytical laboratory is well-equipped for these tasks in both equipment and personnel. NELHA has established a forward-looking, multi-disciplinary environmental monitoring team of experienced technicians.

Much of the Analytical Laboratory's work involves implementation of the Comprehensive Environmental Monitoring Program (CEMP) at NELHA which collects and analyzes samples from more than 100 sites both onshore and offshore. The CEMP allows NELHA to monitor its pristine environment, and serves as an early detection system should any leaks or irregularities in effluent disposal occur.

Some highlights of the Analytical Laboratory's efforts during FY98 and

Gisela Hetherington sets up complex equipment which is used for some of the analysis on the hundreds of routine groundwater and seawater samples for NELHA's Comprehensive Environmental Monitoring Program.

99 include:

- Two more years of NELHA's (CEMP) were completed, and quarterly reports for the CEMP and the associated National Pollutant Discharge Elimination System (NPDES) permit were submitted as required.
- Analytical services were provided to some tenants as time became available beyond the requirements of the CEMP.
- NELHA performed sampling and analyses of new groundwater monitoring wells at Keahole Airport under a contract with the Department of Transportation Airports Division (DOTA) that began early in FY98. An additional laboratory assistant was hired under NELHA's Special Fund to compensate for the extra workload. Though there were unanticipated additional start-up costs to refurbish instrumentation for metals and hydrocarbon analyses and to train staff in its use, the sampling and analyses were successfully performed. In September 1999, The DOTA elected not to renew the contract, so the work was terminated and the additional laboratory assistant was released.

In addition, the NPDES permit was not renewed during FY99 due to the rerouting of the low volume of seawater effluent to the nearby disposal trench which services the Research Compound and neighboring tenants. Over ten years of data had been collected from the small permitted outfall, documenting no detectable impacts on the nearshore waters from the disposal of cold seawater onshore.

SUPPORT FOR AN UNUSUAL MARINE MAMMAL

No marine mammal stranding facilities exist on the Big Island, so, in April 1998 when a dehydrated 4-month old melon-headed whale was orphaned off of the Kona coast, NELHA was called upon to assist. Swimmers had reported the hungry animal had tried to nurse on their toes and noses. Authorities at the U.S. National Marine Fisheries Service (NMFS), in cooperation with Dolphin Quest from the Hilton Waikoloa Village, rescued the baby whale and decided to airlift it to Oahu where care could be arranged at Sea Life Park (SLP). NELHA staff was contacted to see if a temporary stay on shore could be arranged while waiting for the arrival of a U.S. Coast Guard C-130 at the Kona International Airport next door. A vacant seawater pool at NELHA was located, and the approximately 100-pound orphan had a refreshing 3-hour stay at Keahole before being trucked over to the runway. By September 1998, SLP reported that the melon-headed whale, the only one of its kind in captivity, had reached 180 pounds and was thriving in their holding facilities on Oahu.

ABOVE: The orphaned baby whale waits in a seawater pool at NELHA. RIGHT: The baby whale is lifted by stretcher to a waiting pickup truck for transport to Kona International Airport.

Financial Overview

STATEMENT OF OPERATIONS

Fiscal Year 1998 *(For the period July 1, 1997 through June 30, 1998)*

REVENUES

GENERAL FUNDS

State Funds	$962,082.00
Restrictions	0.00
Subtotal	*$962,082.00*

SPECIAL FUNDS

Land Use Fees	$339,503.96
Reimburseables	436,871.77
Interest Received	87,516.45
Vending Machine Sales	591.57
T-Shirt Sales	660.00
Percentage Rents	6,891.00
Subtotal	*$872,034.75*

TOTAL REVENUES	$1,834,116.75

EXPENDITURES

GENERAL FUNDS

Salaries	$710,978.34
Kona Operations	202,646.23
Puna Operations	8,423.86
Subtotal	*$922,048.43*

SPECIAL FUNDS

Salaries	$23,780.00
Operations	$715,516.00
Subtotal	*$739,296.00*

TOTAL EXPENDITURES	$1,661,344.43

Fiscal Year 1999 *(For the period July 1, 1998 through June 30, 1999)*

REVENUES

GENERAL FUNDS

State Funds	$979,829.00
Restrictions	0.00
Subtotal	*$979,829.00*

SPECIAL FUNDS

Land Use Fees	$589,786.13
Reimburseables	449,311.54
Interest Received	78,781.30
Vending Machine Sales	375.13
T-Shirt Sales	245.34
Percentage Rents	25,994.85
Subtotal	*$1,144,494.29*

TOTAL REVENUES	$2,124,323.29

EXPENDITURES

GENERAL FUNDS

Salaries	$747,421.00
Kona Operations	200,025.24
Puna Operations	8,142.70
Subtotal	*$955,588.94*

SPECIAL FUNDS

Salaries	$9,144.00
Operations	$849,672.38
Subtotal	$858,816.38

TOTAL EXPENDITURES	$1,814,405.32

NELHA FINANCIAL POSITION

Fiscal Year 1998 *(For the period July 1, 1997 through June 30, 1998)*

Special Fund Balance as of July 1, 1997	$1,407,444.33
State General Fund Appropriations	962,082.00
Special Fund Revenues	872,034.75
Subtotal	*$3,241,561.08*
General Fund Expenditures	$922,048.43
Special Fund Expenditures/Journal Entries	739,296.00
Unrequired G/F Returned to State Treasury/DBEDT	40,033.57
Subtotal	*$1,701,378.00*
Ending Special Fund Balance as of June 30, 1998	**$1,540,183.08**

Fiscal Year 1999 *(For the period July 1, 1998 through June 30, 1999)*

Special Fund Balance as of July 1, 1998	$1,540,183.08
State General Fund Appropriations	979,829.00
Special Fund Revenues	1,144,494.29
Subtotal	*$3,664,506.37*
General Fund Expenditures	$955,588.94
Special Fund Expenditures/Journal Entries	858,816.38
Unrequired G/F Returned to State Treasury/DBEDT	24,240.06
Subtotal	*$1,838,645.38*
Ending Special Fund Balance as of June 30, 1999	**$1,825,860.99**

Future Plans

INFRASTRUCTURE DEVELOPMENT PROJECTS

The past two years have been crucial to the laying of a foundation for a new era of growth and expansion at NELHA. The resourceful NELHA Staff and Board of Directors face many new challenges in the new millennium. Together, they look forward to expanding the park, thereby helping the state realize its vision of economic sustainability.

Several infrastructure development projects are currently underway, made possible by the legislative allocations of FY 99. These projects are vital steps in the growth and development of the technical park, and will set the stage for a new era of growth at Keahole.

INTERIM SURFACE SEAWATER DISTRIBUTION. The staff looks forward to tackling the challenge of designing an interim surface seawater system, and a new supply pipeline and distribution system for HOSTPark. The current surface seawater distribution system is limited to the NELH section of the technical park. The interim surface seawater distribution is expected to be online within the next year.

NEW 55" PIPELINE DEVELOPMENT. At the heart of the Keahole facility, NELHA's world famous seawater system that accesses the deep ocean will undergo a major expansion. In the first stage of development, two parallel tunnels were completed in January 1997 for the shoreline crossing. Completion of the system expansion awaited further legislative funding, obtained in FY99. To be installed are a new 55-inch supply pipeline to reach chilly 4°C seawater at 3000 feet depths and a second 55-inch pipeline to access surface seawater. The expansion will add pumping capacities of up to 40,500 gpm of surface seawater and 28,500 gpm of deep seawater. The coldwater pipe will reach 1,000 feet deeper than the current supply line, to a 3,000 feet depth with a 4°C temperature. This much-awaited project will make possible the build-out of HOST Park by new and expanding business, research, and educational projects, and is being designed to accommodate the large volume water needs of a demonstration scale OTEC plant.

NEW BUSINESS INCUBATOR AREA. Engineering plans were developed for a new incubator area in the NELH section of the technical park during the reporting period. Four new one to two acre rough graded parcels are planned along the coastal strip makai of the NELHA Access Road.

SEAWATER DISCHARGE REEVALUATION. An environmental consultant will be contracted to assist NELHA staff in determining the best method for seawater disposal as the park continues to expand.

SPECIES MANAGEMENT PROGRAM. NELHA staff have worked in consultation with the marine scientific community, as well as agency representatives, NELHA tenants, and the NELHA Board, to develop a practical species management program to protect tenant businesses and the environment at Keahole. The staff hopes to implement the program in FY00.

NELHA operations staff drive through HOST Park where new infrastructure development is planned.

The past two years have been crucial to the laying of a foundation on which to launch a new era of growth and expansion at NELHA.

HOST PARK GROWTH

Plans for the year 2000 include a new grow-out facility for the Big Island Abalone Corporation which depends on deep seawater supplies to HOST Park.

TENANT OUTLOOK. The HOST Park is being prepared to receive its first tenant development projects in the new millennium. Big Island Abalone Corporation plans to break ground in early 2000 at HOST Park as it begins construction of its growout facility for abalone production.

Other tenants are also making plans to expand into the HOST Park, and NELHA has received a variety of inquiries from both American and foreign interests, spurred by the novelty and potential of products from the increasingly popular deep seawater resource. EagleNet Sea Farms, Inc. intends to develop a 4-acre parcel for an abalone nursery, and Oceanic Institute also plans to break ground for a new research facility in FY00.

Two of NELHA's tenants are founding members of the new National Science Foundation (NSF)-funded Marine BioProducts Engineering Center (MarBEC) at the University of Hawaii at Manoa (UHM) School of Ocean and Earth Science and Technology (SOEST). MarBEC partners UHM with the University of California at Berkeley to lay the groundwork for future use of marine biotechnology products in the chemical, pharmaceutical, nutraceutical and life sciences industries.

The HOST Park is being prepared to receive its first tenant development projects in the new millennium.

In addition, practical training at companies like NELHA tenants Cyanotech and Aquasearch will provide MarBEC students with the necessary realworld experiences in this burgeoning industry, as well as retraining opportunities for the existing workforce. MarBEC will be able to address complex problems by gathering a critical mass of expertise in key disciplines, developing new technologies and biological resources to advance the industry in Hawaii.

HIGHWAY FRONTAGE PROPERTY DEVELOPMENT. The NELHA Board and staff have examined the potential for revenue enhancement from the high value properties located along Queen Kaahumanu Highway, seeking input from members of the business community. The properties on the northern section are slated for commercial and general industrial development, and the southern properties will be reserved for research, outreach, and education tenants in a campus-like setting. This effort has supported the initiative towards sustainability and self-sufficiency for NELHA, and will be furthered in the new millennium.

GATEWAY PROJECT. Through the support of Senator Daniel K. Inouye, federal dollars will support the initiation of the new Gateway Project to expand research and educational facilites at NELHA. Congressional appropriations totalling $2.5 million have been made towards planning, design and program development. Funds are sought to supplement these dollars, which will be leveraged to attract other funding sources.

The facility is planned as a state-of-the-art laboratory and teaching facility geared towards world-class research in energy and ocean sciences and technology. The facility will also accommodate an outreach function for public education as well as for college students who could

participate in scientific research through internship and other practical learning opportunities. A design team for the facility will be convened in FY00.

The project has already attracted the attention of a number of research groups which hope to become tenants and partners as the facility develops. The focus of the facility will be on renewable energy as well as the maintenance of Hawaii's pristine ocean environment.

OTHER INTERESTS. The U.S. Aquarium Team presented a concept for a small commercial aquarium to the Board of Directors. Since NELHA has been involved in reexamining the master plan for the future, the Board elected to issue a request for proposals for a commercial aquarium complex in the HOST Park, forthcoming in FY00.

Other groups interested in developing a demonstration scale OTEC plant are also in the works and have been in ongoing discussions with NELHA staff for several years. One company, Sea Solar Power, Inc. (SSP), presented their initial concept to the NELHA Board in October 1998. The Board voted to approve the proposal in concept with the understanding that, as more data become available, SSP and NELHA will further evaluate the feasibility of the company's designs for the Keahole site.

FUTURE PROSPECTS. A commercial aquarium, a demonstration OTEC plant, a photovoltaic farm, a new abalone project, macro and micro algae farms, and commercial highway property development are all potential prospects for the new millenium at NELHA. The next few years at NELHA, for both staff and tenants, will be very, very busy–both the price and the prize of progress. These efforts promise to bring multiple-fold investment returns to the state economy, as well as benefits to the local community in terms of more jobs, educational opportunities, product development, and business development opportunities.

The next few years at NELHA, for both staff and tenants, will be very, very busy–both the price and the prize of progress.

California abalone are one species of high value marine organisms that will be cultured in HOST Park.

Affiliated Program: CEROS

CEROS

NATIONAL DEFENSE CENTER OF EXCELLENCE FOR RESEARCH IN OCEAN SCIENCES

ABOVE: Aquaculture Technology-- Chaetoceros cell and chain of diatoms

The CEROS Program was created under a $5 million grant provided by the Defense Advanced Research Projects Agency (DARPA) in 1993. CEROS has been an affiliated program of NELHA since 1995, administered through DBEDT and NELHA. The NELHA Board of Directors oversees the operation of CEROS, setting broad goals, developing policy, and providing guidance for the CEROS program. CEROS programs and management are also reviewed and evaluated by DARPA as the CEROS grantor. CEROS maintains a central office in Kona at NELHA's Keahole facilities and a contracts office in Honolulu.

CEROS seeks to advance innovative concepts and new approaches to technology while fully leveraging existing facilities and infrastructure in Hawaii and demonstrating beneficial commercial utility for the Department of Defense (DoD).

The NELHA Board of Directors oversees the operation of CEROS, setting broad goals, developing policy, and providing guidance for the CEROS program.

The CEROS Mission has 5 parts:

1. Support Department of Defense advanced technology development requirements;
2. Encourage leading edge R&D in ocean sciences and technology in Hawaii;
3. Foster use of ocean R&D facilities in Hawaii;
4. Provide an interface between specialized small businesses with expertise in ocean-related R&D and DoD users of advanced technology;
5. Develop avenues to ocean science expertise and facilities at the University of Hawaii.

Five technical topic areas are identified in the legislation that originally funded CEROS:

- Ocean Environment Preservation Technology
- New Ocean Platform and Ship Concepts
- Shallow Water Surveillance Technologies
- Ocean Measurement Instrumentation
- Unique Properties of the Deep Ocean Environment.

CEROS solicits proposals through annual Broad Agency Announcements (BAA). All proposals are evaluated competitively for technical merit, innovation, and value according to criteria published in the solicitations. The CEROS Research Advisory Board determines the best proposals based on the evaluations. Since 1993, the CEROS Research Programs have funded a total of 100 projects for $40.2 million.

The initial DARPA grant for CEROS established and focused the CEROS program. The second DARPA grant, MDA972-94-1-0010, established program credibility through the contractors' results, which clearly demonstrated the level of expertise and infrastructure in Hawaii through "leading edge" ocean technology development. As a result, CEROS increased emphasis on technical developments while solidifying the program's position as the State's principal interface between the DoD science and technology establishment and the highly specialized ocean

ABOVE: Neptune Technologies-- Diver Homing Device

Since 1993, the CEROS Research Programs have funded a total of 100 projects for $40.2 million.

technology development companies in Hawaii. Total funding to CEROS for Grant No. MDA 972-94-1-0010 was approximately $18,737,796. This grant supported a core program of thirty-nine projects involving nineteen prime contractors during CEROS FY94, FY95, and FY96. All contracts were complete by the end of June 1999. The grant was closed and a final technical report was submitted to DARPA.

This relationship continued through a Cooperative Agreement between DARPA and CEROS. The agreement was executed in 1997 and has received over $18 million in funding for technical program support in project years 1997 through 1999. The Agreement enabled a number of companies to develop technologies and demonstrate capabilities that have received subsequent support from the defense sector outside of CEROS (e.g. SBIR) or have transitioned into commercial products or services.

A major thrust under the Cooperative Agreement was to increase CEROS awareness and capabilities. In order to accomplish this, the CEROS Outreach Program increased in scope and activities by initiating the following events:

- CEROS Informational Meetings in May and October of 1998 at locations in Kailua-Kona, Kihei, Maui and Lihue, Kauai
- Hawaii Ocean Technology Expos in June 1998 and June 1999 in Honolulu
- Pre-BAA Information Exchange in September 99 in Honolulu
- CEROS exhibited and attended the Marine Technology Society Oceans '98 and '99 Conferences in Baltimore, Maryland, and Seattle, Washington.

The purpose of the outreach meetings was to familiarize potential applicants with CEROS objectives, resources, and procedures. Program and organizational information was also presented by the following agencies: DARPA, Space and Warfare Systems Center, Pacific Missile Range Facility, Maui High Performance Computing Center, Commander in Chief, U.S. Pacific Fleet, Naval Undersea Warfare Center, Pacific Meteorology and Oceanography Center/Joint Typhoon Warning Center, University of Hawaii, Hawaii Venture Group, Pacific Business Program and the Ocean Resources Branch of DBEDT.

Some CEROS successes include the following funded projects:

- Midfoil Vessel (Pacific Marine and Supply Company)
- Diver Homing Device (Neptune Technologies, Inc.)
- "Solution" Series Raman-based Sensors (Detection Limit Technology)
- Antibiotics from Marine Algae (Aquaculture Technology)
- Bottom Penetrating Synthetic Aperture Sonar (Raytheon Company)
- MakaiPlan Cable Lay Software (Makai Ocean Engineering)
- Sand-Penetrating Sonar (Sea Engineering)
- CableCAD Software (Structural Solutions)
- Laser Heterodyne Imaging System (Varian Corporation)
- Advanced Airborne Hyperspectral Imaging System (Science & Technology International)
- PMOC WebCrawlers (GuideNet)
- The Virtual Tow Tank (Ocean Engineering Consultants)
- Advanced Real Time Sensor (ORINCON Corporation)

LEFT and ABOVE: Pacific Marine & Supply Company--MidFoil Vessel prototype and schematic.

CEROS PROJECT ALLOCATIONS

1993 - 1999

The CEROS program has received a total of $37,040,713 in federal funding. Allocation of that funding is summarized in the following table. From July 97 - June 99, 36 projects began work and 30 projects completed work.

PROJECT TOPIC AREA	PROJECTS	FUNDING ($)	%
Shallow Water Surveillance Technologies	36	17,536,570	40.2
Ocean Environment Preservation	21	9,671,558	22.2
New Ocean Platform and Ship Concepts	12	4,983,322	11.4
Ocean Measurement Instrumentation	24	6,035,822	13.8
Unique Properties of the Deep Ocean Environment	7	1,989,596	4.6
Subtotal	100	40,216,868	92.3
Administration		2,679,368	6.1
Technical Program Development		471,417	1.1
Subtotal		3,150,785	7.2
Uncommitted Project Funds/Reserve		215,000	0.5
TOTAL		43,582,653	100.0

LEFT & BELOW: Structural Solutions-- Prebuckled Cylindrical Hull

CEROS FUNDED PROJECTS 1993-1999

AQUACULTURE TECHNOLOGY, INC.
- Naturally Occurring Antibodies from Marine Algae *Chaetoceros* (FY94: $171,000)
- Naturally Occurring Antibacterial and Antifungal Substances from Marine Algae *Chaetoceros, Nitzschia* and *Thalassiosira* (FY95: $207,000)
- Continuous Production of Marine Algae *Chaetoceros spp.* in an Open System (FY97: $240,000)

BAND, LAVIS & ASSOCIATES, INC.
- Application of Techniques and Comparative Effectiveness of Non-Toxic Anti-Fouling Surfaces to Immersed Nettings Used in Naval and Aquaculture Industries (FY97: $227,198)
  Subcontractor: Black Pearls, Inc. Holualoa, HI

BBN TECHNOLOGIES
- A Proposal to Develop HYDROFIST: A Nonexplosive Means for Generating Intense and Focused Underwater Shock Waves (FY99: $999,819)
  Subcontractor: Navatek Ships, Ltd (a subsidiary of Pacific Marine), Honolulu, HI

BLACK PEARLS, INC.
- Probiotic Bacteria: The Key to Expanded Use of Deep Seawater in Tropical Aquaculture and the Solution to a Growing Industry Problem (FY97: $121,392)

DETECTION LIMIT TECHNOLOGY, INC.
- Development of Fiber-Optic Chemical Sensors (FOCs) for Remote In-Situ Monitoring of pH and Carbon Dioxide in Seawater (FY93: $237,000)
- Development of a Fiber-Optic Based Autonomous Buoy for In-Situ Monitoring of pH, CO_2, Temperature, O_2, and Water Quality in Seawater (FY94: $332,000)
- Solution Plus In-Situ Ocean Sediment Chemical Analyzer (FY96: $320,000; FY97: $360,000)
- PCB Analyzer for Shallow Ocean Water (FY98: $380,000)

EDWARD K. NODA & ASSOCIATES, INC.
- Hurricane Risk Analysis and Modeling of Coastal Flooding for the Hawaiian Islands (FY93: $214,000)
- Modeling of Hurricane-Induced Coastal Flooding for the Hawaiian Islands (FY98: $182,345)

GATEWAY TECHNOLOGIES INTERNATIONAL, INC.
- Radar/Sensor Signal Processing Research of Shallow Water Surveillance Technologies (FY93: $386,000)
- HIRADSIM Workstation Development Project - Continuation of Existing Work Advanced HIRADSIM Small Target - Time Domain - Maritime Radar Mode (FY94: $250,000)
- Personal Emergency Lifesaving System (PELS) (FY98: $240,920)

GUIDENET, INC.
- Using Software Agents to Acquire and Visualize Environmental Information for ASW Surveillance (FY98: $305,000; FY99: $360,000)

IBM/LORAL FEDERAL SYSTEMS; KEWALO BASIN MARINE MAMMAL LABORATORY

- Acoustic Analysis Tool Kit (FY93: $480,000)

INNOVATIONS HAWAII

- Extended Source Apparent Motion (E-Sam) Lighted Signals For Protection of the Marine Environment (FY93: $241,000; FY94: $177,000)

MAKAI OCEAN ENGINEERING, INC.

- Cost-Effective GPS-Based Sensor for Measurement of Heave, Pitch, Roll and Heading on Oceanographic Platforms with O.3 Degree Resolution (FY93: $230,000; FY94: $235,000)
- Loop Avoidance Control During the Deployment and Retrieval of Submarine Cables (FY96: $287,000)
  Subcontractor: Knapp Engineering, Inc. (new name is Structural Solutions), Aiea, HI
- An Automated Control System For Deployment of Small Diameter Cables and Towed Bodies—A Cable Lay Simulator (FY94: $325,000)
- Design, Construction, and Operation of a Fifty Kilowatt Closed Cycle OTEC Plant and Application Of Results to the Design of a One Megawatt OTEC Plant (FY94: $450,000; FY96: 200,000)
- Internet-Enabled Engineering Tool for Dynamically Analyzing and Planning World-Wide Subsea Cable and Array Installations (FY98: $379,985)

MISSION RESEARCH CORPORATION

- Ocean Doppler Lidar (FY95: $381,000)

NEPTUNE TECHNOLOGIES, INC.

- Diver Homing Device (FY95: $200,000; FY97: $39,000)

OCEAN ENGINEERING CONSULTANTS, INC.

- Swath Motion/Structural Software Development (FY94: $121,000)
- Swath Motion/Structural Software Development and Verification (FY95: $168,000)
- Flow Simulation and Visualization for Swath Ships (FY96: $161,000)

OCEANIC IMAGING CONSULTANTS

- The DiVRS (ROVer's) Eye Terrain Database Visualization as an Aid to Underwater Navigation (FY98: $239,652; FY99: $275,482)

THE OCEANIC INSTITUTE

- Cultured Fish as Biological Indicators of Pollution (FY99: $216,766)
  Subcontractor: Associated Laboratories, Orange, CA

OCEANIT LABORATORIES, INC.

- Computational and Physical Modeling of the Hurricane Tower Desalination System (FY97: $150,000)
- Low-Cost Prebuckled Cylindrical Pressure Hulls (FY93: $343,000; FY94: $91,000)

OCEANTEK, INC.

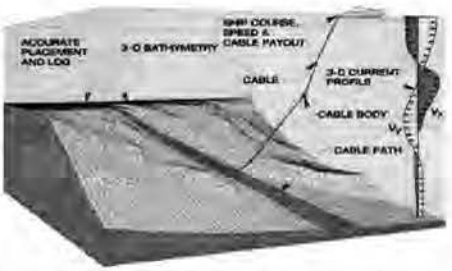
- An Ocean Bottom Span Analyzer for Survey Planning and Installations of Submarine Cables and Pipelines (FY99: $188,000)

OCEANTRONICS, INC.

- Submarine Electronic Charting System (FY99: $95,000)

ORINCON HAWAII, INCORPORATED

- Underwater Echolocation for Object Recognition (FY93: $770,000; FY94: $653,000; FY95: $697,000)
  Subcontractor: Hawaii Institute of Marine Biology-University of Hawaii, Kailua, HI



BELOW: Makai Ocean Engineering--Cable Lay Software

RIGHT: Raytheon Systems-- Synthetic Aperture Sonar.

- Advanced Real-Time Signal Processor (ARTS) and ASW Commanders Workstations (ADM-3) (FY95: $862,000; ,FY96: $872,000)
- An Upgraded ARTS Processor for Maritime Patrol Aircraft Applications (FY98: $373,000)
- Antisubmarine Warfare Commander's Workstation Upgrades and Advanced Real-Time Signal Processor for CTF-12 Applications (FY97: $500,000)
- Submarine-Launched, Two-Way, Fiber Optics-Linked Communications Buoy (FY96: $160,000)
  Subcontractor: Sippican, Inc., Marion, MA
- An Improved Acoustic Intercept Receiver for Submarine Applications (FY97: $450,000; FY98: $560,000)
- An Integrated System for Detection, Classification, Localization, Tracking and Reporting of Submarine Contact Data (FY97: $700,000)
- Situation Awareness System (SAS) Processor for Submarine Applications, Phase 2 and At-Sea Evaluation (FY 98: $171,777; FY99: $775,864)
- Automation and Integration of Environmental Factors into ASW Tracking. (FY99: $497,415)

PACIFIC ENVIRONMENTAL TECHNOLOGIES

- Development of a Miniaturized Mass Spectrometer-Based Sampling System for In-Situ Measurements of Dissolved Gas and/or Solutes in Marine Waters, and for Protein Characterization that Leads to Microbial Identification (FY99: $141,743)

PACIFIC MARINE & SUPPLY COMPANY, INC.

- Tri-Strut Ship Research and Development (FY94: $366,000)
- Design, Construction and Sea Trials of a 30-Foot Manned Test Model of a Midfoil SWAS (FY95: $500,000; FY96: $280,000)
- CFD Code Validation and Improvement Using Large Scale Tests: Optimization of Design for High Froude Number Underwater Body Operating at Near Surface (Midfoil and Slice) and Subsequent Construction and Testing of Optimized Underwater Body (FY97: $654,000)
- Development, Fabrication, and Demonstration of a Patentable Combination Propeller-Pump Jet Integrated Propulsion Pod with Boundary Layer Suction (FY98: $300,000; FY99: $800,000)

RAYTHEON SYSTEMS (formerly HUGHES AIRCRAFT, formerly ALLIANT TECHSYSTEMS)

- High-Resolution Bottom-Penetrating Acoustic Sensors and Signal Processing Algorithms for Reduction of False-Alarm Probability in UXO Hunting (FY 94: $981,000)
  Subcontractors: University of Hawaii School of Ocean and Earth Science and Technology, INTECH, Inc., Sea Engineering, Inc.
- High-Resolution Bottom Penetrating Synthetic Aperture Sonar Using Multi-Vertical Row Array and Subbottom Classifier Sonar (FY95: $990,000)
  Subcontractors: University of Hawaii School of Ocean and Earth Science and Technology, INTECH, Inc., Sea Engineering, Inc.
- High-Resolution Bottom Penetrating Synthetic Aperture Sonar for Use in Buried UXO Hunting (FY96: $996,000)
  Subcontractors: University of Hawaii School of Ocean & Earth Science & Technology, INTECH, Inc., Sea Engineering, Inc.
- Integrated Sensor System for Search and Classification of Subbottom Objects (FY97: $758,000)
  Subcontractors: University of Hawaii School of Ocean and Earth Science and Technology, INTECH, Inc., Sea Engineering, Inc.
- Multi-Spectral, Interferometric Synthetic Aperture Imaging Sonar (FY98: $550,034)
  Subcontractors: University of Hawaii School of Ocean and Earth Science and Technology, INTECH, Inc., Sea Engineering, Inc.
- Frequency Agile Sequential Transmission Synthetic Aperture Sonar (FastSAS) - Risk Reduction Technology Demonstration for NetTORP (FY99: $865,631) Subcontractors: University of Hawaii School of Ocean and Earth Science and Technology, INTECH, Inc., Sea Engineering, Inc., Honolulu Shipyard, Inc.

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

- Web-Based Processing for State-of-the-Art Large Aperture Multi-Dimensional (SLAM) Array (FY99: $500,000)

SCIENCE & TECHNOLOGY INTERNATIONAL (STI) (formerly SETS Technology, Inc.)

- Hyperspectral Remote Sensing for Maritime Applications (FY93: $692,000; FY94: 648,000)
- Dual Mode Fluorescence Imaging for Maritime Applications (FY95: $795,000; FY96: $996,000; 100,000)
  Subcontractor: SAIC, Woods Hole, MA
- Grazing Angle Imaging Lidar For Organic Mine Countermeasures (FY96: $698,000)
  Subcontractor: SAIC., San Diego, CA
- Undersea Fanbeam Spectral Imaging (FSI) Risk Reduction Technology Demonstration (FY98: $398,895)

SEA ENGINEERING, INC.

- Development of a Technique to Identify Pollutant Sources and Impacts in Coastal and Oceanic Waters (FY94: $146,000)
- Development of a Broadband FM Sub-Bottom Profiler for Seafloor Imaging and Sediment Classification (FY93: $292,000; FY94: $224,000)
  Subcontractor: Precision Signal, Inc., Boca Raton, FL
- Development of a 3-D, Forward/Aft Sweeping High Resolution

ABOVE: Detection Limit Technology--Raman SOLUTION 633 System.

ABOVE: Sea Engineering, Inc.-- Broad-Band FM Sub-bottom

Buried Object Imaging System (FY97: $389,000; FY98: $421,200)
Subcontractor: Precision Signal, Inc., Boca Raton, FL

- On-Site, Preliminary Analysis of Sediment Core Samples (FY97: $103,000)
  Subcontractor: Jet Propulsion Laboratory, California Institute of Technology
- Development of an Ultra-High Resolution Non-Destructive Technique for Stress Detection for Marine Applications (FY98: $319,154)
- Development of an Enhanced Resolution Filter for Improving Sonar Imagery. (FY99: $148,287)
  Subcontractor: MultiSpec Corporation, Cherry Hill, NJ

SEE/RESCUE CORPORATION

- Life/Float the One-Person Survival Craft (FY98: $70,000)
- Enhanced Sea and Land Rescue Visibility System (FY99: $253,839)
  Co-contractor: TerraSystems, Inc., Honolulu, HI

STRUCTURAL SOLUTIONS (formerly KNAPP ENGINEERING)

- Low-Cost Prebuckled Cylindrical Pressure Hulls (FY93: $414,000; FY94: $571,000)
  Project partner: Oceanit Laboratories, Inc., Honolulu, HI
- 3-D Finite Element Design of Cables (FY 96: $145,000; FY97: $190,000)
- Smart Scuba (FY98: $319,000; FY99: $366,000)
- A Probe for In Situ Characterization of Marine Carbonate Sands and Other Sediments (FY98: $220,000)

SYNTHETIC TECHNOLOGY CORP.

- Bioactive Marine Isonitrile Compounds from Hawaiian Sponges as Models for Synthetic Nontoxic Antifoulant and Antibiotic Agents (FY95: $155,000)
- Bioactive Marine Isonitrile Compounds from Hawaiian Sponges as Models for Synthetic Nontoxic Antifoulant and Antibiotic Agents. Synthetic Analogs, Paint Formulations, and Mechanisms of Action (FY96: $327,000; FY97: $300,000)
  Subcontractor: Pacific Biomedical Research Center of the University of Hawaii

TERRASYSTEMS, INC.

- Development of an Underwater Video Camera for Optical Contrast and Range Enhancement Using Spectral Stretching (FY96: $247,000)
  Subcontractor: Sea Engineering, Inc., Waimanalo, HI
- Development of an Underwater Compositional Mapping (UCM) System (FY98: $351,177)
  Subcontractor: Sea Engineering, Inc., Waimanalo, HI
- Enhanced Sea and Land Rescue Visibility System (FY99: $253,839)
  Co-contractor: SeeRescue Corporation, Honolulu, HI

THERMAL ENERGY STORAGE, INC.

- Development and Testing of a Clathrate Desalination Research Facility (FY96: $250,000)
  Subcontractor: Makai Ocean Engineering, Kailua, HI

VARIAN ASSOCIATES

- Laser Heterodyne Imaging for Shallow Water Surveillance (FY95: $300,000; FY97: $396,000)
  Subcontractor (FY95): Oceanit Laboratories, Honolulu, HI
  Subcontractor (FY97): Detection Limit Technologies, Inc. Honolulu, HI

Appendix

INFORMATION FOR PROSPECTIVE TENANTS

PROJECT APPLICATION PROCEDURES

NELHA welcomes applications from individuals, businesses, research organizations, and educational groups desiring to engage in research, commercial, or educational activities at its Keahole Point facilities. The skilled professional staff at NELHA apply their scientific, technical, and business knowledge to support tenants during all phases of operation, from research and development to full commercialization. The NELHA staff is available to enable tenants to complete a smooth transition from R&D to fully operational businesses.

PROJECT APPROVAL

Individuals or groups with an interest in starting a project at NELHA are invited to submit proposals following the guidelines in the Project Initiation Packet (PIP). Project areas must fit within the guidelines established by legislative mandate, HRS 227D, utilizing the unique resources available on-site, while not harming the environment. The Board seeks projects that will make significant contributions to the advancement of research, education, or economic development for the region. Research projects are required to submit a proposal and complete one round of staff review and board approval. Commercial projects must complete a two-stage approval process that involves two rounds of approval, including the submission of a preliminary proposal and a business plan with financial projections.

INCUBATION FOR START-UP BUSINESSES

NELHA is the only ocean science and technology park of its kind in the world. Its major goal is to encourage economic development and diversification which can capitalize on the unique complement of resources available at Keahole Point. Master permits and the existing infrastructure save business start-ups thousands of dollars in capital investment and many months of time. Through the support NELHA provides, it creates an environment which is very attractive to small, new businesses starting out in a highly competive business world. NELHA not only incubates new business entities, but contributes to the growth of new industries that can offer economic alternatives to tourism and traditional agriculture for Hawaii.

SERVICES AVAILABLE TO NELHA TENANTS

OPERATIONS AND MAINTENANCE

- Seawater Systems
- Equipment Rental and Repairs
- Heavy Equipment Operators
- Mechanical Technicians
- Plumbing, Welding
- Metal and Wood Shop
- Fabrications
- Marine Operations

ENGINEERING

- Piping Design
- Site Development
- Computer-Aided Drafting (CAD)
- Utility Design Analysis

ANALYTICAL LABORATORY

- Certified Environmenal Laboratory
- Environmental Monitoring Services
- Chemical Analysis
- Microbiological Analysis
- Microbiological Reference Library
- Technical Assistance
- Instrumentation Rental

ADMINISTRATION

- Leases and Service Contract Support
- Telecommunications Support
- Fiscal Support
- Educational Programs
- Business Development and Marketing Assistance

NELHA ON THE WEB

KEAHOLE OCEAN SCIENCE IN THE VIRTUAL WORLD

The Natural Energy Laboratory of Hawaii Authority and its tenants are described at the NELHA website on the Internet, the electronic superhighway, at its URL:

http://bigisland.com/nelha

Here visitors can make a virtual visit to Keahole Point from the comfort of a home or office computer station. At our website, they can learn about NELHA and its mission, resources, facilities, tenants, and many contributions to the advancement of economic development in Hawaii, as well as global science and technology.

Both NELHA and a number of its tenants entered cyberspace in the last few years with their own electronic websites to take advantage of this electronic medium. The World Wide Web provides its travellers with not only textual information but also digitized graphics, illustrations, photographs, and sometimes even soundbytes and video clips. The NELHA website serves both marketing and educational functions, broadening the facility's public outreach.

The electronic medium has allowed NELHA and its tenants to reach an international audience. NELHA tenants with websites include:

Aquasearch, Inc.	**http://www.aquasearch.com**
Big Island Abalone Corporation	**http://www.bigislandabalone.com**
Common Heritage Corp.	**http://www.aloha.com/~craven**
Cyanotech Corporation	**http://www.cyanotech.com**
Indo-Pacific Sea Farms	**http://www.ipsf.com**
Pacific International Center for High Technology Research	**http://www.pichtr.htdc.org**
Sea Grant Extension Service, West Hawaii (University of Hawaii)	**http://www.soest.hawaii.edu/seagrant**
Stockly's Aquariums, Inc.	**http://www.ecosaqua.com**

The NELHA-affiliated program, CEROS, also maintains a website at

http://www.ceros.org

PUBLICATIONS RESULTING FROM WORK AT NELHA'S KEAHOLE POINT FACILITIES

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Brewer, Wm. A., Jack P. Huizingh and Jane E. Sexton, NO 1/85, "Hawaii's OTEC Park Triggers High-Tech Aquaculture Development", *Info-Fish Marketing Digest*, p. 18-21.

Craven, J.P., Mar 8-11, 1994, "Coldwater agriculture as a component of a deep ocean water recovery system", *Conference Proceedings: Oceanology International '94*, Brighton, U.K., Vol 5, No. 17, 9p.

Creber, D.K., Mar 8-11, 1994, "Design considerations for a closed-cycle OTEC plant for Keahole Point, Hawaii", *Conference Proceedings: Oceanology International '94*, Brighton, U.K., Vol 5, No. 9, 20p.

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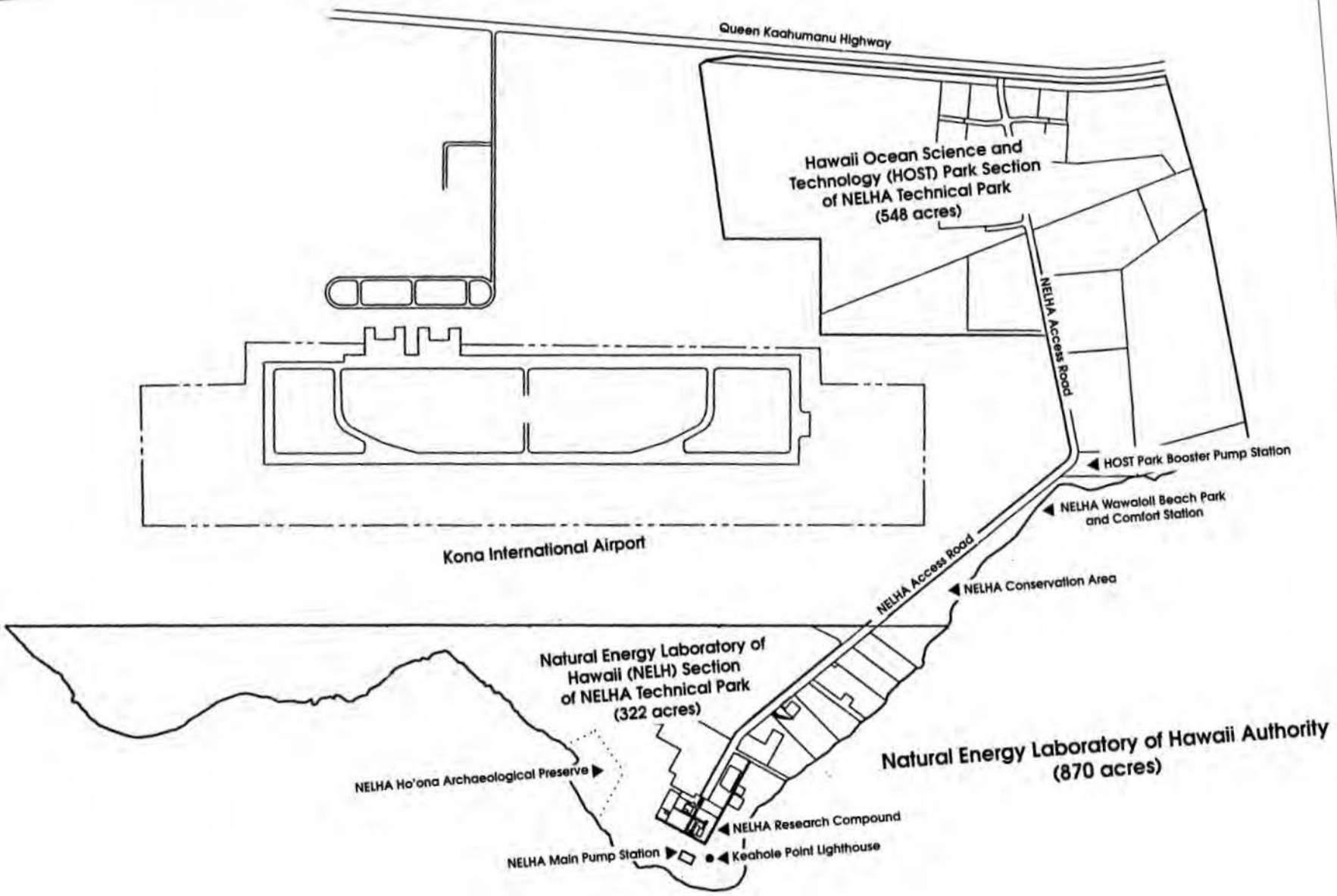

Figure 7. Map of NELHA properties.

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