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JOHN WAIHEE
GOVERNOR OF HAWAII

WILLIAM W. PATY, CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES

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

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FILE NO.: OA-10/28/91-2530
DOC. NO.: 1979E

MEMORANDUM

TO: The Honorable Brian J. J. Choy, Director
Office of Environmental Quality Control

FROM: William W. Paty, Chairperson
Board of Land and Natural Resources

SUBJECT: Document for Publication in the OEQC Bulletin
Environmental Assessment for Conservation District Use Application OA-10/28/91-2530 for Commercial Aquaculture at Heeia Fishpond, Koolaupoko, Oahu, Hawaii
TMK: 4-6-05: 01

The above mentioned Chapter 343 document was reviewed and a negative declaration was declared based upon the environmental assessment provided with the CDUA.

Please feel free to call me or Roy Schaefer of our Office of Conservation and Environmental Affairs, at 587-0377, if you have any questions.

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1991-12-08-OA-FEA-Heeia Fishpond Commercial aquaculture

FILE COPY

CONSERVATION DISTRICT USE TEMPORARY VARIANCE APPLICATION

V. ENVIRONMENTAL REQUIREMENTS

1) **Identification of Applicant;**

Mark Brooks, dba Pacific Aquaculture Consultants
46-077 Ipuka Street
Kaneohe, HI 96744

The manager and caretaker of Heeia Pond is Mark Brooks. Mr. Brooks holds a Master's Degree in Aquaculture (1978) from The Auburn University International Center for Aquaculture (Auburn, Alabama). Mr. Brooks practiced aquaculture professionally for 6 years in North and Central America. Then from 1982 to 1989 he served the Sea Grant Extension Service and the Hawaii State Aquaculture Development Program as Extension Specialist, advising aquaculture farms in production systems and species selection and husbandry. A resume is attached as Appendix IV.

2) **Identification of Approving Agency:**

Department of Land and Natural Resources

3) **Identification of Agencies Consulted in Making Assessment; (Documentation attached, Appendix. VIII)**

Department of Land and Natural Resources; Land Management, Conservation and Environmental Affairs,
Historic Preservation Division
Water Resource Management
State Parks Department
Friends of Heeia (State Park)
U.H. Institute of Marine Biology (Coconut Island)
U.S. Army Corps of Engineers
The Bishop Museum, Applied Research Group
City of Honolulu, Dept. of Public Works
State Department of Health, Environ. Permits Div.
State DOT, Harbors Div., Shore & Shore Waters
U.S. Coast Guard Aides to Navigation Div.
State Office of Environmental Quality Control
City and County of Oahu, Dept. of Land Utilization
State Land Use Commission
U.S. Fish & Wildlife Service

4) **General description of the action's technical, economic, social, & environmental characteristics;**

4.1 SUMMARY

The purpose of this document is the Conservation District Utilization Application to repair and operate Heeia fishpond in conservation resource land. It outlines the environment, the pond and its history and the proposed operations. The permit application applies to 3 major topics:

1) Repair of the ancient Hawaiian fishpond to working order as an essential step towards it eventual complete archaeological restoration.

2) Commercial operation of the pond for the production and sale of a variety of marine products and services.

3) Development of the aquaculture potential of the site through research and testing of a variety of combined traditional and modern aquaculture production systems and techniques.

The project intends to preserve the pond as a living, working, economically viable monument. The pond is an expression of the ancient Hawaiian people's knowledge and harmony with the land and sea. Making the pond work today in the economic realities of modern times is a challenge to the advancement of the art and science of ocean management and food production. Success would be a hybrid creation combining the best of the old and the new.

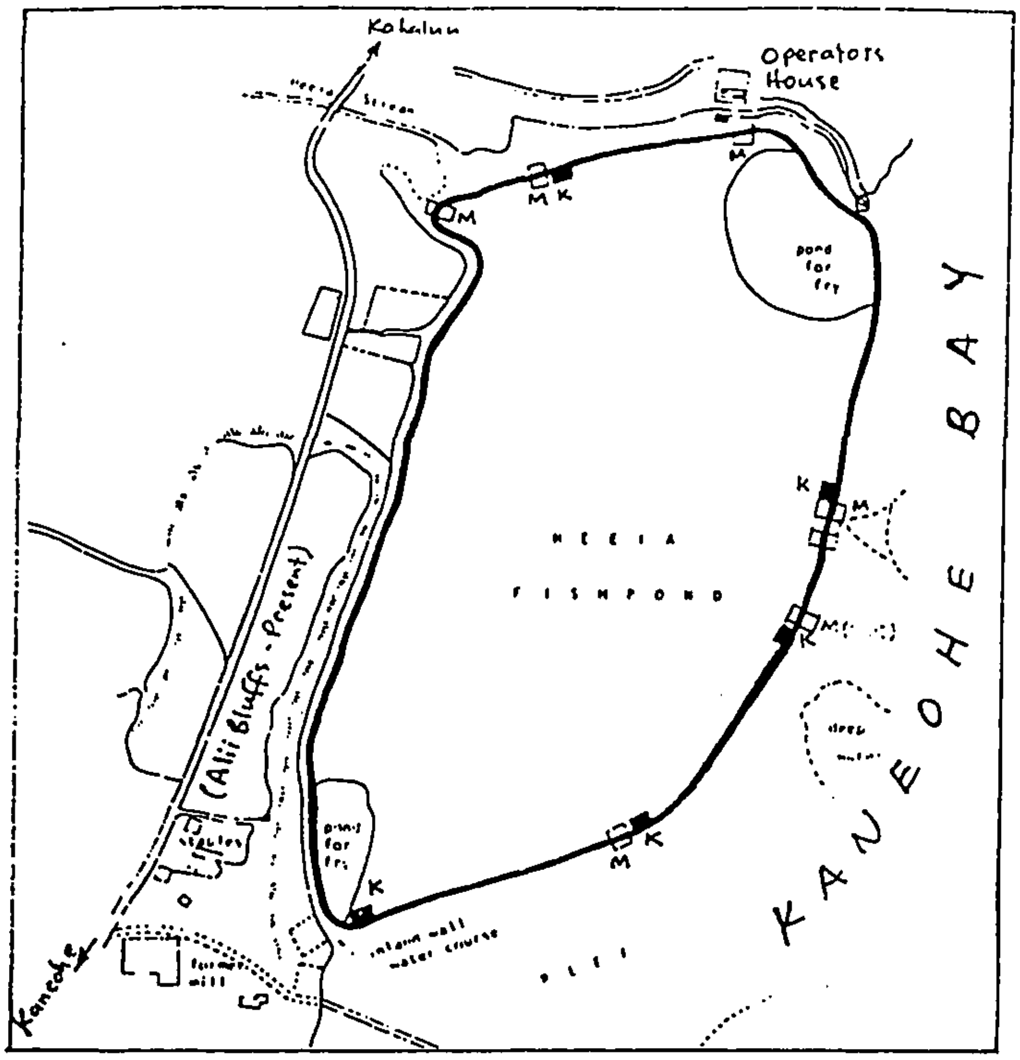
The establishment of a fully working Heeia fishpond can contribute to the community economically, educationally, scientifically, and culturally. A primary goal of the facility is to contribute to food production and fishery management improvements through stock enhancement and baitfish production.

The eight major goals of the project are outlined in the figure on the following page.

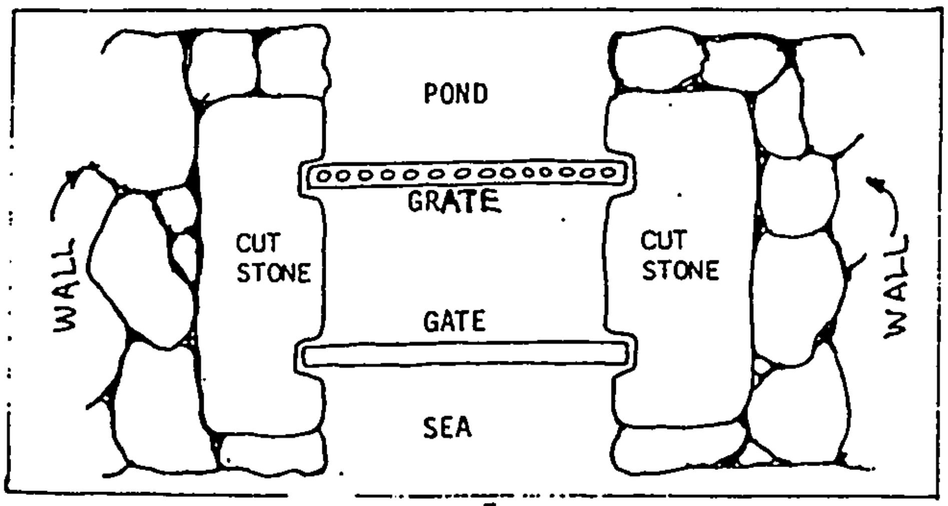
HEEIA POND
RESTORATION AND OPERATION GOALS

I	WATER DEPTH FIXED TO MINIMUM WORKING LEVEL A. Repair Makai break with single wall of cement cylinders and/or Geoweb B. Makaha repair C. Hatchery / support structures PRODUCTION CAPABILITY: Cage production of hardy fish protected from lowtide heat and lack of water.
II	INITIAL RIVER BREAK REPAIR A. Use of "geoweb" erosion control along stream wall breaks to create single wall B. Selected mangrove clearing C. Nursery pond construction PRODUCTION CAPABILITY: Improved pond water quality. Begin testing potential species in enclosures. Effect salinity and siltation control.
III	FLOOD CONTROL AND RIVER REPAIR A. State contract for stream clearing and deepened channel. B. Reinforce with double wall ("geoweb" material) at main break. C. Increase river wall strength with fill from stream and pond silt bottom. PRODUCTION CAPABILITY: Full water quality control prevents siltation, fish crop escape and predator entry. Allows expanded variety of species, science contracts, fisheries, stock enhancement. Begin primary open pond fish stocking of mullet, milkfish and threadfin.
IV	ENHANCE WALL REPAIR USING DOUBLE WALL AND FILL TECHNIQUE Strengthens pond wall resistence to storms, high tides, and floods. Center of double wall filled and capped with crushed coral, ready to receive rock-wall facing to match existing.
V	INNER AND OUTER ROCK LINING OF WALLS Completes restoration of walls to visually match adjacent walls, and insures long-term preservation of fish pond.
VI	INSTALATION OF LARGE MAKAHA IN "MAIN-BREAK" MAKAI WALL AREA Allows greater control of water management, aquaculture managment, and flood control.
VII	POND BOTTOM SILT MANAGEMENT Restores pond bottom to orginal condition by utilizing silted materials in interior and perimeter pond walls.
VIII	MOUNTAIN FRESHWATER CANAL (AUWAI) Completes renovation of pond to historical condition. Allows culture of freshwater animals.

Figure 2



PLAN OF HE'EIA FISHPOND ABOUT 1930. M = makahā K = hale kia'i



DRAWING OF TYPICAL MAKAHĀ AREA IN FISHPOND WALL

4.2 TECHNICAL CHARACTERISTICS

The technical characteristics of this operation fall broadly into two categories; Pond Restoration and Aquaculture Facilities Development.

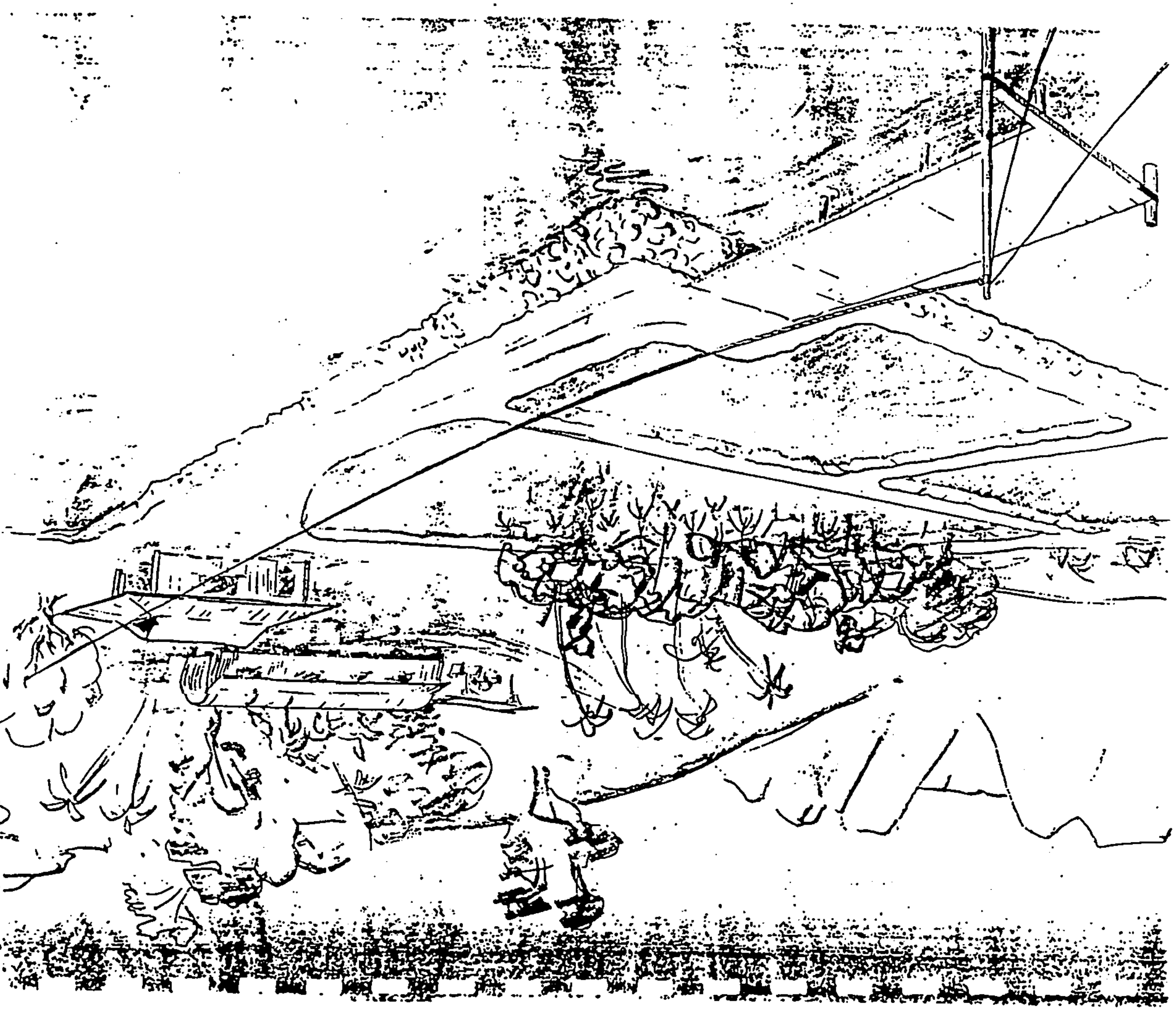
4.2.1. Pond Restoration and Historic Site Preservation

Significant repair of the working part of the pond wall must take place before aquaculture activity can occur. Pond restoration will occur in successive phases. The wall restoration technique is described in Appendix III. Restoration activities fall within guidelines set during discussions with personnel at the State of Hawaii Historic Site Preservation Office.

The existing Hawaiian-built makai wall is a double rock wall, approximately 3 meters wide at the top. The rock used in the original construction is of moss rock and blue rock. The source of these rocks is unknown. The space between the rock wall exteriors is filled with sand, coral, coral rubble, dirt, rock and gravel. At least during this century, interior wall height was maintained by routine replacement of sloughed wall fill material from the substrate adjacent to both sides of the wall. Gates and Makahas were re-constructed in the 1930's through the 1950's using cemented rocks. Some examples of cut blue-stone still remain. The mauka river wall is primarily earth with some rock lining and cement reinforcement. It was rebuilt after flood occurrences at least several times during this century.

Over twenty sections of the wall in need of repair are noted in Appendix III Figure 1. The proposed method of reconstruction of the areas where the wall has been completely destroyed is shown in Appendix III Figure 3. Funding to support the repair and reconstruction of the pond is intended to come from income produced by the utilization of the pond for aquaculture and/or from possible historical preservation funds or legislative grants. The initial wall repair will be of cement cylinders (12"x6" Diameter, 30 pounds each). These initial walls will later be faced with rock and filled to match the original adjacent walls. Interiors of the repaired wall sections will be filled with materials sloughed from the original and existing wall. The top of the wall above the cylinders will eventually be covered with 10-15 centimeters of crushed coral gravel. Therefore all repaired sections will eventually be of similar exterior material and appearance and (except in the main makai break) of the same alignment with existing walls.

Figure 3



The great depth of the tidally scoured channel in the main makai break eliminates the economic feasiblity of repairing the area in its original position in the initial stages. Instead, the wall will be built from break to break aligned inside the pond where the water is shallower.

Fill material for the wall will be obtained by the following methods. Fill volume calculations are shown in Section 4.2.1.2. of this application.

1) Trucked aggregate from Kailua quarry, or other clean (non-toxic) economically available materials.

2) Pond bottom materials adjacent to wall by manual shoveling, pumping, a bulldozer, backhoe, or crane.

These fill materials are, for the most part, erosional sloughings from the original wall.

4.2.1.1. PHASE I (1-2 Years)

The goal of initial repairs will be make the pond at least minimally functional for aquaculture. Any repairs to the wall will be documented with before, during and after photographs. To allow for initial aquaculture efforts and testing, the first phase will make repairs to the pond wall with cylinders to achieve the maintenance of a minimal tidal water level within the pond. Pond restoration in Phase I may be divided into three activities;

a) Repair water gates and severely broken wall sections

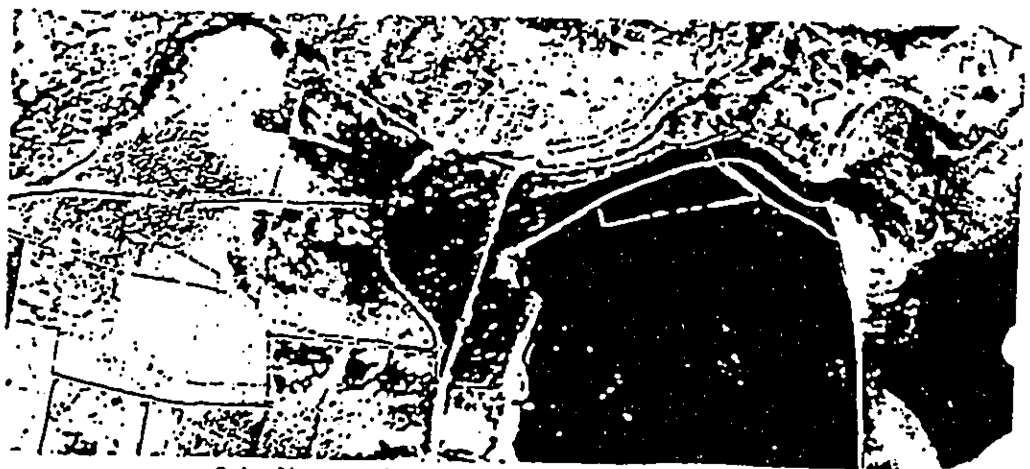
b) Create broodstock/nursery enclosures

c) Control vegetative growth on walls

a) The eight water gates (Makaha's) will be made functional by cleaning and minimal repair. Cement cylinders and recovered fallen rock will be used to restore walls and to partially repair existing breaks in the pond wall. In addition to the main break in the makai wall, there are two primary breaks in the river-side (mauka) pond wall (each about 50 meters long) and several smaller ones which need repair. Because of the depth of the channel scoured in the primary makai wall breach, the cylinder placement will be in shallow water arching towards the inside of the pond, adjacent to the deeply scoured (2 meter deep) channel (Appendix III Figure 2). This wall will be built to a height of about 1 meter above the substrate and is designed to hold back an additional 50+ centimeters (cm) of water at mean low tide (Appendix III Figure 3). Less water retention would not allow for successful aquaculture.

Figure 4

In 1928, mangrove was present but not abundant enough to be seen in this aerial view. Rice was being grown in the terraces at left.



Only 21 years later, mangrove had spread to occupy the area at center (dark vegetation). It was growing on both sides of the Heeia viaduct and seaward into the Heeia Stream channel.

This aerial shot illustrates additional spread of mangrove by 1971, when it had further choked the Heeia Stream channel and advanced inland. It was growing along the north wall of Heeia Fishpond and on an islet in the pond formed by the 1965 flood. Today mangrove has established itself along almost the entire [illegible] of the fishpond.

c) General repair of the perimeter wall and removal of harmful vegetation is necessary to control further damage to the wall structure. Along the visible seaward portion of the pond wall, destructive vegetation, primarily hale-koa, Christmas berry, akulikuli and some mangrove will be removed. Displaced wall rocks will be reset by hand. All clearing will be done by hand.

The mauka wall of the pond (north to south-east) has been densely overgrown, primarily by mangrove and Hau tree (Appendix III, Figure 5). Figure 4 shows the progression of mangrove growth since 1928. Hau and mangrove trees currently tower up to 10 meters above the existing wall and extend as much as 50 meters into the pond along some sections (figure 10, and Appendix III, Figure 5). We would like to maintain this forest as much as possible. However, to properly manage the pond, access will be made to the mauka wall buried within the forest, primarily to those areas where access is necessary for wall repair.

Observations indicate that a cleared zone through the foliage around the wall and auwai leaving as much of the canopy as possible intact may not substantially alter the character of the forest area, but will allow access along the wall. The percentage of forest coverage will not be substantially diminished by this limited clearing because, in most cases, the clearing will not reach the canopy. Areas requiring limited clearing correspond to sections of broken wall near Makaha #8 and the "Historic Caretaker's Home Site" indicated in Appendix III, Figure 1.

4.2.1.2. PHASE II (3-6 Years)

The second phase will involve the reconstruction of damaged portions of the entire full perimeter original wall using displaced wall rocks for repairs, and the cement cylinder, fill, and rock face technique described in Appendix III. The core wall will be faced with gravel and rock and topped with coral gravel to match the existing wall. This phase will include a complete overhaul of the Makaha and gate system including those located in the forest on mauka wall that control fresh water intake to the pond. Based on assessment of initial clearing, further vegetation clearing along the wall may occur at this time. All repairs will be documented with before, during and after photographs.

4.2.2. Aquaculture facilities development.

4.2.2.1 PHASE I

Phase one will initiate aquaculture efforts through tilapia broodstock and nursery care within enclosures (Appendix III, Figure 4), cage culture of tilapia, algae culture, and harvest of species of opportunity within the pond. Tilapia is currently the dominate species within the pond and has been chosen for early culture due to its tolerance of wide ranging water conditions.

a) Nursery pond enclosures will be constructed. These enclosures are of a similar magnitude (1/10 acre to 2 acres) as used by the Hawaiians. Each enclosure will be connected to the pond by one or more gates for water exchange.

b) Fish cages and pens will be constructed and placed in the main body of the pond during Phase I. Cages, each measuring approximately 4x8x2 feet will be constructed of PVC coated wire mesh or similar material. Some will float, extending approximately 5 cm. above the surface, and be anchored to the substrate (See Appendix II, Figure 1). These cages constitute the primary growout container for tilapia. Mullet and awa will be stocked in larger pens. These pens will probably have an area of 500 to 1000 square feet and consist of plastic coated fencing material fixed to the pond bottom. Demand feeders will be employed above most cages and pens. There may be some research and development activity utilizing round pens to culture moi in conjunction with local, professional, research organizations.

c) Algae, primarily of the genera <u>Gracilaria</u>, has constituted a viable aquaculture crop in Hawaii. Although there has been only limited success growing algae under minimally controlled pond conditions, we will be developing this crop. Algae culture techniques that may be tried include:

* net or string culture where the algae is fixed to the twine suspended above the substrate,
* batch culture, where the algae is enclosed in cages or on raised beds,
* enclosed pen plots,
* open pond culture; promotion of algae growth by transplant and predator control on the pond bottom substrate, or raised beds.

Pond Catch by Species
Fiscal Year 1987

Division of Aquatic Resources

Species	Lbs. Landed	Lbs. Sold	Value
Omilu	1,108	1,108	$ 1,214.45
Ulua	287	277	627.51
Aholehole	1,548	1,548	3,782.72
Amaama	2,613	2,420	7,831.65
Awa	262	255	375.22
Awaawa	39	39	32.00
Kaku	392	341	1,046.92
Oio	6,166	6,072	6,665.91
Pualu	2,032	2,032	1,977.40
Summer Mullet	178	178	497.60
Toau	194	194	696.36
Tilapia	2,045	2,045	6,845.07
Crab (Moala)	10	—	—
Crab (Samoan)	65	26	119.20
Crab (White)	132	—	—
Misc.	14,885	14,885	35,416.87
TOTAL	31,956	31,420	$67,128.88

TABLE 1. AVERAGE ABUNDANCE OF COMMONEST REEF FISH SPECIES IN KANEOHE BAY

Species	Mean Abundance, Measured as Number of Fish per Station				
	Lagoon Reef Flat	Patch Reef Flat	Fringing Reef Flat	Barrier Reef Flat	Fore Reef
Pranesus insularum	0.0	10.7	0.0	0.0	0.0
Mulloidichthys samoensis	0.0	0.0	0.8	2.1	0.7
Paraupeneus porphyreus	0.3	0.0	<0.1	0.1	0.0
Chaetodon miliaris	1.0	1.1	0.4	0.5	0.3
Dascyllus albisella	6.0	3.9	1.0	1.4	6.4
Abudefduf abdominalis	7.8	0.1	1.9	0.7	10.2
Pomacentrus jenkinsi	0.2	1.1	<0.1	0.2	0.3
Chromis ovalis	0.2	0.0	0.0	0.0	22.1
Labroides phthirophagus	0.5	0.4	0.1	0.0	0.0
Stethojulis axillaris	0.7	0.1	1.6	5.5	4.2
Thalassoma duperreyi	4.3	7.5	1.1	2.1	2.1
Gomphosus varius	0.7	1.8	0.2	0.1	0.0
Scarus spp	73.2	11.1	24.3	18.0	1.4
Acanthurus triostegus	2.4	0.1	2.1	8.2	4.8
A. dussumieri	3.0	0.0	0.0	<0.1	2.2
Ctenochaetus strigosus	1.0	0.4	0.3	0.0	0.6
Zebrasoma flavescens	1.6	2.5	<0.1	<0.1	0.2
Psilogobius mainlandi	-	-	+	-	-

d) Harvest of species of opportunity within the pond may constitute an important portion of the aquaculture effort. Figure 5A lists species currently harvested from similar Hawaiian fish ponds. Traditional harvests at Heeia include Tako, Aholehole, Lai, Ohua, Amae, Moi, Nehu, Kala, and Akule. Figure 5 shows relative abundance of reef fish species likely to frequent the pond's exterior margin fringing reef flat. It is anticipated that once the pond is partially enclosed (Phase I) production rates will increase due to feed input and nutrient enrichment associated with the caged fish production. Species of opportunity are harvested with traditional fishing techniques including Makaha harvest, gill net, seine net, traps, or hook and line. Open pond stocking will not be attempted during this phase because crop escape and predator would not yet under management control.

e) To facilitate operation within the pond it is necessary to relocate the existing 5 meter long dock structure to water deep enough to float a shallow draft boat at a '0.0' tide level. Plans for this floating dock structure are shown in Appendix I, and Appendix III, Figure 4.

4.2.2.2. PHASE II

Aquaculture facilities development in PHASE II will focus on increasing the number of tilapia cages under culture, open pond stocking, and improving upon other species (algae, mullet, moi, awa, baitfish, etc.) which are found to be of promise during PHASE ONE operations. During PHASE II the magnitude of the operation should be large enough to warrant the construction of an aquaculture support building. This building will provide space for feed, net and material storage, office, lab, hatchery, shop, ect..

4.3 ECONOMIC CHARACTERISTICS

The primary goal of this project is to create an economically viable and profitable aquaculture farm. This level of productivity will be attained through local whole sale and possible export sales. There is no intent to sell product at the retail level or to provide for on-site sales.

This project is of economic importance to the State for several reasons. When it is successful, the Heeia aquafarm will serve as a model for the development of some of the 70 remaining fishponds in Hawaii, at a great benefit for the State's diversified economy. Most of these ponds have remained fallow for over 50 years, a great loss of opportunity. Success of the project will preclude the development of this, or other fishpond sites for alternate, less desirable, activities.

4.4 SOCIAL CHARACTERISTICS

An important goal of this project is to develop the site in a socially and culturally responsible manner. The Heeia site is one of great cultural and historical significance. These qualities need not only to be preserved, but brought more to the surface of awareness of the community through future educational programs. Attainment of this goal will help to preserve the cultural traditions and values of Hawaii's traditional social system. The establishment of the Heeia aquafarm will preserve the beauty of this site rather than allowing it to be overcome by the mangrove swamp or developed for other uses. Of the 30 fish ponds that once lined Kaneohe Bay's shore, 23 have either been filled in or destroyed, 6 lay idle, and only one is being utilized for it's historic purpose of raising fish.

4.5 ENVIRONMENTAL CHARACTERISTICS

This project is dependent for success upon the unique environmental characteristics recognized by the Hawaiians when they chose and developed this pond site hundreds of years ago. The 88 acres of enclosed pond is situated on a pre-historic fringing reef flat juxtaposed between a fresh water stream and the salt waters of Kaneohe Bay. Photographs of the area are attached as Appendix VII. The site encompases and is adjacent to several distinct ecosystems including;

* Hau tree forest
* Mangrove swamp estuary
* Stream ecosystem
* Grass marsh
* Mud flat
* Tropical coral reef

The dynamic interplay at the salt and fresh water interface is the key factor responsible for some of the most complex and prolific ecosystems around the world. The Heeia pond, if properly managed, should be able to take advantage of this euryhaline environment to produce significant aquaculture crops. However, the productivity of the pond will always be dependent upon the health of the surrounding environment and the quality of the fresh and marine waters which are the major inputs to the system. Every measure will be taken to insure that the project itself does not adversely modify the surrounding environment upon which the project depends for long term success. Company management has had years of extensive training and practical application in water quality monitoring and management.

Sea food production in Hawaiian ponds such as Heeia is among the most environmentally sound agriculture methods in the world. Because Hawaiian fishponds rely on natural tidal energy to pump vast quantities of water through the ponds this reduces dependence on and pollution from fossil fuel derived energies.

5.0 Summary Description Of The Affected Environment, Including Suitable And Adequate Location And Site Maps

The Heeia fishpond encloses 88 acres of prehistoric reef-flat at the mouth of the Heeia/Haiku/Ioleka stream in the central section of Kaneohe Bay, Oahu. The environment of the pond can be best understood by analyzing it in context of the surrounding watershed and adjacent Kaneohe Bay waters.

5.1 KANEOHE BAY

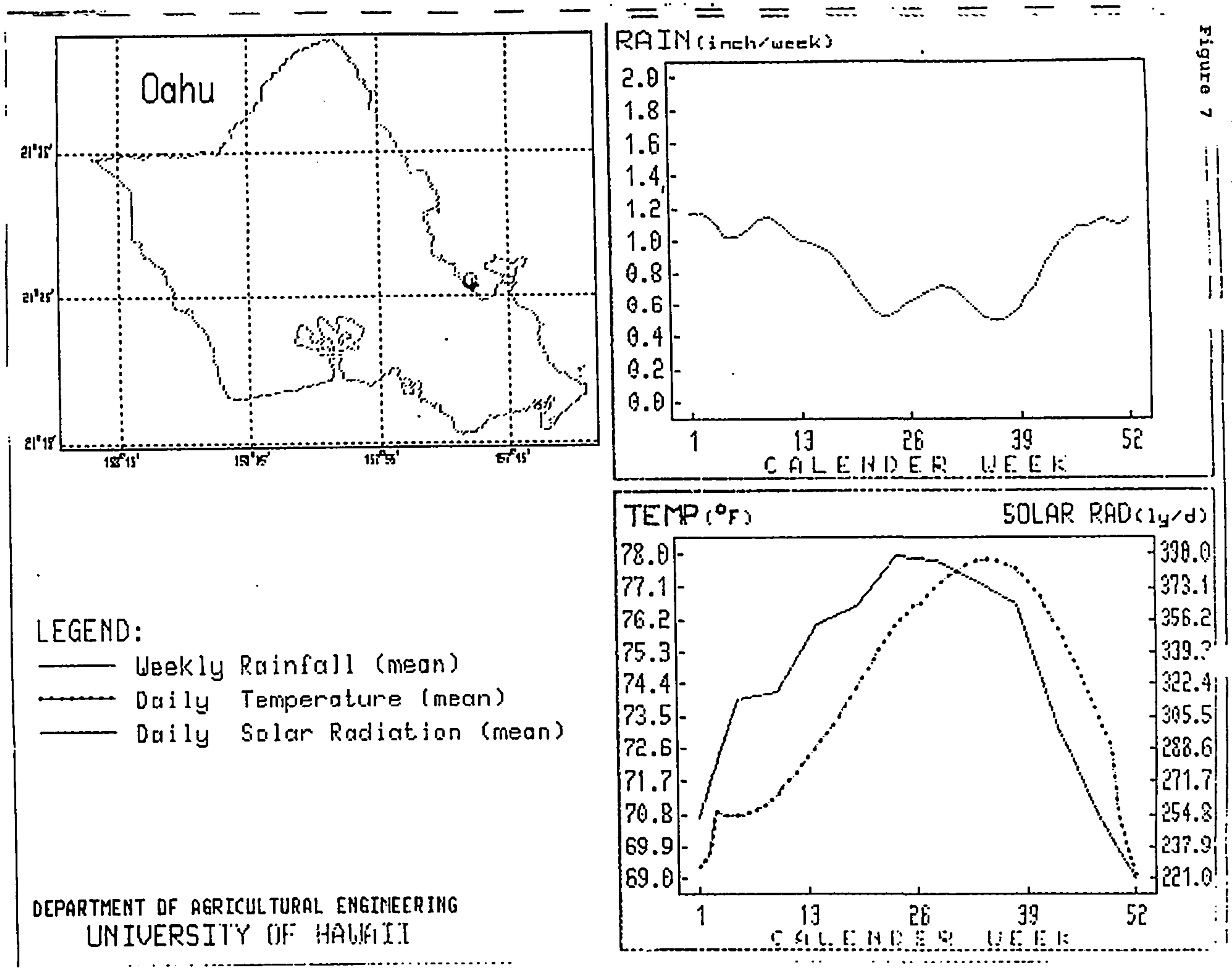
5.1.1 General

Hawaii's geographic isolation, relatively small land mass, and its position at the boarder of tropical/sub-tropical waters limits our marine species diversity and standing biomass. The nearshore ecosystem of windward Oahu's waters are characterized by a moderate species diversity, overall low biomass and rapid nutrient recycling. Kaneohe Bay is a partially enclosed embayment on the northeast coast of Oahu, Hawaii, and fully exposed to the onshore tradewinds. The general weather characteristics of the area are given in the table below and in Figures 7 and 8.

CLIMATOLOGY

	BAY	OCEAN
RELATIVE HUMIDITY	62.2%	77%
AIR TEMPERATURE	25.6° (18-29)	24.2°
WATER TEMP. (summer)	26°	25°
WIND VELOCITY	8.7 Kts	14.9
WIND DIRECTION	350-190°	
%CLOUD COVER	55%	49%
RAINFALL	2400 mm/yr	
INCIDENT SOLAR RAD.	300-500 ly/da	
EVAPORATION	1700 mm/yr	
MEAN TIDE RANGE	62.6 cm.	
MAX. TIDE RANGE	112 cm.	

Figure 7


Oahu
21°35'
21°25'
21°15'
158°15'
158°05'
157°55'
157°45'
RAIN (inch/week)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1
13
26
39
52
CALENDER WEEK
TEMP (°F)
SOLAR RAD (ly/d)
78.0
77.1
76.2
75.3
74.4
73.5
72.6
71.7
70.8
69.9
69.0
390.0
373.1
356.2
322.4
305.5
288.6
271.7
254.8
237.9
221.0
1
13
26
39
52
CALENDER WEEK
LEGEND:
Weekly Rainfall (mean)
Daily Temperature (mean)
Daily Solar Radiation (mean)
DEPARTMENT OF AGRICULTURAL ENGINEERING
UNIVERSITY OF HAWAII

.igure 8

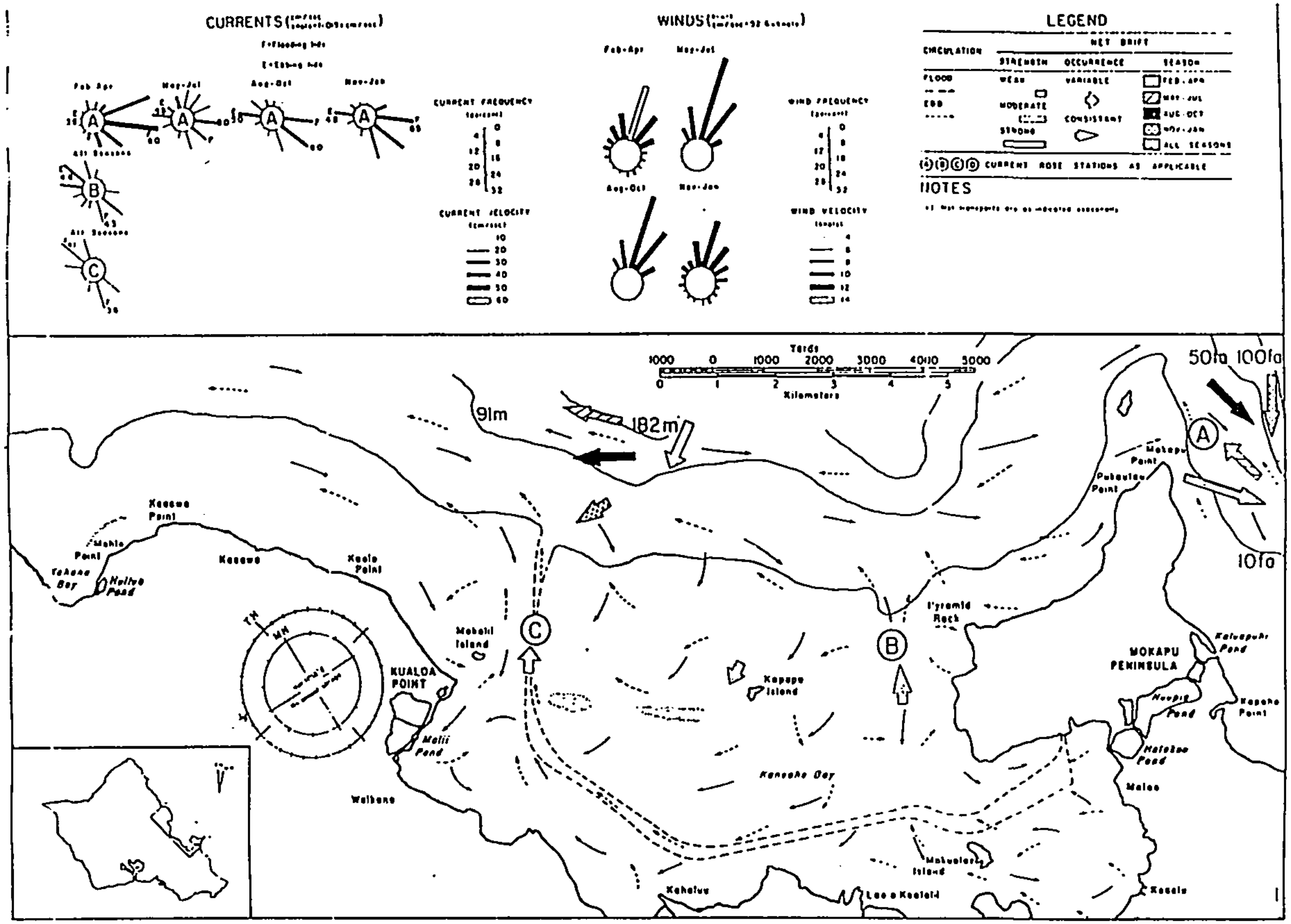


Figure 8. K-B Sector, Kualoa Point to Mokapu Peninsula

Kaneohe Bay stretches about 12.5 kilometers along the coast of windward Oahu from Kualoa Point to Mokapu Peninsula although the inner maximum length of the bay approaches 18 kilometers. The breadth of the bay from the barrier reef to Heeia is about 4 Km. The total surface area at mean sea level (MSL) is 31 KM2 (11,360 acres). the total volume of the bay is 266,000,000 M^3. The floor of the bay is generally deep (>10 M) lagoon (46% of area) or shallow reef flat or shoal (33% of area), with relatively little of the bay at intermittent depths. While the mouth of the bay is wide, two-thirds of its length is restricted by an extensive barrier reef of sand, shoal reef and coral rubble.

The entire bay is classified as a weakly developed estuary with terrestrial influences of freshwater, sediment and nutrients. It is the largest estuary in the State of Hawaii. Both estuarine and coral reef environments are found within the bay's boundaries, locations for these diverging ecosystems being primarily a function of water circulation patterns and their proximity to terrestrial inputs. Two general areas are evident (1) the offshore coral/sand reef ecosystem has a predominantly marine influence (34% of total area, average depth 1.8 M), and (2) the inshore lagoon (66% of total area, average depth 16 M).

Currents within the bay are affected by the tides, wind, proximity to ocean channels and bottom topography. Currents in the South Bay are generally circular, clockwise, forming a relatively stable water-cell with slow exchange rates. This gyre often affects current direction in the south part of the central bay near Heeia pond, tending to push the shoreside current north westerly. The ten patch reefs extending out from the Heeia peninsula towards Coconut Island tend to break up any deep strong currents in the area. Surface currents are usually wind generated by tradewinds from the north west. A summary of current direction is shown for incoming and outgoing tides in Figure 8.

Kaneohe Bay has been subjected to widely fluctuating environmental impacts from both nature and man during the past century. Man has been responsible for introducing large amounts of nutrients to the bay through construction, agriculture erosional run-off, dredging and sewage disposal. The last major sugar cane field in the bay's watershed ceased operations shortly after the sewage was diverted from the bay in 1977. The sewer outfall was extended from the inner bay to several miles off shore into deep oceanic water. The recovery of the bay has been superbly documented primarily through the efforts of the Hawaii Institute of Marine Biology (HIMB) (Pacific Science 35(4): Oct. 1981).

One of the most destructive (but "natural") elements changing the character of the Bay's living reefs has been fresh water floods and resultant siltation. The majority of coral reef animals can not survive long in water of reduced salinity or high inorganic turbidity. During major storms the runoff into the bay is sufficient to form a layer of lethal fresh water several feet thick over the reefs. Even during minor storms, the silt carried from the streams can coat the corals and other invertebrates, blocking out their life-giving light or physically smothering them under a mud blanket.

5.1.2 INNER BAY

This inshore section is typified by a deep muddy floor interspersed with isolated irregular coral patch reefs rising abruptly to within 1 meter of the surface. The lagoon floor consists of grey mud, coral rubble, and fine coral sand. The proportion of non-calcareous material in the lagoon sediments increases with proximity to the shore where basalt mineral clays with higher organic content predominate as a consequence of land erosion sediments.

The inner bay is classified into three contiguous yet distinct bathymetric sections (Figure 9); the southeast (southbay) basin, the northwest (northbay) section and the central area. The south basin is surrounded on three sides by land with a high population density and is moderately isolated hydrographically due to a fairly persistent counter-clockwise eddy. The central and north-west sectors are considered somewhat as a transition zone between the outer barrier reef/oceanic conditions, and the south basin. The north basin has the largest channel to the open sea, the greatest tidal exchange volume, a large number of patch reefs, and the largest number (7) of major streams inputting fresh water. The south bay has the least exchange with the open sea, is fairly deep with few patch reefs, and has three major streams inputting freshwater and nutrients.

The more than 50 KM of shoreline boundary of the bay is typified by a fringing reef flat which may extend outward several hundred yards from the shore. While the steep face of these fringing reefs is usually lush with coral reef ecosystem growth, the landward reef flat often resembles a mud-flat ecosystem with encroaching mangroves at the shore line. Estuarine conditions are strong within these areas. The ratio of fresh to salt water at stream mouth areas show considerable seasonal variation. The inner-bay fringing reefs have a prominent component of land-derived mud, sand and rubble, with a higher standing crop of algae.

The reef flat area of the bay was the site of the more than 30 active fish ponds whose walls accounted for 30% of the total shoreline. Only seven of the fishponds are still in existence, and only 1 is in production. The remaining 6 inactive ponds (including

Figure 9

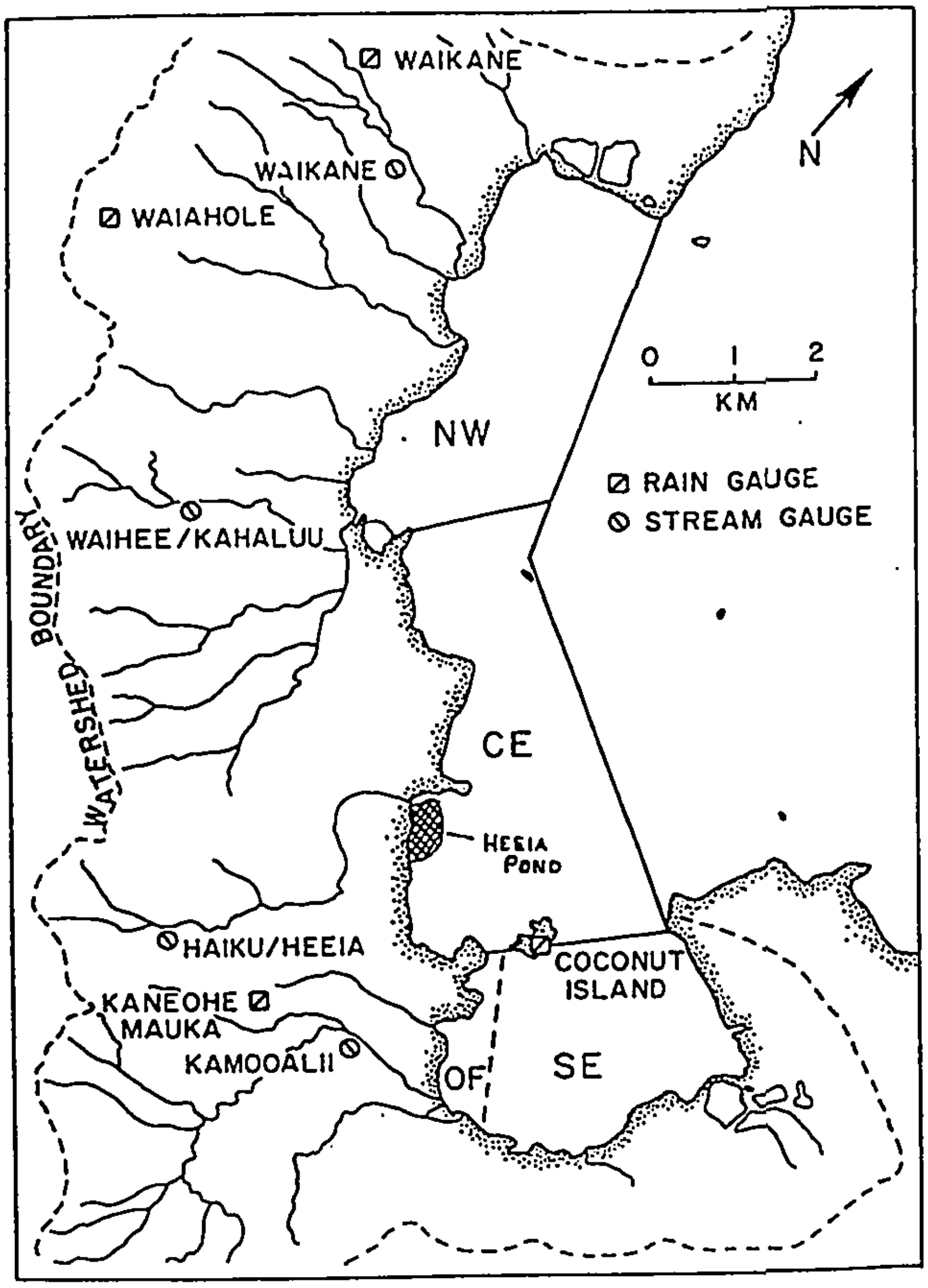


FIGURE 9. Map of Kaneohe Bay, watershed boundary, and stream and rain-gauge stations used in this investigation.

Heeia) have undergone various degrees of physical structural degradation and are often clogged with the thick, fine brown silt and clay deposits from the streams entering the bay.

5.1.3 MID BAY

The Mid Bay, in which Heeia lies, has moderate exchange rate with the ocean, numerous patch reefs, and only one principal stream (Heeia). The Mid Bay extends from Coconut Island (Moku O loe Island) and the Sampan Channel at the South to Kahaluu in the north. the waters of the central bay are classified under the Water Quality Standards of the State of Hawaii as Class AA. Most shoreline waters and margins are designated Class A and the few small harbors are designated Class B.

Patch reefs and intervening deep channels abound in the mid bay region. The channel area just off the Heeia pond shoaled about 1.5 meters between measurements taken in 1927 and 1976, possibly the result of dumping of reef dredging matgerial during the 1940's. Many of the reefs in this area have been extensively studied by researchers at the Hawaii Institute of Marine Biology.

5.1.4 HEEIA FRINGING REEF

Studies on the reef fronting Heeia fishpond (1979 Kaneohe Bay Coral Reef Inventory) have shown that this is an area of transition. Southeast of the pond, coral covers less than 10% of the upper slope of the reef face. The majority of the benthic biomass at the time of the above study was made up of tunicates, sponges, soft corals, and algae (primarily Dictyosphaeria cavernosa). This biofauna mix is indicative of high nutrient water. North of the break in the pond wall corals are more abundant (20-30% cover) and the filter-feeders that characterize the South Bay are less abundant.

Corals are the primary reef building organisms. Porites lobata is the dominant coral north of the break with Porites compressa and Tubastrea aurea also occurring on the slopes and Montipora verrucosa common on the upper flat reef within 10 meters of the slope. coral cover on the patch reef just off Heeia and on adjoining reefs north of Heeia ranges from 20-75% in the upper 2-3 meters. Corals seldom occur deeper than 4-5 meters on the sandy talus slope because of the silt and lower ambient light.

Algae are also plentiful on the shallow reefs, reef flats, and mud flats, although the absolute population levels vary considerably with seasonal, monthly, and/or weather generated fluctuations being the rule rather than the exception. Algae common on the reef flats include Acanthophora spicifera and Eucheuma (both introduced as a possible aquaculture species), Dictyosphaeria cavernosa, Dityota, Padina, Gracilaria, and Amansia. The level of Dictyosphaeria cavernosa currently (1990) on the reefs fronting Heeia appears qualitatively to be lower than that reported in the 1979 Kaneohe Bay Reef Inventory report.

The most common species of reef fish off the Heeia reefs (1979, Kaneohe Bay Reef Inventory) were Abudefduf abdominalis, Chaetodon miliaris, C. trifasciatus, Thalassoma duperreyi, Acanthurus triostegus, A. dussemieri, and juvenile parrot fishes of several species. Juvenile hammerhead sharks are also abundant in the deeper areas. Recent qualitative observations by skin diving confirm that these species are still dominant.

Bay waters offshore of Heeia are classified pursuant to Chapter 54 of Title 13, Water Quality Standards for marine waters as Class AA.

> "It is the objective of this class that these waters remain in their pristine state as nearly as possible with an absolute minimum of pollution or alteration of water quality from any human-caused source or actions. Uses to be protected in this class of waters are activities such as oceanographic research, aquaculture, conservation of coral reefs and wilderness, and compatible recreation."

5.2 WATERSHED

The lands adjacent to the Heeia fishpond include;

* Heeia Stream bank which borders the Heeia State Park.
* Low-lying mangrove forest floodplain, and
* Sand/mud flat beach,
* Residential area of approximately 37 single family dwellings,
* 45 meter wide 600 meter long Hau tree slope forming a buffer between the pond and a residential district.

5.2.1 HEEIA STREAM AND WATERSHED

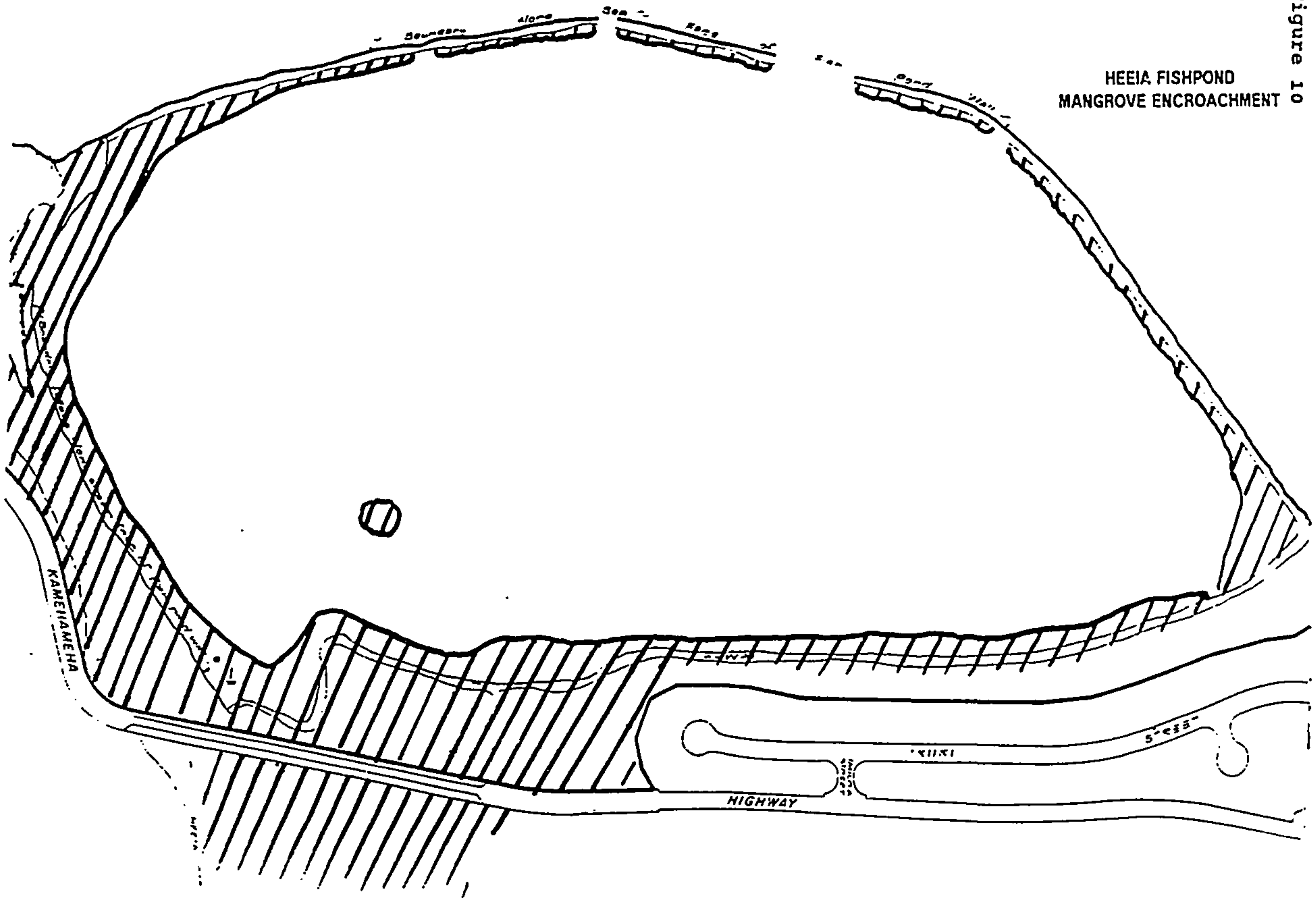
The watershed adjacent to Kaneohe Bay covers about 97 KM^2, or about three times that of the bay area. The landward boundary of the watershed is set by the almost vertical slopes of the Koolau Mountain range, rising abruptly from 250M to the 800M ridgeline. Most of the watershed consists of rolling hills at elevations of 5-250 M. The Haiku/Heeia stream is the only major stream entering the central section of the bay. The stream's watershed covers approximately 13 KM^2 and accounts for 15-20% of the total freshwater runoff into the bay. The construction in 1940 of the Haiku tunnel caused a 50% decrease in the flow of Iolekaa Stream which is a tributary of Heeia. Overall diversion of stream water for agriculture and other uses has resulted in a 40% decrease of freshwater inputs to the bay. During moderate to heavy rain (>1cm/day) the southeast Kaneohe Bay basin and the northwest portions of the bay receive the greatest portion of total runoff.

Although the bulk of the 13 KM^2 drained by Heeia Stream is lowland swamp, agriculture, or upland watershed, there is a significant portion which emanates from residential and commercial districts. Heeia stream is given an ecological rating of II: moderate to high quality water or natural values. Stream flow rate is highly dependent upon season. Extremely high flow rates are common during periods of heavy rainfall. At these times there is a very heavy sediment load from erosion (often dependent upon construction or agriculture activities) which colors the pond and bay waters dark red-brown. During a heavy runoff in 1965, the stream flooded Heeia pond, breaking its river wall and creating a 50 M break in the makai wall. since this time the stream has freely flowed through the pond, which has acted as an additional settling basin for watershed sediment. Shoreline, pond and bay water remains a bright brown-red for one to three days following heavy rainfall. On-shore winds and parallel shore currents force the sediments against the shore and keep it in suspension. The low salinity of the runoff, its high nutrient and sediment load and its low temperature, serve to laterally and vertically stratify these waters from the deeper, more oceanic waters of the bay for extended periods.

Heeia Stream has rapidly become overgrown with mangrove. The stream which previously flowed next to the fishpond helped to create an environmentally diverse estuary. This stream historically was used inland for agricultural purposes in the terraced wetlands. Maintenance of the stream channel in a open and flowing natural condition is essential to regulation of both the wetlands and Heeia pond. Correspondence attached in Appendix IV addresses regulatory and legislative issues regarding jurisdiction of Heeia Stream flow from the long bridge to the stream mouth. This portion of the stream's open flow is the most essential for Heeia pond's operability, flood protection, wall integrity and long term existence. Mangroves restrict stream flow and increase shoaling through silt deposition. These tendencies can increase the water level of the Heeia wetlands altering the habitat characteristics of the ecosystem. The original, historical design of the fishpond included the stream's three gates to control salinity, depth, nutrient level and fish behavior within the pond.

Figure 10

HEEIA FISHPOND
MANGROVE ENCROACHMENT



Pond wall repairs and pond operations will be subject to natural disaster (flooding, wall collapse, crop loss) as long as the stream can not follow it's natural bed along the edge of the pond to the historical stream mouth. Certain repairs in Phase II and most of the Phase III repairs should not be attempted until the stream channel issue is resolved.

5.2.2 MANGROVE SWAMP FLOODPLAIN

The large freshwater marsh and mangrove swamp bordering the north and west sides of Heeia pond function as an efficient trap for nutrients and sediments from Heeia stream. Saltwater intrusion into the swamp is confined to the makai side of Kamehameha Highway, and a short distance in the main stream bed above the highway bridge. Historically there was a man-made island and two gates at the stream mouth to prevent saltwater intrusion into the stream tidal area. The dominant species in the swamp is the Red mangrove, Rhizophora mangle, first introduced to the area about 1910. Two other species, Bruguiera sexangula and B. gymorhiza also are present. The mangrove swamp and freshwater marsh of Heeia Stream provide habitat for several endangered species including Hawaiian coot, gallinule, and several other water birds. California grass (Brachiaria mutica) and Honohono (Commelina diffusa) cover the marshland upstream from the mangroves. The mangrove cover the marshland upstream from the mangroves. The mangrove extend about 400 M upstream into Heeia meadows and 5-15 M into the pond itself over the makai wall in the west side of the pond. The extent of mangrove intrusion can be seen in the series of photographs in figure 10 (1928, '48, '71) and Figure 1 (1989), and in the color photographs of Appendix VII.

5.2.3 SAND/MUDFLAT BEACH

Interaction between the Southern Heeia Pond wall and the prevailing trade wind driven currents has created a small sand/mudflat beach where the pond wall joins the shoreline. The reef flat is a mixture of mud, sand and rubble near shore, grading to a more sandy base strewn with coral boulders and rubble nearer the low water mark. There is abundant algae growth in the tidal area, primarily Gracilaria, and many bird tracks at low tide indicating an abundant mud dwelling invertebrate population.

5.2.4 RESIDENTIAL AREA

There are two residential areas adjacent to the pond. The newest subdivision at the south end of the pond, Alii Landing, faces the sand/mud beach described above. There are 9 units recently constructed only one of which has a common boarder with the Heeia property. One additional lot within the condominimum land area also adjoins Heeia Pond property, but there is no

Figure 11

a. Looking southeast from above the northwest walls, c. 1915. (R. J. Baker, photog., BPBM Coll.)

b. Looking toward Mokapu, c. 1920. Notice wide stream, bridge, and internal pond for fry. (C. S. Judd, Jr. coll.)

Fig. LATER PHOTOS OF NORTHWEST PORTION OF HEEIA FISHPOND.

construction currently on this lot. All of the units overlook the bay across the beach, towards Makapu peninsula, and two have additional views overlooking the Heeia pond.

The second residential area, Alii Bluffs, consists of 27 homes on the bluff above the southwestern border of the pond and buffered from the pond by about 10 meters of clearing, 40 meters of mature Hau forest, and 10-15 meters of mature mangrove forest (see Appendix III, Figure 5). These homes overlook portions of the pond and beyond to the entire bay and barrier reef.

5.2.5 HAU TREE FOREST

The Hau tree forest has grown from the banks of the pond, covering the pond wall, auwai (fresh water channel mauka of wall) and up the slope to the Alii bluffs residential area. Hau is considered by some to be a noxious weed. This is the area in which we propose to clear at the water line, leaving the canopy where ever possible. In some cases the Hau extends up to the property line but more often it has been kept cleared up to 15 meters from the boundary. The Hau forest is about 45 meters wide, 600 meters long, 6-9 meters tall, and extremely dense. The auwai forms a fresh water holding basin behind the pond wall under the Hau (see Appendix III, figure 6). Fallen leaves and other vegetative matter on the floor of the forest are rarely dried out due to the thick canopy of leaves. This forms habitat for mosquitos and other insects which in turn may act as feed for juvenile fish in the adjacent mangrove fishpond area.

5.3 THE RESOURCE: HEEIA POND

The Heeia pond was made by building a wall on a coral reef flat. Called a "loko kuapa", unique to Hawaii, it was the type of pond built between the 15th and early 19th century by communal labor for kings and chiefs. Historically, the pond was used to raise mullet and milkfish which were captured in the double gates (makaha's) along the wall. The pond has many unique and positive features which distinguish it and contribute to its value both as a seafarm and a cultural treasure. It is sheltered by the reefs outside of the Bay. It is located at the mouth of a stream originating in the conservation mountain districts of the Koolau range. In addition, these waters are natural attractants for the fry of many commercially available fish species. The 3 meter wide wall was faced inside and out with basalt rock, filled with coral and "cemented" with coraline algae. A main water control gate allowed control of the pond's water level.

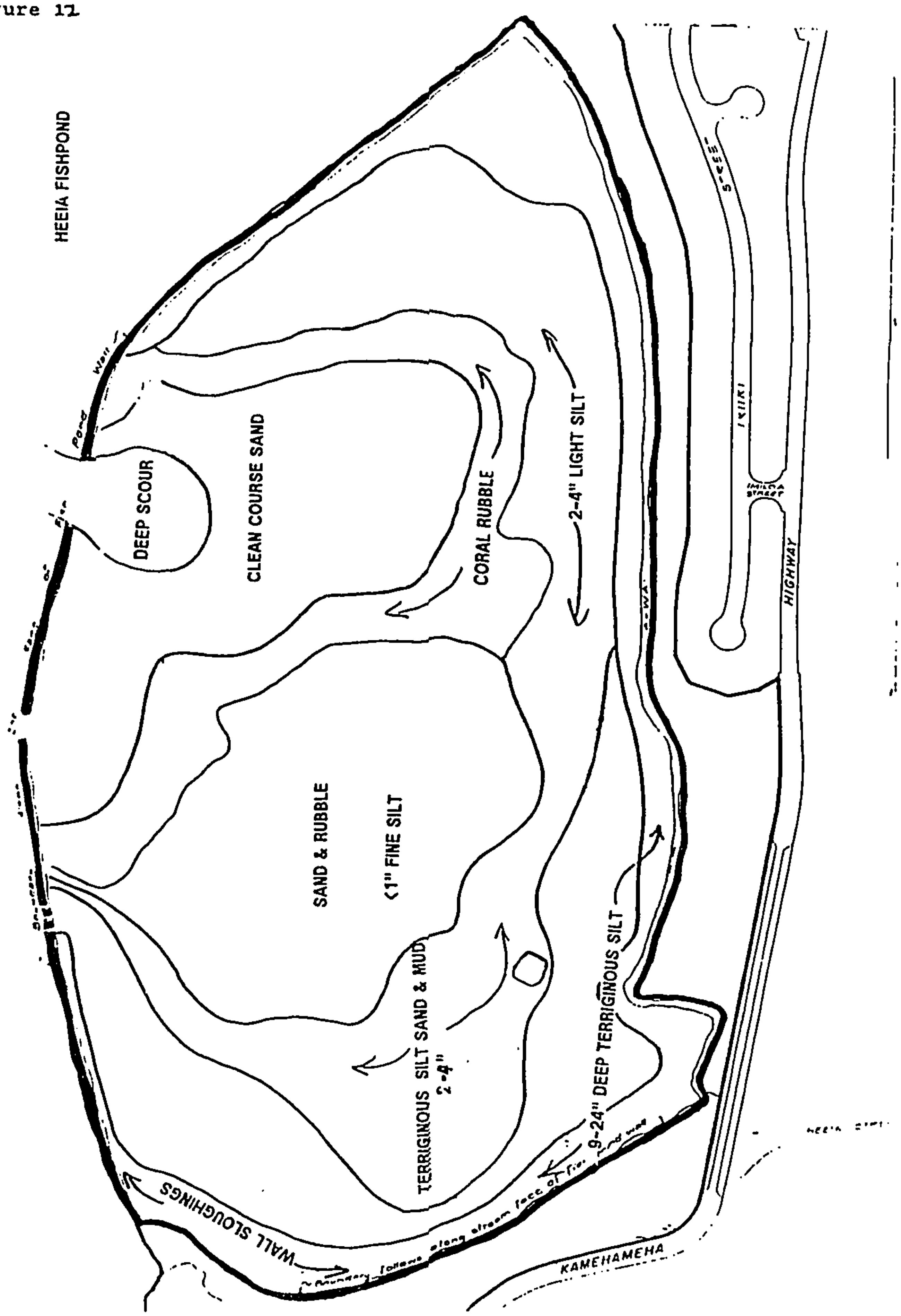
The pond area is 88 acres and is one of the very few built with a wall around its total perimeter, 7650 feet long. The main wall along the bay front (makai) is 3,500 feet long. A section of this wall 130 feet long was broken by the May 1965 Keapuka Flood. This break has brought the fishpond under the uncontrolable outside influence of ocean tides. Thus, the pond has not been utilized for fish culture since 1965. The mauka wall is 2,800 feet long. It was constructed as an earthen dike and is thus more easily damaged from erosion than the rock portions of the wall. The stream-bed wall is 1,200 feet long.

The mauka and stream sections of the pond wall are currently under the influence of a dense stand of mangrove. The mangrove affects the wall in both a positive and negative fashion by alternatively stabilizing and breaking apart the wall. The mangrove increases siltation, sedimentation, pond encroachment, and acts as fish nursery habitat. Although most of the wall is lined by mangroves, the heaviest concentrations are in the Northwest, Northeast and Southeast corners where encroachment is as much as 50 meters into the pond.

The bottom of the pond is sandy mud over the original hard coral substrate. The depth of the sediment over most of the bottom varies from a few centimeters in the central portion to 50 centimeters where the stream enters the pond. In the windward and leaward corners of the pond where the mangroves have trapped sediments, the depth is generally about 35-40 centimeters and is anaerobic to various degrees depending upon the amount of entrapped organic material. The mud also tends to be thicker, up to 25 centimeters, adjacent to the entire makai wall. The composition of the deposits adjacent to this wall is a mixture of mud, sand, coral rubble and rock. This composition indicates that the deposits are probably erosional material from the wall. Hawaiian legend indicates the probable existence of a kepuka (hole) in the bottom of the pond. If it is similar to kepukas on other reef flats, the mud depositions in this limited area may be several meters deep.

Water quality within the pond has been documented by the DLNR Division of Aquatic Resources (Appendix V). Additional water quality data has been monitored from May 1989 to the present. Seasonal, tidal, and meteorological conditions are the primary factors affecting the water quality measurements at any given time. The results of these tests vary widely, depending upon conditions. However, the overall water quality of the pond is intermediate between that of a typical land-based pond and conditions found in the open bay.

Figure 11


HEEIA FISHPOND
DEEP SCOUR
CLEAN COURSE SAND
CORAL RUBBLE
2-4" LIGHT SILT
SAND & RUBBLE
<1" FINE SILT
TERRIGINOUS SILT SAND & MUD 2-4"
9-24" DEEP TERRIGINOUS SILT
WALL SLOUGHINGS
KAMEHAMEHA
HIGHWAY

6.0 IDENTIFICATION AND SUMMARY OF MAJOR IMPACTS AND ALTERNATIVES;

The project will have a major overall positive impact on the community as it provides income and employment from a neglected resource, while restoring that resource to its historically high level of social and aquacultural significance. The project will have a major positive impact on the future of alternative traditional aquaculture practices in the state. Cooperative research opportunities, such as the one already established with HIMB, will hopefully contribute to stock enhancement programs and other types of aquaculture research and development. Due to the unique historical nature of the resource, its close ties with the Bishop Estate and Kamehameha School, and its proximity to Heeia State Park, HIS will offer a unique opportunity for Hawaiian cultural anthropologists and archaeological specialists to empirically study and document the characteristics of the site. HIS will eventually seek to provide training and educational opportunities for private and public groups.

The primary negative impacts and alternatives considered associated with PHASE I development are discussed below:

6.1) General operation of a commercial aquafarm in what has been for the past 25 years, essentially been an unused "natural" wild habitat will have primarily a social impact as follows;

a. Some increase of local traffic, including a work truck, workboats and machinery appropriate to size of operation.
b. Changes to the visual characteristics of the pond as seen from surrounding properties.
c. During pond renovation and construction, noise consistent with these activities will be generated during normal work hours.
d. General operation of aquafarm equipment will generate some degree of noise associated with boats, aeration, trucks, etc.
e. Loss of recreational fishing habitat within the pond. (Although access has never been granted for fishermen to use the pond, this practice has become not uncommon).

6.2) Repair of the natural river pond wall will cause a shift of freshwater flow from pond outflow to the original adjacent stream outflow:

a. Some stream water will be rerouted through the original stream bed leading to the original stream mouth, possibly causing;

1 Scouring of the plugged stream mouth
2 A change of sedimentation patterns (but no increase in sediment deposition into the Bay) will shift from the pond and the main makai wall break back to the original river mouth.
3 Temporary rise in the level of the low tide out-flowing stream water level until the original stream channel becomes unclogged.
4 Lowered salinity within the stream bed due to revised flow patterns.
5 Modification of substrate biota at the mouth of the stream reflecting the more concentrated input of fresh water and return to the original estuarine conditions.

b. Increase in the minimum water level of the pond;

1 Decrease in total water exchange to the pond with resulting increased average resident time of water and increased algae density within the pond.
2 Loss of tidal exposed pond mudflat habitat.

c. Loss of mangrove and halekoa habitats on the existing walls as these areas are cleared.

6.3) Construction of broodstock/nursery ponds;

a. Containment of a stand of mangroves within one nursery pond in the south east corner of the pond.
b. Increased residence time and fertility of waters within the ponds, and associated algae blooms.

6.4) Pond bottom management;

a. The effect of pond bottom conditions on the health and productivity of cultured animals is unknown, but is postulated to be a serious potential problem under several common culture conditions.

b. The project will attempt to produce under the existing silty pond bottom conditions and will monitor for impact.

c. If silt levels adversely impact aquaculture operations then the silt may be shifted from culture areas and/or used to reinforce pond walls.

d. Incorporation of silt from the pond bottom into pond walls would improve wall integrity, strength, and help in the prevention of further depositions of silt from the stream.

e. Silt may be repositioned within the pond using either a bulldozer or a water-suction lift pump.

6.5) Placement and use of fish cages, nets, algae lines, stakes and other aquaculture related materials in the pond will cause:

a. Visual change within the open waters of the pond as seen from surrounding properties;

b. Increased nutrient levels within the pond due to fish feed and metabolic by-products causing;

1 Algae (macro & micro) increase within the pond,

2 Increased biomass of brackish water pond fish such as mullet and milfish in the open pond waters,

3 Alteration of biological community structures just outside the pond adjacent to water gates with a probable increase in biomass and decrease in diversity,

4 Attraction of fish from the bay to the water gates,

5 Attraction of seabirds to the pond, and

6 Increased organic load of the pond bottom sediments with temporary and isolated cases of anaerobia and a corresponding buildup of trapped hydrogen sulfide gasses.

6.6) Relocation of the existing pier within the pond will have no significant impact on the surrounding area.

6.7) Clearing of limited sections of the Hau and Mangrove forests overlying the mauka and stream borders of the pond will have limited impact to the pond's forest in these restricted areas. The purpose for clearing these relatively small sections is to provide access to the wall for repair

(6.8) Implementation of the project will also have some very positive impacts on the pond and surrounding environments.

a. Maintenance of a more uniform temperature within the pond.

b. Increased fish biomass within the pond, both in cages and open waters.

c. Prevention of further damage and degradation to the pond.

d. Increased attraction of gamefish to the mouths of the stream and pond, due to increased primary production.

7.0 PROPOSED MITIGATION MEASURES, IF ANY;

Mitigating measures proposed to lessen the impact of the project on the social and physical environment have been discussed in the above sections. To summarize, these measures include:

7.1 Active participation and interest in historical and anthropological and historical studies of the site.

7.2 Plans to repair the pond in a historically accurate fashion.

7.3 Field site investigations have been held with State Parks and Bishop Estate to reach concensus as to the management of the watershed, particularly the clearing of the stream mouth and near-shore stream bed. Cooperative efforts for stream clearing and maintenance are in the early planning stages.

7.4 Cooperative relationship with Heeia State Park (Friends of Heeia), Kamehameha Schools, and other educational institutions interested in utilizing the site for field trips and/or instruction.

7.5 Sensitivity to the need for minimum impact on the mangrove and Hau forests, even though these trees currently encroach within the pond and choke the mouth of the stream.

7.6 Sensitivity to the proximity of adjacent residential neighborhoods will be shown by utilizing aeration devices and other machinery with cause minimum noise. Work hours will be scheduled to minimize impact on adjacent residential communities.

8.0 DETERMINATION;

The positive benefits inherent in the success of this operation far out-weigh the limited negative environmental and social impacts.