1991 - Oahu - FEIS - Lihi Lani II

LIHI LANI RECREATIONAL COMMUNITY

PAUMALU AND PUPUKEA, KOOLAULOA, OAHU, HAWAII

FINAL ENVIRONMENTAL IMPACT STATEMENT

APPLICATION FOR NORTH SHORE DEVELOPMENT PLAN AMENDMENT

VOLUME II

OBAYASHI HAWAII CORPORATION
HONOLULU, HAWAII

APRIL 1991

FINAL ENVIRONMENTAL IMPACT STATEMENT
Application for North Shore Development Plan Amendment

Volume II

LIHI LANI RECREATIONAL COMMUNITY

Paumalu and Pupukea
Koolauloa District, Oahu, HI

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APPENDIX A

COMMUNITY FACILITIES PACKAGE
NOVEMBER 5, 1990

I. SOCIAL IMPACT

A. Affordable Housing

Based on a 60/40 ratio for residential use, 180 affordable units is proposed for the property.

B. Community Park and Center - Over the past several years, numerous discussions have taken place between Obayashi and local community groups and individuals in regard to the use of an approximately 10 acre site next to the Sunset Beach Elementary School. These preliminary discussions have resulted in a tentative plan to dedicate the land for public use, and develop the property into a recreation area and community center.

1. Dedicate land to City or Community-Based Trust for use by the local community for a community center and recreational park.

2. Develop and dedicate to the City or Community-Based Trust the community facilities and infrastructure as agreed to by the developer. These include:

* Community Center (used for meeting room and other community programs)
* Baseball/soccer field
* Outdoor pavilion
* Children's playground
* Picnic and barbecue area
* Parking
* Swimming pool and pool deck

3. Funding for the operation and maintenance would be partially subsidized by Obayashi through a funding program tied to the golf course green fees. A $1.50 premium would be charged to each golfer to help pay into this operation fund for the community facilities. Each year, the funds would be deposited into a community fund.

4. Additional funding would be provided by charging a $2,000 premium to each golf membership sold.

C. Child Care

Approximately a one acre site would be dedicated to the City or user - to provide for a Child Care Center.

D. Community Garden Program

A one acre site will be dedicated to the City with infrastructure, to allow residents to participate in the City's "Community Gardening Program".

E. Education Program

There are 11 public and private schools in the North Shore area. It is proposed that contributions to an endowment fund for the purpose of scholarships or support for other educational programs be created.
This would be funded by assessing all initial market lot sales only, a $5,000 premium.

1. Kahuku and Waialua High Schools - Scholarship Fund to promote college studies in environmental programs or golf course superintendent programs.

2. Private and Public Elementary Schools - Support for education programs.

F. Hiking and Horse Trails

About 2 1/2 years ago, a hiking committee was formed out of the North Shore to assist in developing a hiking trail plan to meet some of the needs of the area. There will be several trails developed that would include a 6-8 mile loop trail, an ocean bluff trail, a trail connecting the State trail system (mauka of the property) and others that would accommodate different levels of hikers. These trails would be open to the public at no cost. The Boy and Girl Scouts would be consulted prior to any trails being built that might affect their campsites.

G. Equestrian Facilities

The North Shore area is home to many horse owners and activities. Through an equestrian committee formed over two years ago, the owner concluded that an equestrian facility and trail system was supported by many residents. Trails and places to practice equestrian and other horse-training skills are quickly disappearing on the North Shore.

1. Trails

It is proposed by the owner to develop a trail system that will allow horse back riding around the property. This trail system will share trails with hikers at times and be separated where necessary. The system would be approximately 6-8 miles at no cost to local residents.

2. Facilities

It is proposed that a covered practice arena and open arenas be built in addition to 80-100 horse stables. Also, there will be numerous acres of open pasture land. The owner proposes to allow up to 30% of the facility be eligible for a kamaaina rate for the use of the facilities and stabling charges. The pasture land will be available to 4-H clubs.

H. Golf Course

The owners plan to operate the golf course as a semi-private course with some private membership. It is proposed that 30% of all tee times will be reserved for kamaaina play. These kamaaina players will be allowed a 40% reduction off rates.

I. Preservation of Endangered Trees

Just outside the Lihi Lani property, the rare Eugenia Koolauensis was found. Working with the DLNR, a cooperative effort to protect the site is being created. This would include a long-term management program by the owner.

J. Creation of a Conservation Park

Develop and maintain a "conservation park" within the mauka areas of Lihi Lani where the majority of native species are excellent, adding, as possible specimens removed from other sites of the property being developed.

The trail system would be designed to wind through this conservation park and provide educational opportunities.

K. Job Training Program

Establishment and maintenance of a job training program to assist community residents to prepare for job interviews and employment in the project. The training programs and their schedules of implementation shall be jointly developed with the community. Review committee to be established to annually review the

implementation and the hiring practices and policies for the golf course and make recommendations to the golf course operator.

L. Junior Golf Program

Developer will work with the community to organize a Junior golf program for full-time students living in the area between the ages of five to eighteen. Hours of free play shall be designated. Adequate hours to be established to fully encourage and develop the Junior program.

II. ADDITIONAL SUPPORT FOR COMMUNITY ACTIVITIES AND PROGRAMS

Over the past three years, Obayashi has supported a number of programs for the youth. The following is a list and a brief description of this support.

A. Pa'u Riding Group

Over the past two years, Obayashi has sponsored a Pa'u riding team made up of 12-18 riders living on the North Shore in order to ride in the Aloha Week and Kam Day Parades. Obayashi intends to continue this tradition as long as there is strong interest by the community.

B. Golf Tournament Fund-Raiser

For the past two years, Obayashi has sponsored a local golf tournament to raise money to support local youth groups and the Kahuku High School Golf Team. It is anticipated, after the project is built, that this type of fund-raiser will continue in a much larger scale than it is run today.

C. Surfing Tournament Clean-Up

Over the past two years, Obayashi has sponsored a beach clean-up program during the Triple Crown Surf Tournament. In coordination with the tournament organizers, Obayashi compensates different youth organizations to clean up after each day of the tournament. Last year, through the program, Sunset Beach Elementary School was able to purchase computers for the school.

D. Additional Donations

In addition to the above mentioned programs, Obayashi has also responded to donation requests from various groups on the North Shore. The following is a list of organizations who have received donations.

1. American Youth Soccer Assn
2. Hawaii Junior Golf Assn
3. Kahuku Lokahi Youth Athletic club
4. Waialua Lion's Club (Waialua High Scholarship Fund)
5. Kahuku High School Scholarship Fund
6. Waialua High School Scholarship Fund
7. Girl Scout Council of the Pacific
8. Kahuku Little League Baseball
9. Waialua Little League Baseball
10. Haleiwa Community Assn (Waialua High Scholarship Fund)
11. St. Michael's School (Microscopes)

LIHI LANI BENEFIT VALUATION
NOVEMBER 5, 1990

	Benefit	Approx. Market Value 1990 ($)
I.	COMMUNITY PROGRAMS	
A.	Affordable Housing	
	1. Provide affordable housing with 180 units at a per lot cost for land and infrastructure of $70,000, and a $70,000 cost for home construction.	$25,200,000
B.	Community Center	
	1. Dedicate the land (approx. 10 acres) @ $170,000 per acre.	$ 1,700,000
	2. Construction cost	$ 4,700,000
	3. Operational & maintenance subsidy program - cumulative 50 year total @ 150 rounds per day x 360 days/year x $1.50 per round, @ 2% increase per year.	$ 6,900,000
	4. Additional funding for maintenance subsidy will be from premiums from golf memberships-$2,000/member @ est. 500 members.	$ 1,000,000
C.	Child Care	
	Dedicate one acre to City @ $170,000 per acre.	$ 170,000
D.	Community Garden Program	
	Dedicate one acre to City @ $170,000 per acre.	$ 170,000
E.	Education Program	
	After each residential sale, a $5,000 premium will be put into an escrow account for the program. 120 units @ $5,000/unit.	$ 600,000

F. Hiking Trails

Clearing and grading for a 10 mile system @ $25,000/mile (includes benches, signage, restroom facilities and parking)	$ 250,000
Trail maintenance program - $25,000/ year, cumulative 50 year total @ 2% increase per year.	$ 2,100,000

G. Equestrian Facilities

1. Trail System - approx. 2.0 miles (in addition to 6 miles also used by hikers) of special horse trails - $25,000/mile.

Construction cost	$ 50,000
Maintenance cost-2 miles-$8,000/ year, cumulative 50 year total @ 2% increase per year.	$ 680,000
2. Facility - 30 of the 100 stables at kamaaina rates @ $100/month net, 40 x 30 stables,cumulative 50 year total @ 2% increase per year.	$ 1,800,000

H. Golf Course

Green Fees - There would be 30% of all tee times @ 150 rounds per day -$65.00 rack rate, cumulative 50 year total @ 3.5% growth rate every 5 years.	$51,500,000

I. Preservation of Endangered Trees

Preservation and maintenance program.

* initial costs	$ 15,000
* maintenance - $2,000/year, cumulative 50 year total @ 2% increase per year.	$ 170,000

J. Conservation Park

* initial costs	$ 125,000

* maintenance cost - $25,000/year, cumulative 50 year total @ 2% increase per year.	$ 2,100,000

K. Job Training Program

* before opening	$ 100,000
* after opening - $8,000/year, cumulative 50 year total @ 2% increase per year.	$ 680,000

L. Junior Golf Program

* organization costs	$ 15,000
* operating costs	NA
SUB-TOTAL (A-L)	$100,025,000

II. PRIOR COMMUNITY CONTRIBUTIONS

A. Pa'u Riding Group

1. Aloha Week Parade 1989 Costumes, Horse Gear, Seamstress, Leis	$ 6,900
2. Kam Day Parade 1990 Costumes, Leis, Seamstress	$ 2,900
3. Aloha Week Parade 1990 Costumes, Leis, Seamstress	$ 3,800

B. Golf Tournament Fund-Raiser

1. Lihi Lani 1st Annual Golf Tournament	$ 1,200
2. Lihi Lani 2nd Annual Golf Tournament Green Fees, Trophies, Kahuku High Golf Team, Kahuku Lokahi Youth Athletic Club	$ 1,500

C. Surfing Tournament Clean-Up

1. Kahuku Second Ward LDS	$ 4,400
2. Sunset Beach Elementary School	$ 2,400

D. Additional Donations

1.	American Youth Soccer Assn	$	400
2.	Hawaii Junior Golf Assn	$	1,500
3.	Kahuku Lokahi Youth Athletic Club	$	1,500
4.	Waialua Lion's Club (Waialua High Scholarship Fund)	$	500
5.	Kahuku High School Scholarship Fund	$	1,000
6.	Waialua High School Scholarship Fund	$	1,000
7.	Girl Scout Council of the Pacific	$	1,500
8.	Kahuku Little League Baseball	$	
9.	Waialua Little League Baseball	$	1,000
10.	Haleiwa Community Assn (Waialua High Scholarship Fund)	$	500
11.	St. Michael's School (microscopes)	$	
	SUB-TOTAL (A-D)	$	32,000
	TOTAL		$100,057,000

APPENDIX B

WASTEWATER MANAGEMENT PLAN

FOR THE

PROPOSED LIHI LANI RECREATIONAL COMMUNITY

PUPUKEA, PAUMALU, KOOLAULOA, OAHU, HAWAII

Prepared by:

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December 1990

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FIGURES

INTRODUCTION

Obayashi Hawaii Corporation is proposing to construct a golf course/residential development on the north shore of Oahu at Pupukea (TMK: 5-9-05:38 and 5-9-06:1, 18, 24). The 1,143 acre site is located mauka of Kamehameha Highway and Sunset Beach, surrounded by the COMSAT facility, forest reserve, and the Pupukea Highlands and Sunset Hills subdivisions (see Figure 1).

The objective of this report is to present preliminary engineering information on the proposed wastewater collection, treatment and disposal facilities for the project development. Specifically, this report will address--

1. Background information on the proposed project;
2. Projected wastewater flow quantities and characteristics;
3. Proposed methods of wastewater collection, treatment and disposal; and
4. Impacts of effluent disposal.

At present, there are no public sewers servicing the site or surrounding areas. The neighboring Pupukea Highlands and Sunset Hills subdivisions are serviced by individual cesspools.

The proposed wastewater infrastructure presented in this report is intended to be privately owned and operated. Expansion of the proposed facilities, to include other existing or proposed developments, is not foreseen.

PROJECT BACKGROUND

Proposed Project

The proposed Lihi Lani Recreational Community project will result in the development of approximately 598 acres within the 1,143 acre project site. Included is the proposed development of an 18-hole golf course with driving range and a clubhouse with banquet facilities; a tennis center, including a clubhouse with a snack shop and pro shop; an

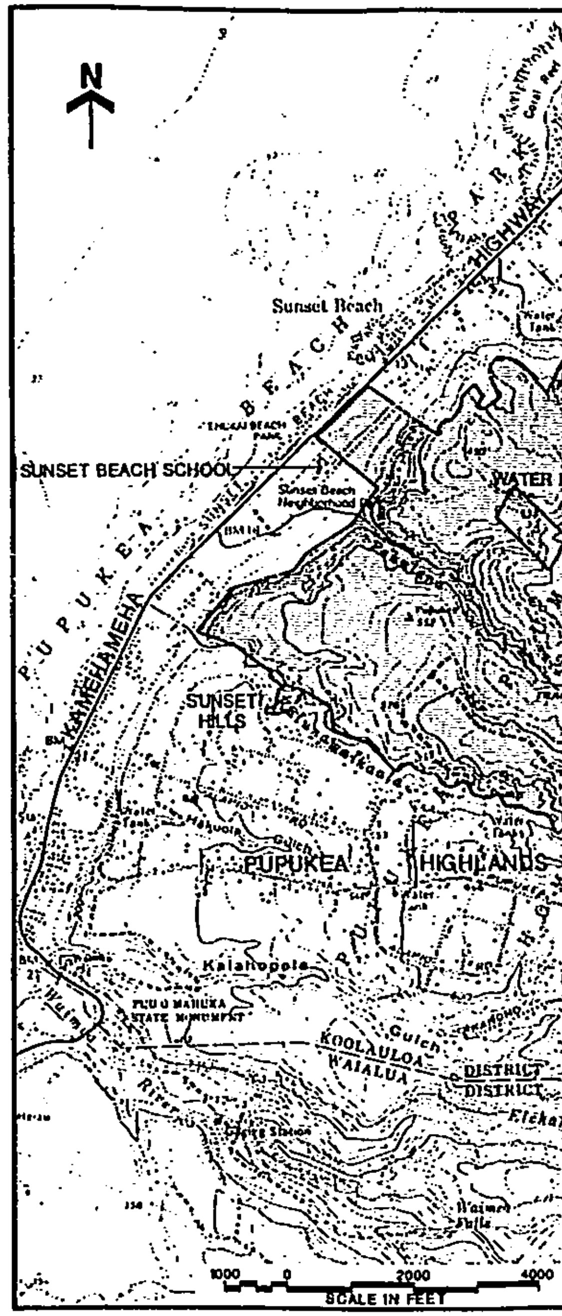

FIGURE 1

LOCATION MAP

equestrian ranch with stables and riding trails; 120 estate-type residential home sites of one acre or larger; a 180-unit affordable housing complex; campground; several horse pastures (approximately 84 acres); and community facilities.

Topographic Features

Approximately 30 acres of the project site are situated along the coastal plain mauka of Kamehameha Highway and northeast of Sunset Beach Elementary School. The remaining area is located on an expanse approximately 6,000 feet wide and 8,000 feet in depth, separated from the coastal plain by a 200- to 400-foot high bluff.

The site is isolated from neighboring properties on Kamehameha Highway by the bluff, and from neighbors on the northeast and southeast by the valleys of Paumalu Stream and Kalunawaikaala Stream respectively. Pakulena Stream bisects the site interior. The three streams flow intermittently, only during periods of heavy rain.

The elevation of the 30-acre coastal plain parcel varies from 20 feet to 75 feet while the elevation of major portions of the site varies from 200 feet at the bluff to 840 feet at the mauka forest reserve region. Approximately one-fourth of the site slopes at less than 20 percent.

Climate

The median annual rainfall is 51.7 inches. Tradewinds from the northeast average 8.9 mph, blowing slightly stronger during the day. The average temperatures in the summer are 83 degrees during the day and 69 degrees at night, while winter temperatures average 77 degrees during the day and 64 degrees at night. Relative humidity averages 74.6 percent during the day.

PROJECT WASTEWATER QUANTITY AND CHARACTERISTICS

Wastewater Quantity

The wastewater design quantity is derived from estimates of wastewater generation from different types of establishments as contained in Chapter 62 of Title 11, Hawaii State Department of Health's Administrative Rules on "Wastewater Systems." Design criteria for sewage infrastructure is based on the City and County of Honolulu, Department of Public Works' "Design Standards of the Division of Wastewater Management," Volume 1, dated February 1984. Wastewater contributions from the proposed facilities within the project are listed below:

	Average Wastewater Quantity (gpd)
Clubhouse	10,000
Tennis Center	2,000
Equestrian Ranch	1,000
300 Residences	180,000
Campground	3,000
Community Facilities	2,000
Maintenance Facility	1,000
Total	199,000

For planning purposes, the total average wastewater quantity for the project is estimated to be 200,000 gpd.

Wastewater Characteristics

Wastewater generated at the project site is expected to be of typical domestic composition. Thus, the following parameters are assumed:

Biochemical Oxygen Demand (BOD)	= 200 mg/l
Suspended Solids (SS)	= 200 mg/l

PROPOSED WASTEWATER MANAGEMENT PLAN

Wastewater Collection System

Gravity sewers will collect and convey wastewater to a network of sewage pumping stations for transmission to a central wastewater treatment facility located near the tennis center.

For ease of construction and maintenance, sewers and pump stations will be located along the proposed roadways, to the extent that terrain and site layout will allow.

Wastewater Treatment Scheme

The proposed method of wastewater treatment is stabilization ponds followed by a wetlands system providing advanced secondary treatment. A typical flow diagram for the facultative pond and wetland treatment system is shown on Figure 2.

Facultative ponds are the most common type of stabilization pond and the easiest to maintain and operate. A pond depth of 6 feet is typical, providing aerobic stabilization in the upper layer, anaerobic fermentation and sludge storage in the lower layer. Mechanical aeration is generally not required due to surface reaeration by winds and oxygen production by photosynthetic algae.

Based on a projected wastewater flow rate of 200,000 gpd, a total of 8 acres of pond surface area is required. Thus, two ponds operating in series will require 4 acres each. Berms, 10 feet wide, encircling the ponds, provide sufficient access for mowing machines and vehicles used for maintenance. Berm walls normally provide 2-foot freeboard above the maximum liquid level to prevent overtopping. Wall slopes of 4 horizontal to 1 vertical on the inside face and 3 horizontal to 1 vertical on the outside will be incorporated in the pond construction.

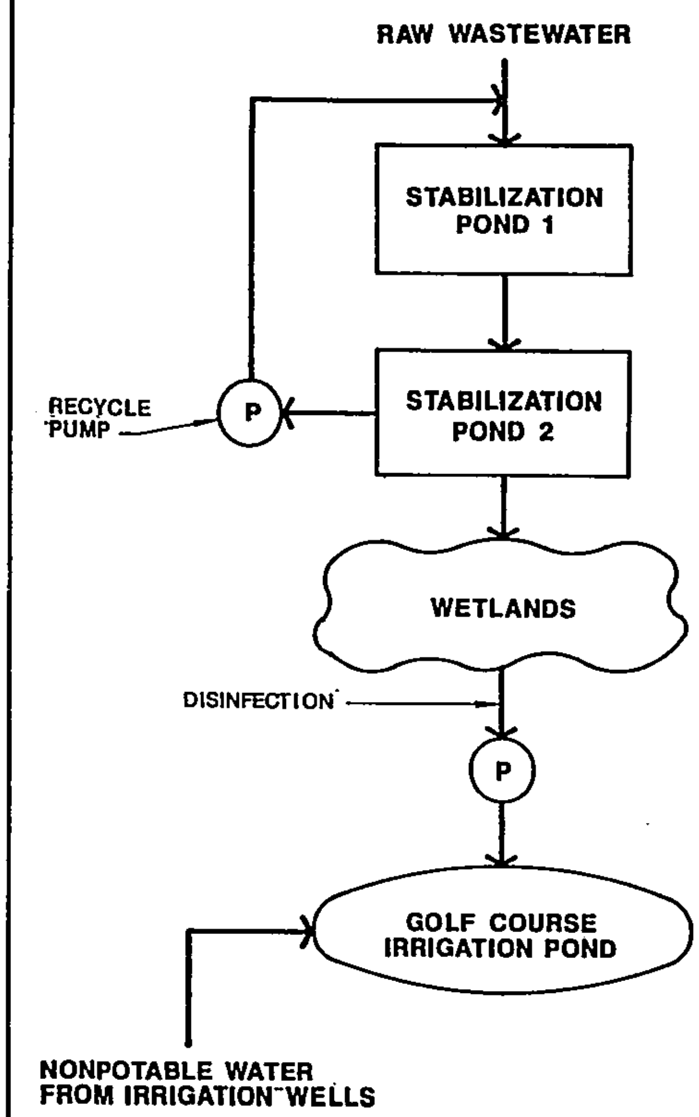

FIGURE 2

FLOW DIAGRAM FOR WASTEWATER TREATMENT AND DISPOSAL

The wastewater treatment facility would require about 10 acres of fenced area to accommodate the ponds, berms, perimeter and access roads, chlorination facilities, pumps, piping, and appurtenances. An additional 2 acres will be developed for a wetlands system to receive pond effluent. Therefore, altogether, about 12 acres will be used in the proposed wastewater treatment system.

The wetlands system acts as a "polishing" facility to improve the quality of effluent delivered to the golf course irrigation pond. The treatment of wastewater in the wetland system is accomplished by the mechanisms of bacterial metabolism, physical sedimentation and straining. While the aquatic plants actually perform little in the treatment process, the roots and stems provide surfaces for bacterial growth and attenuation of sunlight to prevent algae growth. (see Figure 3)

Two acres of wetlands will be compartmentalized into several smaller cells to afford two or more stages of enhanced treatment and disinfection. Effluent from the stabilization ponds will be proportioned and delivered into individual cells, or a battery of cells, according to the assimilation characteristics of the growing vegetation and biota. Discharges from these compartments will be collected in a common sump for disinfection by chlorination or ultra-violet light. Bulrushes, or a variety of similar grasslike plants, will be the type of vegetation that will be used and cultured in the wetland system. Bulrushes are ubiquitous plants that grow in a diverse range of brackish and salt marshes and are capable of growing well in water that is 2 inches to several feet deep.

<u>Effluent Characteristics</u>

The stabilization pond-wetlands treatment system will be designed to achieve the following effluent characteristics:

BOD:	5 - 15 mg/l
SS:	5 - 15 mg/l
Nitrogen:	5 - 7 mg/l
Phosphorus:	< 6 mg/l
Total coliforms:	< 23/100 ml

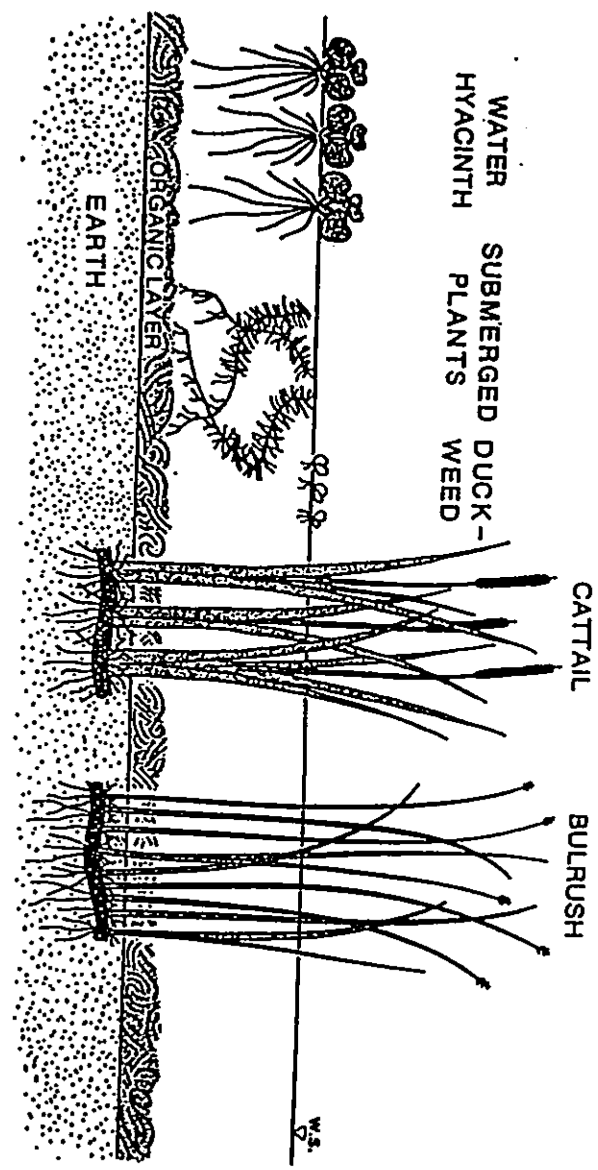

FIGURE 3

WETLANDS TREATMENT SYSTEM

The effluent will meet criteria stated in the proposed Hawaii Administrative Rules, Title 11, Department of Health, Chapter 62, Wastewater Systems. The total coliform organisms in five grab samples of reclaimed water used for golf course irrigation taken during a 30-day period shall not exceed 23 per 100 ml. Adequate disinfection will also insure coliform counts do not exceed 240 per 100 ml in any sample.

Wastewater Collection and Treatment Safeguards

Certain special measures will be taken to safeguard public health in case of malfunctions in equipment or power failures.

Safeguards proposed for the wastewater stabilization ponds (WSP) and sewage pumping stations (SPS) are--

1. Generators. Standby power will be provided to each SPS and the WSP to provide emergency power in case of electrical power outage. Thus, pumping operations and disinfection can continue uninterrupted, therefore preventing sewage spills.
2. Storage vaults. A storage vault will be constructed at each SPS as a backup wet well in the event equipment failure results in wastewater overflow.
3. Redundancy. Parallel sets of waste stabilization ponds, equal in capacity, will be constructed to provide operational redundancy during periodic instances for pond maintenance. Pump stations will be equipped with dual pumps, each capable of handling the entire flow entering the station.
4. Odor Abatement. Due to the limited expanse of the sewer system and the relatively high velocities in the steeply sloped gravity sewers, the detention time of the sewage in the sewer system should be relatively short, thereby minimizing the emission of odors. As a contigency, provisions will be included in the design to incorporate odor abatement facilities, should the need arise.
5. Alarms and telemetering. Alarms indicating high/low liquid level conditions, equipment malfunction, and other emergency conditions will be installed at

each SPS. Visual and audio alarms will be mounted in areas routinely accessed by maintenance personnel. As far as practicable, signals will also be transferred through telephone lines by telemetry to the homes of key maintenance personnel as an additional safety measure during nonworking hours.
6. Restricted Public Access. Pump stations, the treatment ponds, and the wetlands will be fenced to restrict public access. Additionally, these facilities will be landscaped or otherwise shielded from direct view.
7. Warning Signs and Special Precautions. Effluent reuse facilities, including piping and appurtenances, in areas subject to public access will have warning signs that irrigation water is not fit for consumption. Piping and appurtenances will be labeled to distinguish the product as reclaimed sewage effluent.

PROPOSED METHOD OF EFFLUENT DISPOSAL

The proposed method of ultimate effluent disposal is irrigation of the golf course. Figure 4 illustrates the master plan for wastewater collection, treatment, and disposal. Disinfected effluent from the wetlands ecosystem will be pumped to an irrigation storage pond. The pond capacity, estimated at four to eight million gallons, will contain a blend of reclaimed effluent and nonpotable irrigation water from onsite wells. Two to three feet of freeboard will be provided as additional storage during prolonged periods of inclement weather. The pond will be lined to prevent infiltration of irrigation water.

IMPACTS OF EFFLUENT DISPOSAL

Effluent disposal through reuse for golf irrigation will primarily impact the groundwater and coastal waters due to infiltration of excess irrigation water. An evaluation of three elements (nitrogen, phosphorus, and biological organisms) will be discussed further.

Nitrogen

Based on typical secondary treatment effluent data, a nitrogen concentration of 20 mg/l is expected. At a flow rate of 200,000 gpd, approximately 33 lbs/day of nitrogen will remain in the stabilization pond effluent.

In the wetlands treatment system, nitrification/denitrification have been reported to remove up to 60 to 90 percent of the nitrogen. Artificial wetlands managed in a way to provide even short detention times of 2 to 7 days have been known to produce an effluent of less than 10 mg/l nitrogen. Assuming that the nitrogen concentration in the wetlands effluent is 5 to 7 mg/l (8 to 12 lbs/d), and all of the nitrogen in the effluent is applied to the golf course turf, an 18-hole golf course will require an average of 75 additional pounds per day of slow-release nitrogen in fertilizer supplements. Hence effluent will supply approximately 12 percent of the nitrogen requirement for the golf course.

Typically, 5 to 10 percent of applied soluble nitrogen eventually infiltrates the groundwater; the other 90 to 95 percent being used in plant uptake. (Less than 1.5 percent of the nitrogen in slow-release fertilizers are expected to escape plant uptake and infiltrate through the soil layer.) It is assumed that 0.5 to 1 lb/day of nitrogen attributable to the reclaimed wastewater effluent will eventually percolate to the groundwater. The impact of nitrogen should not be detrimental to the groundwater or coastal water quality due to the following factors:

1. The quantity of percolate and its corresponding quantity of nitrogen is relatively small in comparison to the groundwater movement toward the ocean.
2. The immense "mixing" characteristics of the coastal waters fronting the project should significantly dilute any percolate entering the coastal waters. Further, the net transport characteristics of the coastal water should further preclude any significant impact to the ecosystem of the coastal waters.

Phosphorus

Phosphorus removal in many wetland systems is not very effective because of the limited contact opportunities between the wastewater and the soil. Thus, for purpose of this assessment, it is assumed that a 6 mg/l phosphorus concentration in 200,000 gpd of effluent is delivered to the golf course irrigation storage pond. Thus, 10 lbs/day of phosphorus will be applied to the golf course turf. Phosphorus tends to strongly fix itself to the soil particles. Because of this natural affinity for fixation and the very small amounts involved, virtually no quantity of phosphorus is expected to infiltrate into the groundwater.

Bacteria and Virus

Public health concerns generally associated with the use of wastewater effluent for irrigation are:

1. the effects of aerosols generated during irrigation;
2. the impact of the effluent on water resources.

There has been little research on the topic of public health concerns associated with the use of effluent for irrigation. The following provides experiences at other locales:
In the city of St. Petersburg, Florida approximately 6500 residential units are irrigated with reclaimed water. In response to an absence of definitive criteria, a panel of engineering and public health experts was commissioned to prepare a document addressing public health issues on the practice of irrigation by reclaimed water in St. Petersburg. The panel's finding were:

- there is currently no evidence of increased enteric diseases in urban areas irrigated with treated reclaimed wastewater using coagulation, filtration, and disinfection.
- there is no evidence of significant risks of transmission of viral or microbial diseases as a result of exposure to effluent aerosols from spray irrigation with reclaimed water.

Other areas have been using reclaimed water without incident. In a study of 83 cooperative agricultural settlements in Israel, preliminary results indicated no apparent difference in the overall enteric disease incidence between settlements practicing wastewater sprinkler irrigation and those that do not. Investigators also concluded that aerosols are probably not an important pathway of infection in the agricultural settlement. In another study of morbidity risk factors from irrigation with treated wastewater, investigators at Ada, Oklahoma, found no instance of disease attributable to spray irrigation of chlorinated secondary effluent.

Bacteria and viruses in effluent from the treatment system will, to some degree, be inactivated in the competing soil bacteria environment of the wetlands. The wetlands treatment system is expected to produce a polished effluent similar in quality to that achieved by chemical coagulation and filtration; i.e. less than 10 mg/l BOD and suspended solids. Disinfection by chlorination or ultra-violet light of the wetlands effluent should further reduce the level of pathogenic organisms in the reclaimed effluent. The recommended standards for reuse of effluent in Florida, California, and other mainland states will be followed where practicable, such as maintaining chlorine residuals to attain an average fecal coliform concentration of 2.2/100 ml with an upper limit of 23/100 ml in not more than 10 percent of samples taken.

Data assessing the impact of land application of effluent on groundwater bacteriological quality is virtually nil. Studies conducted by the Water Resource Research Center of the University of Hawaii reported that bacteria and viruses were not present in the percolant from the application of secondary treatment effluent. Researchers attributed the removal of these organisms to soil adsorption, dessication, elevated temperatures, and exposure to sunlight. Thus, infiltration of these organisms to deep aquifers is not probable.

<u>Conclusion</u>

Significant adverse impacts due to effluent disposal by irrigation of the golf course are not foreseen. Mitigation measures include--

1. Ample storage for effluent in the irrigation pond during prolonged periods of inclement weather;
2. Land application of an advance secondary treatment effluent attained through a wetlands ecosystem polishing step, and
3. A disinfection step prior to reuse of effluent for golf course irrigation.

APPENDIX C

WATER SUPPLY REPORT

FOR THE

PROPOSED LIHI LANI RECREATIONAL COMMUNITY

PUPUKEA, PAUMALU, KOOLAULOA, OAHU, HAWAII

Prepared by:

Engineering Concepts, Inc.
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Honolulu, Hawaii 96814

December 1990

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FIGURES

INTRODUCTION

Obayashi Hawaii Corporation is proposing to construct a golf course/residential development on the north shore of Oahu at Pupukea (TMK: 5-9-05:38 and 5-9-06:1, 18, 24). The 1,130-acre site is located mauka of Kamehameha Highway and Sunset Beach, surrounded by the COMSAT facility, forest reserve, and the Pupukea Highlands and Sunset Hills subdivisions (see Figure 1).

The objective of this report is to present planning and preliminary engineering information on the proposed potable and nonpotable water infrastructure to meet domestic and irrigation water requirements for the project development. Specifically, this report will address--

1. Background information on the proposed project;
2. Existing water supply infrastructure;
3. Projected water requirements; and
4. Proposed water distribution system.

PROJECT BACKGROUND

Proposed Project

The proposed Lihi Lani Recreational Community project will result in the development of approximately 598 acres within the 1,143-acre project site. Included is the proposed development of an 18-hole golf course with driving range and a clubhouse with banquet facilities; a tennis center, including a clubhouse with a snack shop and pro shop; an equestrian ranch with stables and riding trails; 120 estate-type residential home sites of one acre or larger; a 180-unit affordable housing complex; campground; several horse pastures (approximately 84 acres); and community facilities.

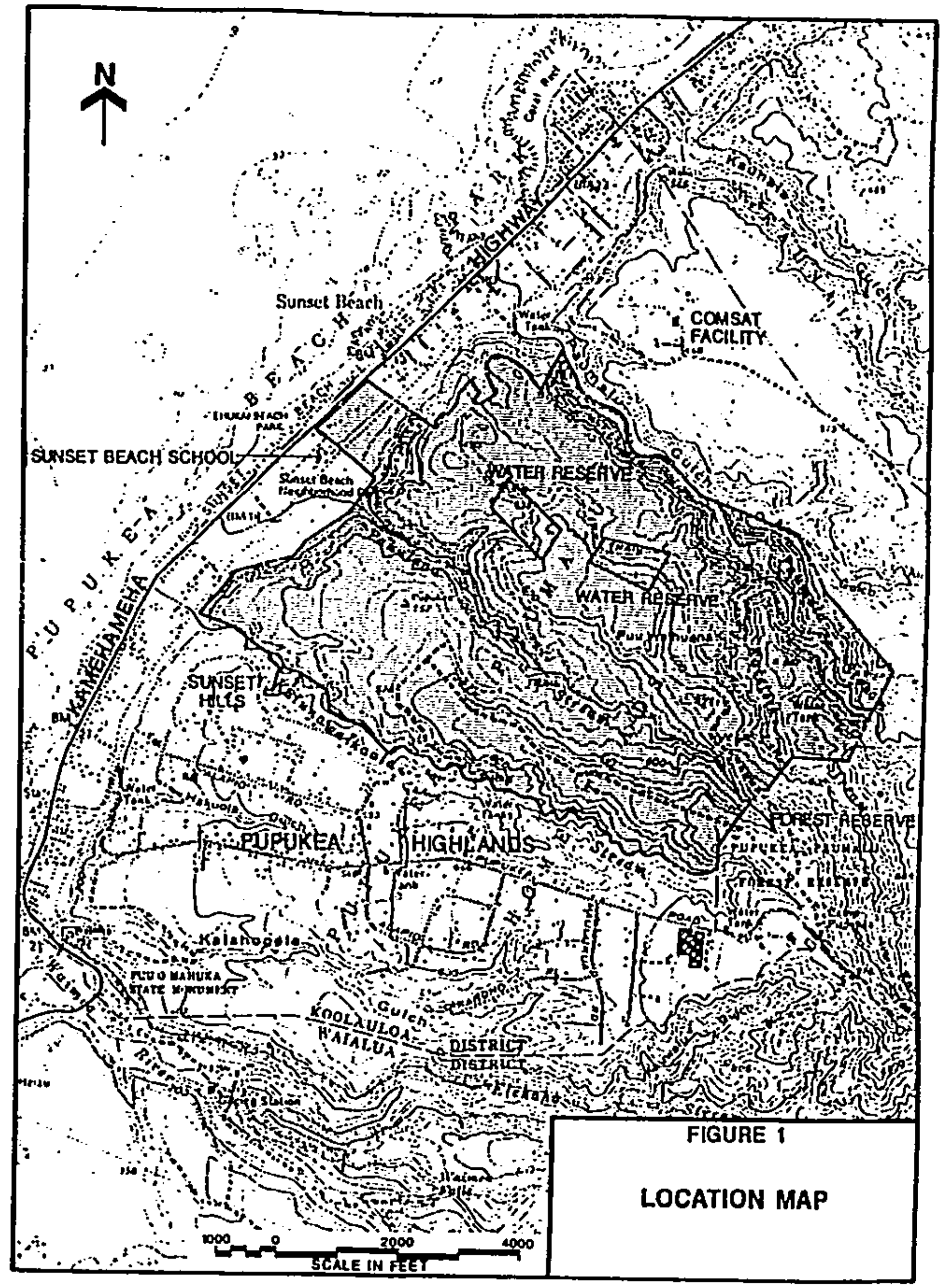


FIGURE 1

LOCATION MAP

Topographic Features

Approximately 30 acres of the project site are situated along the coastal plain mauka of Kamehameha Highway and northeast of Sunset Beach Elementary School. The remaining area is located on an expanse approximately 6,000 feet wide and 8,000 feet in depth, separated from the coastal plain by a 200- to 400-foot high bluff.

The site is isolated from neighboring properties on Kamehameha Highway by the bluff, and from neighbors on the northeast and southwest by the valleys of Paumalu Stream and Kalunawaikaala Stream respectively. Pakulena Stream bisects the site interior. The three streams flow intermittently, only during periods of heavy rain.

The elevation of the 30-acre coastal plain parcel varies from 20 feet to 75 feet while the elevation of major portions of the site varies from 200 feet at the bluff to 840 feet at the mauka forest reserve region. Approximately one-fourth of the site slopes at less than 20 percent.

Climate

The median annual rainfall is 51.7 inches. Tradewinds from the northeast average 8.9 mph, blowing slightly stronger during the day. The average temperatures in the summer are 83 degrees during the day and 69 degrees at night, while winter temperatures average 77 degrees during the day and 64 degrees at night. Relative humidity averages 74.6 percent during the day.

EXISTING INFRASTRUCTURE

The project site is located within the Board of Water Supply (BWS) Pupukea-Waialua subsystem. Groundwater resources for the subsystem are tapped at the Waialua and Haleiwa wells. Storage facilities are located in Waialua, Haleiwa, and Pupukea.

Source

The Waialua and Haleiwa wells are located in the Waialua Ground Water Control Area (GWCA), established by the Board of Land and Natural Resources (BLNR). Although the wells have a combined capacity of 6.0 MGD, limitations on groundwater withdrawal, established and controlled by the BLNR, restrict the draft rate. Currently, the BWS allotment from the Waialua and Haleiwa wells totals 2.73 MGD. The actual water use rate in 1988 was 2.17 MGD. With future commitments up to 2.5 MGD, 0.23 MGD of the BWS's current allotment remains uncommitted and available for future developments.

The sustainable yield is set by the BLNR to indicate the maximum draft from the source that can be sustained indefinitely without detrimental effects on the aquifer or other water developments. Wells at Waialua and Haleiwa have a total sustainable yield of 3.0 MGD. Thus, another 0.27 MGD in water allotment can be granted to the BWS by permit from the BLNR before the total sustainable yield is reached.

Storage

Three reservoirs are located in the vicinity of the project site, each with 0.5 MG capacity. The Pupukea 892-foot reservoir services areas located between elevation 500 and 792 feet. Areas between elevations 70 and 500 feet are serviced by the Pupukea 600-foot reservoir. Areas located below an elevation of 70 feet are serviced by the Pupukea 170-foot reservoir.

Transmission

The Pupukea-Waialua subsystem is illustrated on Figure 2. Water is transported from the Waialua and Haleiwa wells via a 16-inch main starting near Weed Circle along Kamehameha Highway. The 16-inch main transports water to Kawailoa and Waimea. An 8-inch main branches off parallel to the 16-inch main to service portions of the coastal area. The 8-inch main along Kamehameha Highway begins approximately 1,000 feet before Kapuhi Street (on the Waimea side) and continues along Kamehameha Highway to the Sunset line booster,

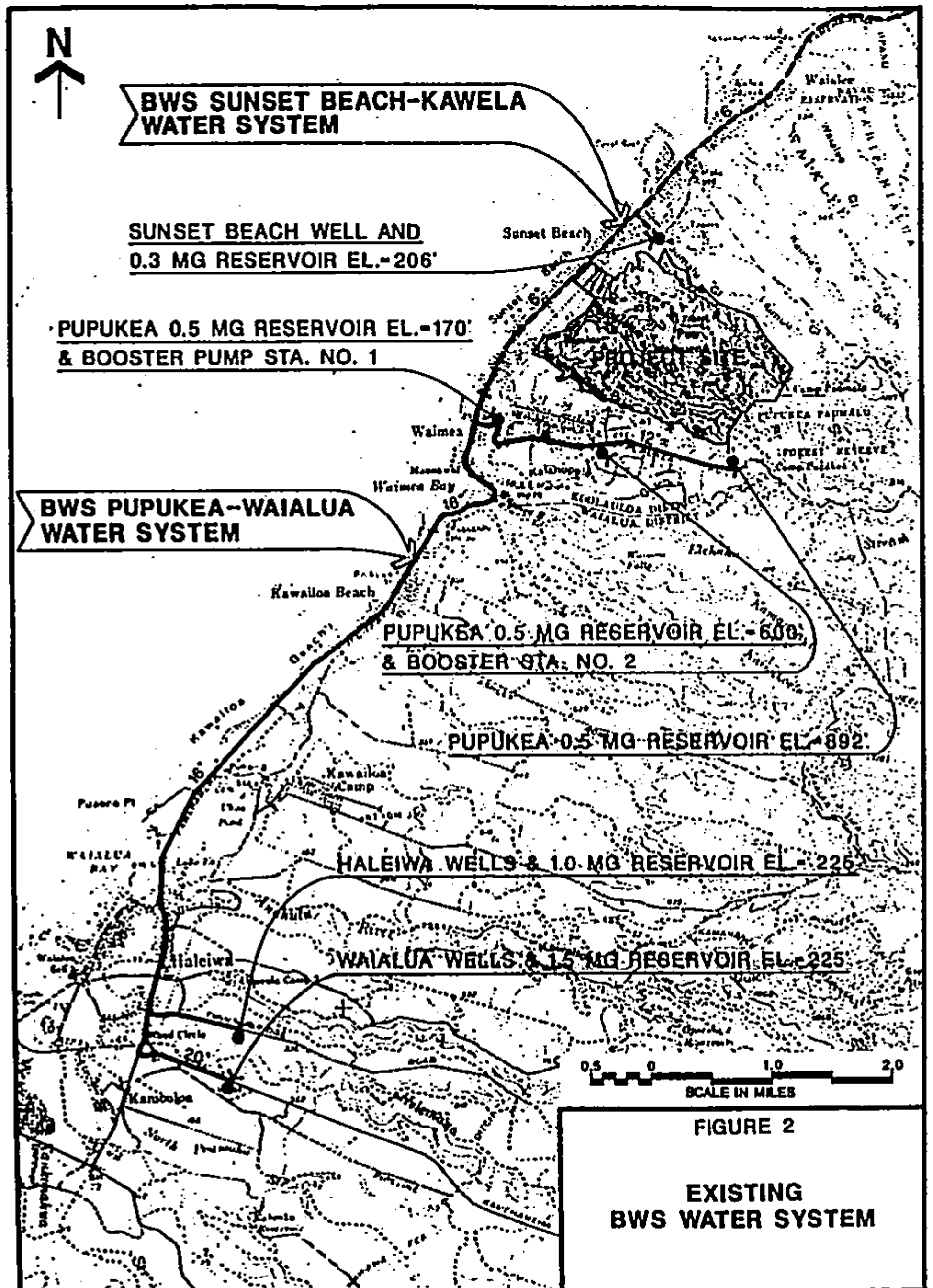


FIGURE 2

EXISTING BWS WATER SYSTEM

located just north of Puula Road. A valve on the Sunset line booster bypass line is normally closed, separating the Pupukea-Waialua and Sunset Beach-Kawela subsystems.

Two 800 gpm pumps at booster station no. 1 transport water via a 12-inch main along Pupukea Road to Pupukea 600-foot reservoir. Two 800 gpm pumps at booster station no. 2 transport water via a 12-inch main along Pupukea Road to the Pupukea 892-foot reservoir.

PROJECTED WATER DEMAND

Potable Water

The projected potable water demand for the proposed development is based on the BWS Water System Standards (1985) and on the book Wastewater Engineering: Treatment, Disposal, Reuse (1979) by Metcalf & Eddy, Inc.

An average potable water demand of approximately 185,000 gallons per day (gpd) is estimated for the entire project site based on the following projections:

	Average Water Demand (gpd)
Clubhouse	20,000
Tennis Center	3,000
Equestrian Ranch	2,000
300 Residential Home Sites	150,000
Campground	4,000
Community Facilities	3,000
Miscellaneous	3,000
Total	185,000

Average water demand for residential home sites is based on 500 gpd per homesite using the BWS standard for a single family residence.

Due to the elevation differences within the project site, the water demand can be divided into a high service zone (elevation >500 feet) and low service zone (elevation <500 feet).

Nonpotable Water

Approximately 100 acres of greens, tees, fairways, roughs and driving range will require irrigation. A maximum irrigation rate of 1.5 inches per week (0.6 MGD) is estimated initially to establish grass during periods of dry weather. An average annual irrigation rate of 0.4 MGD is expected for 18 holes based on an irrigation rate of 1.0 inch/week, once the grass has been established.

Water is also required for irrigation of the landscape areas of the clubhouse, tennis center and other areas. Based on 4,000 gallons per acre per day (gpad) irrigation rate over 25 acres, an additional 0.1 MGD is required for irrigation of these areas.

To reduce potable water demands, landscape irrigation for the 120 market homes will be performed with nonpotable water from on-site wells. The average landscape irrigation rate for these lots is estimated at 0.4 MGD.

Thus, the average irrigation water requirement is estimated to be 0.9 MGD under normal conditions. With the use of up to 0.2 MGD of reclaimed effluent for golf course irrigation, the nonpotable water requirement will be about 0.7 MGD.

Fire Demand

The BWS Water System Standards require the following fire flow rate for the various land uses:

	flow rate (gpm)	duration(hours)
Non-residential: (clubhouse, tennis facility, etc.)	2000	2
Residential	1000	1

The water distribution system and the storage reservoir will be designed to deliver the fire flow rates prescribed by the BWS Water System Standards.

PROPOSED DEVELOPMENT

The proposed development will have separate potable and nonpotable water systems. The proposed potable water system will utilize the BWS system presently serving the Pupukea Highlands and Sunset Hills developments (Figure 3), while the proposed nonpotable water system will utilize onsite wells as the water source (see Figure 4).

Potable Water System

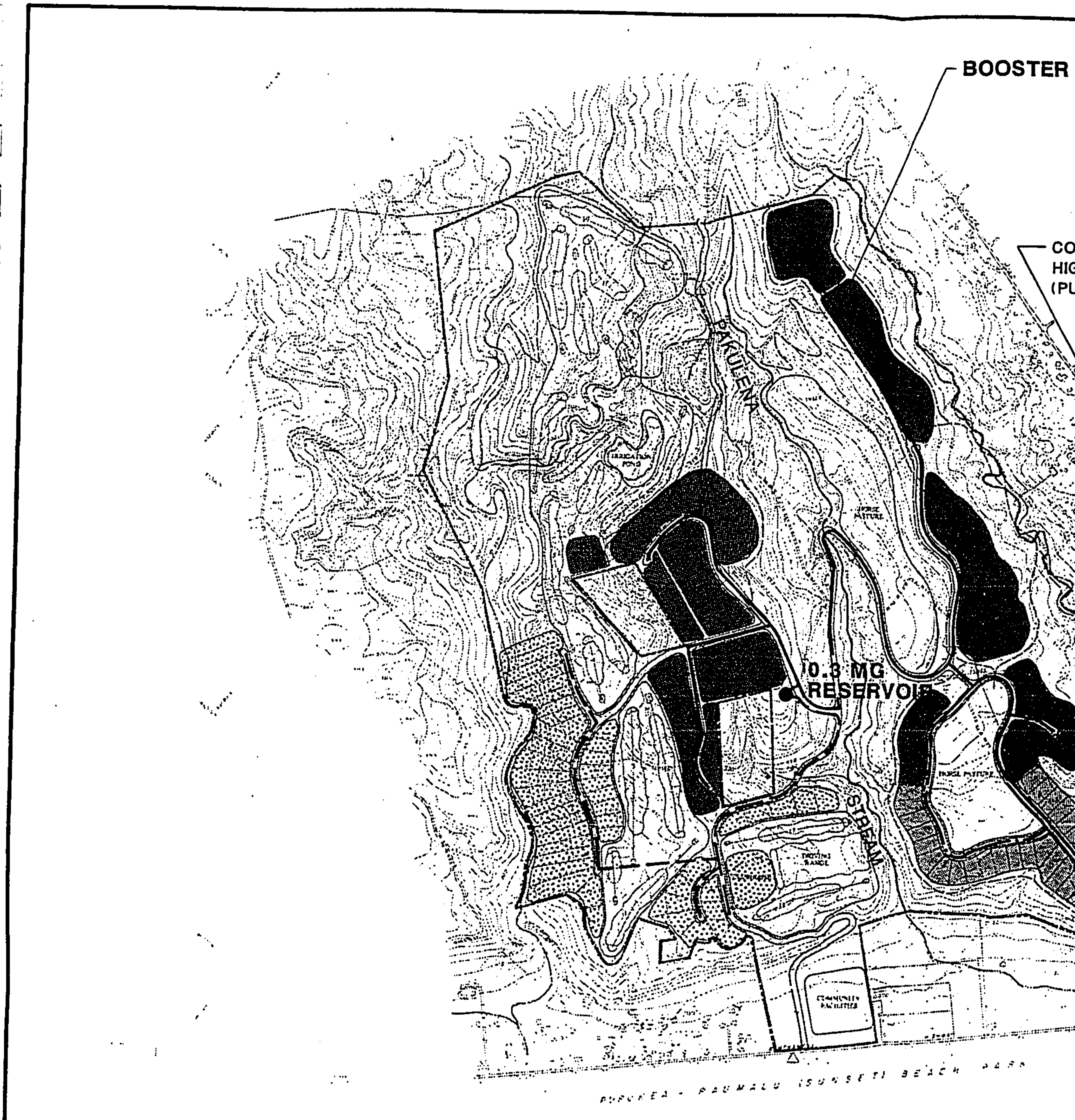
The proposed potable water system will be compatible with the existing BWS system. The proposed high and low service zones within the development will be compatible with the service zones established for the Pupukea Highlands and Sunset Hills communities. The high service zone will be supplied by the Pupukea 892-foot reservoir, and the low service zone will be supplied by the Pupukea 600-foot reservoir.

Storage and transmission rights have been credited to the project by BWS. These credits include--

170-foot system:	242,500 gallons at Pupukea 170-foot reservoir
600-foot system:	242,500 gallons at Pupukea 600-foot reservoir; two 390 gpm capacity at Pupukea booster station no. 1 (one standby capacity)
892-foot system:	242,500 gallons at Pupukea 892-foot reservoir; two 390 gpm capacity at Pupukea booster station no. 2 (one standby capacity)

Reservoir capacity is based on the maximum daily demand, equal to 1.5 times the average daily demand. The storage credits reflect maximum rather than average quantities. Thus, the corresponding storage volume is 242,500 divided by 1.5, or 161,667 gallons on the average for each of the three systems.

The proposed potable water system will be separated into three distribution systems within the project site: low service, high-high service, and high-low service. The proposed low service system will tap off the Pupukea 600-foot system to provide water for the 33 nearby homes located below the 500-foot elevation. The proposed high service system will hook up to the


BOOSTER
CO
HIG
(PL
PAKULENA
0.3 MG
RESERVOIR
STREAM

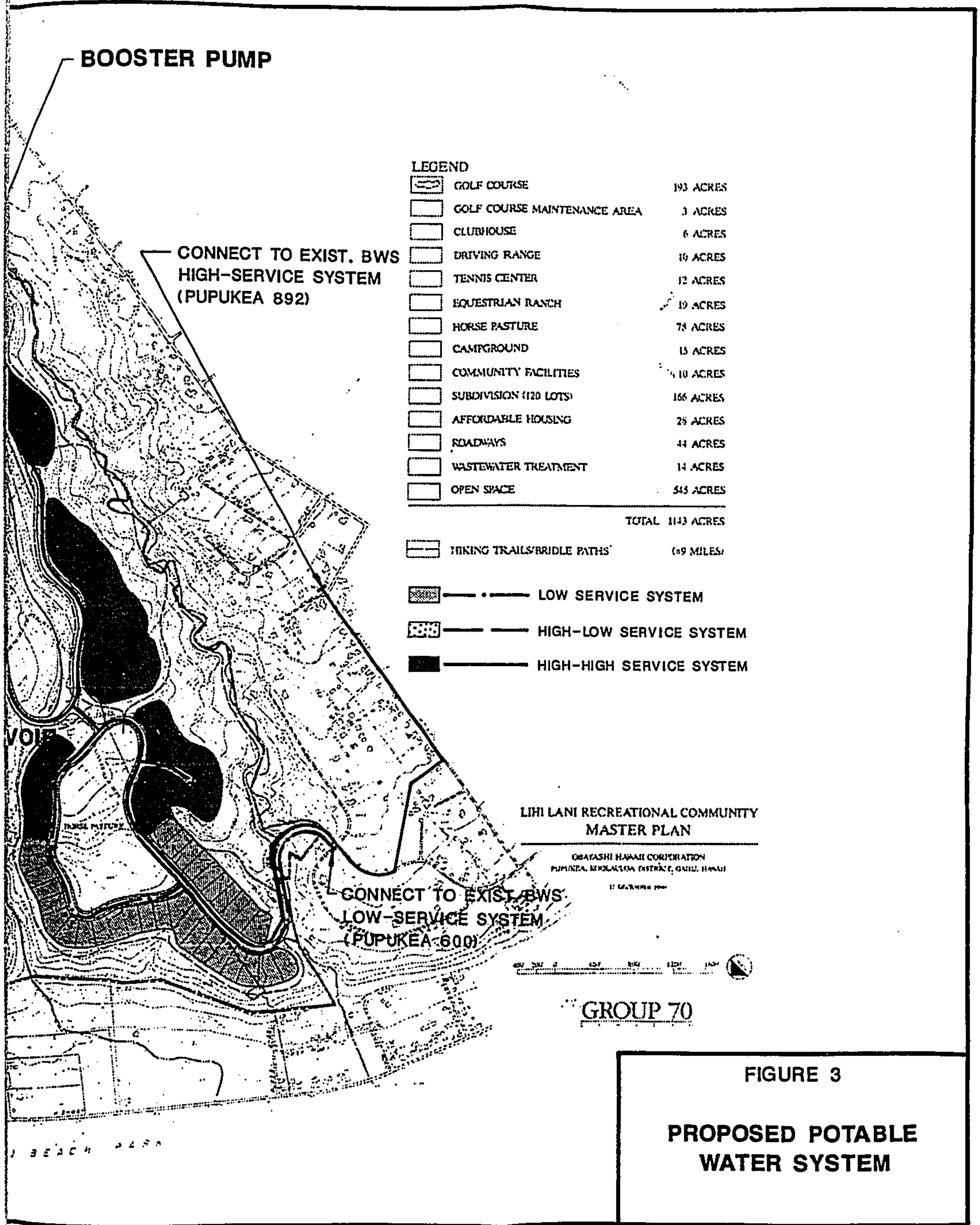
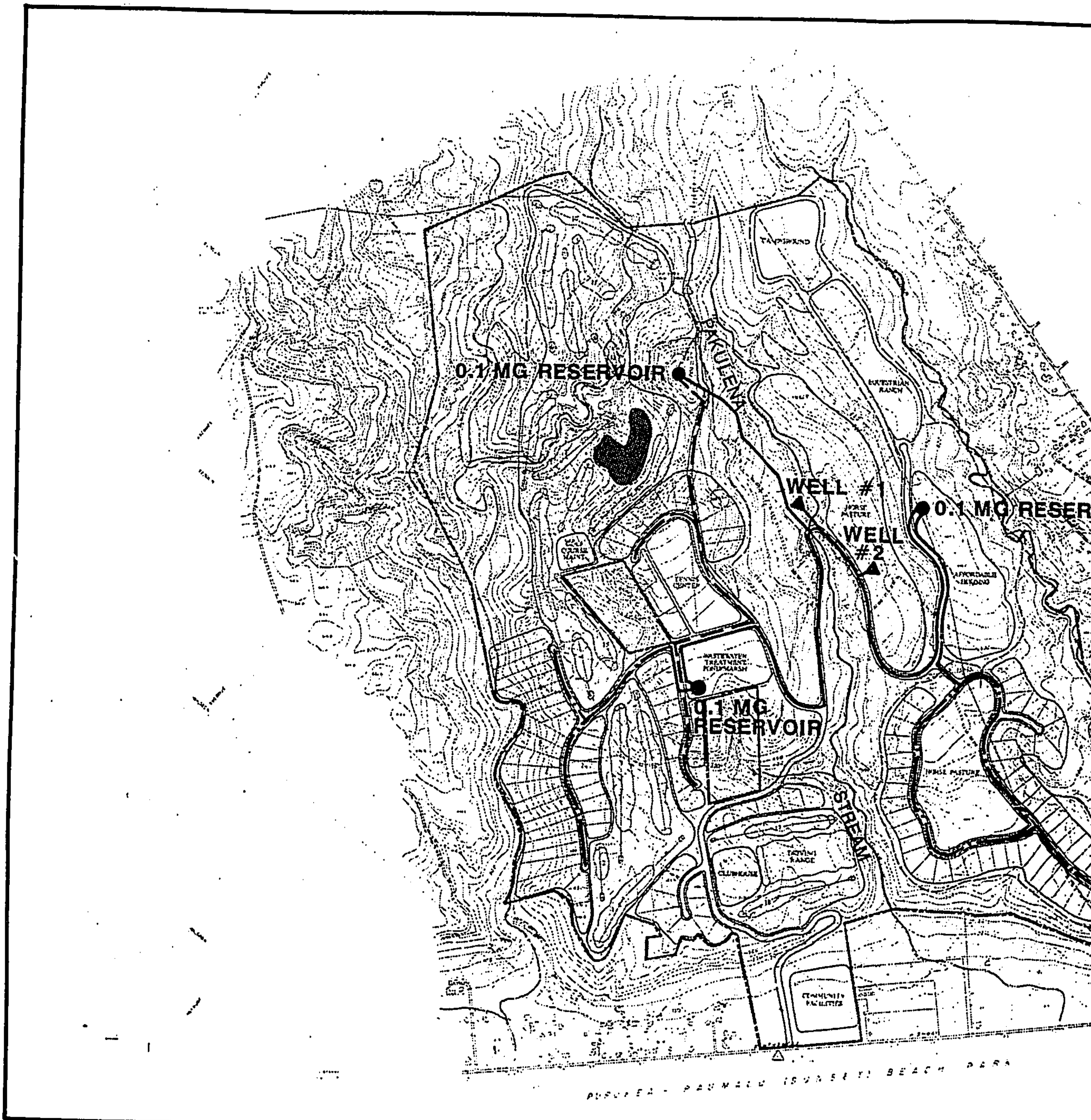


FIGURE 3

PROPOSED POTABLE WATER SYSTEM


0.1 MG RESERVOIR
PAKULENA
WELL #1
WELL #2
0.1 MG RESER
0.1 MG RESERVOIR
STREAM
PUPUKEA - PAUMALU (SUNSET) BEACH PARK

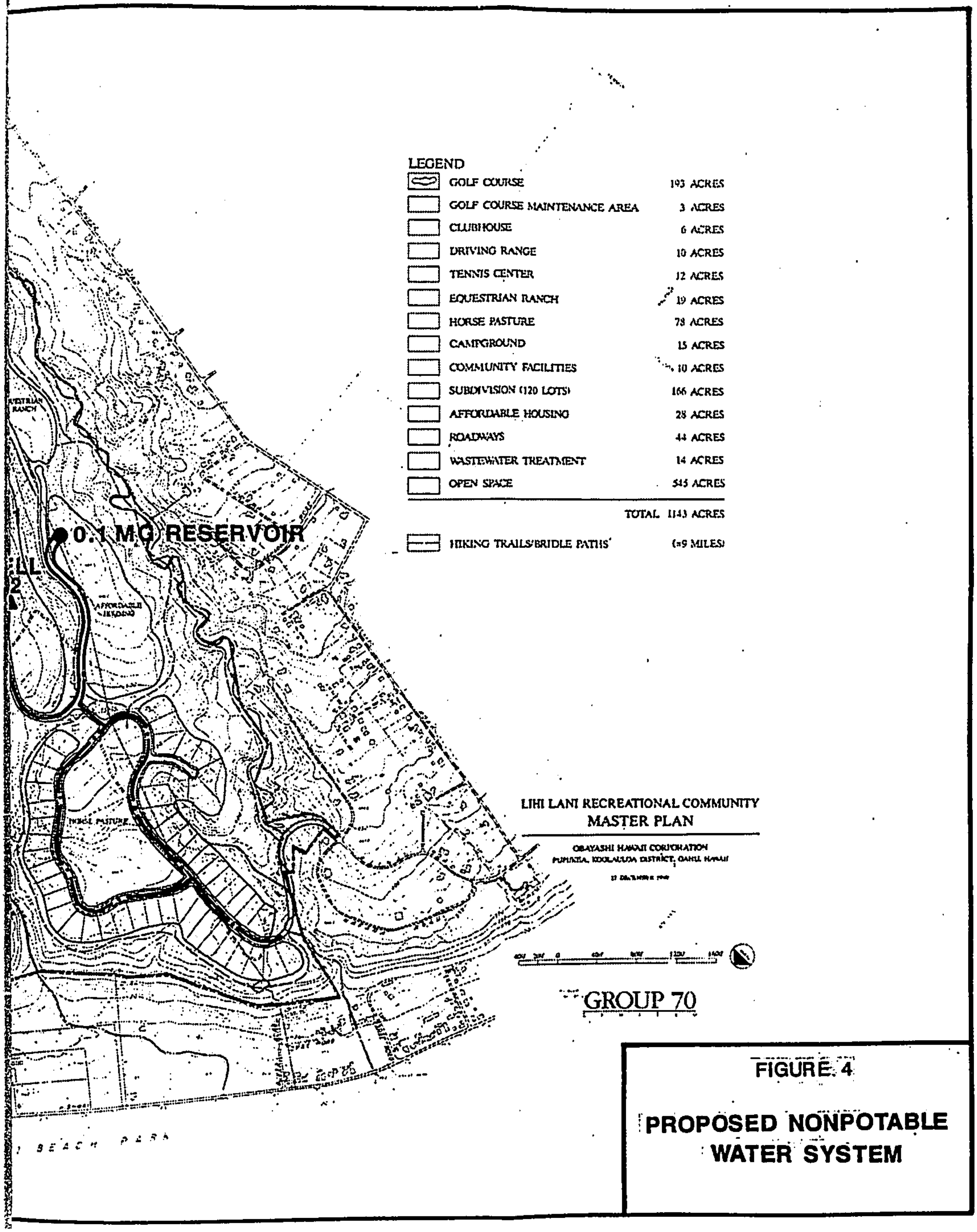
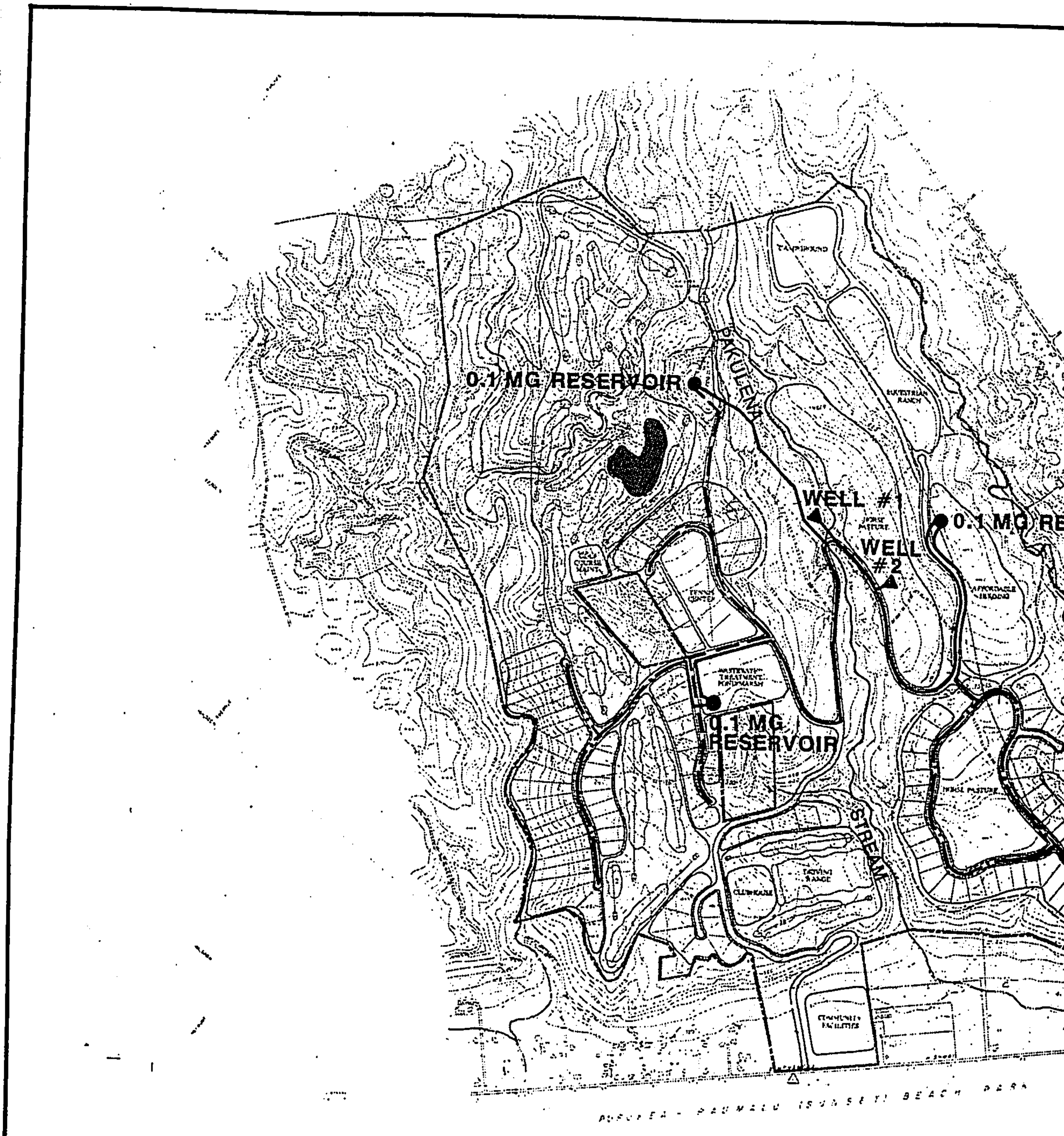


FIGURE 4

PROPOSED NONPOTABLE WATER SYSTEM

CORRECTION

THE PRECEDING DOCUMENT(S) HAS
BEEN REPHOTOGRAPHED TO ASSURE
LEGIBILITY
SEE FRAME(S)
IMMEDIATELY FOLLOWING


0.1 MG RESERVOIR
PAKULENA
WELL #1
WELL #2
0.1 MG RE
0.1 MG RESERVOIR
STREAM

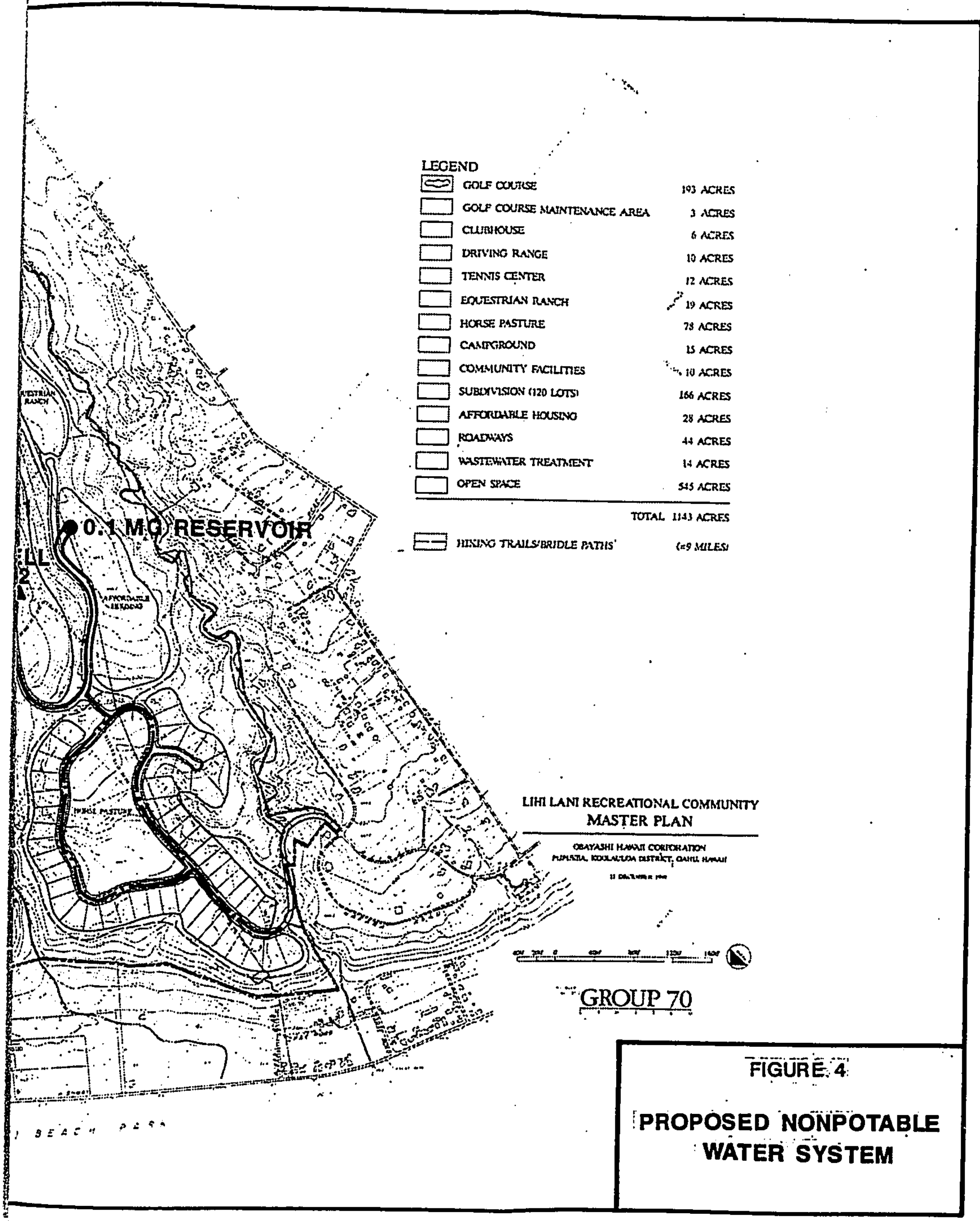


FIGURE 4

PROPOSED NONPOTABLE WATER SYSTEM

Pupukea 892-foot system and will be divided into high-high and high-low service zones. The high-high service zone will serve the equestrian center, campground, and 221 homes located above the 500-foot elevation. The high-low service zone will service the clubhouse and 46 homes located below the 500-foot elevation on the Kahuku side of the project site.

The 170-foot system is able to provide potable water to the planned Community Facilities at the 30-acre portion of the project site located in the coastal plain.

A new 0.3 MG reservoir will be constructed onsite at the 600-foot elevation to provide storage to meet clubhouse fire flow demands. The reservoir also acts as a breaker tank to reduce water pressure in the 892-foot system for distribution below the 500-foot elevation. The high-how system is necessary due to topographic constraints of the site. The alternative to the high-low system is a booster pump station to lift the low service water above the 500-foot elevation to service the clubhouse and homes in the low service zone on the north end of the site.

The estimated potable water demand for the three systems is--

<u>Low Service</u>		
33 Homes	<u>16,500 gpd</u>	
		16,500 gpd
<u>High-High Service</u>		
Equestrian Center	2,000 gpd	
221 Homes	110,500 gpd	
Campground	4,000 gpd	
Tennis Center	3,000 gpd	
Miscellaneous	<u>3,000 gpd</u>	
		122,500 gpd
<u>High-Low Service</u>		
Clubhouse	20,000 gpd	
46 Homes	<u>23,000 gpd</u>	
		<u>43,000 gpd</u>
	Total =	182,000 gpd

Thus, averge water withdrawal from the 892-foot reservoir will be the sum of the high-high and the high-low service demand, which is 165,500 gpd. The daily storage credit for the 892-foot reservoir system (161,667 gallons) is insufficient to meet the estimated demand. The additional 3,300-gallon storage capacity, required to meet the average daily demand, may be purchased from BWS through payment of a facility service charge.

<u>Nonpotable Water System</u>

Nonpotable water required for irrigation of the golf course and landscaping of the 120 market lots, clubhouse and other miscellaneous areas will be provided by existing onsite wells.

Two wells, drilled to depths below sea level, yield 0.5 MGD each, sufficient to meet irrigation water requirements. For additional information on groundwater conditions and well development, refer to the report "Groundwater Conditions, Pupukea Paumalu, Oahu" by John Mink (June 1988).

In addition to the onsite wells, an estimated 200,000 gpd of wastewater effluent will be available for irrigation once the project is fully developed. Effluent quality will be better than secondary treatment and will meet the standards set by the proposed Hawaii Administrative Rules, Title 11, Department of Health, Chapter 62, Wastewater Systems. Chlorinated effluent will be pumped from the onsite wastewater treatment and effluent polishing facility to a storage pond. Effluent and nonpotable well water will be blended in this pond for irrigation of the golf course. For additional information on effluent irrigation, refer to the report "Wastewater Management Plan for the Proposed Lihi Lani Recreational Community", by Engineering Concepts, Inc. (December 1990).

The irrigation pond situated within the golf course will have 4 to 8 MG capacity, providing up to ten days of storage capacity for irrigation of the golf course. In addition, the pond will be designed with 2 to 3 feet of freeboard above the normal water level to provide up to 10 days of effluent storage (during rainy periods when irrigation is not required). The irrigation pond will be lined to prevent exfiltration of irrigation water.

Irrigation of the lawn and landscape of market home lots will be accomplished by a separate sprinkler irrigation system fed by the nonpotable water distribution system. This system will be an underground piping system with sprinkler heads for lawn and landscaping watering. Hose bibb connections will not be permitted to the nonpotable water system.

POTENTIAL IMPACTS AND MITIGATION

Short-Term Impacts

Short-term impacts are construction related and may include dust, noise, and traffic disturbances in the Pupukea Highlands and Sunset Hills residential communities due to installation of water lines. Mitigation of these nuisances can be accomplished by limiting construction to weekdays during working hours when many residents are not at home; use of wind breaks or watering to reduce dust; and observance of approved traffic control plans.

Long-Term Impacts

Impact on the Waialua Aquifer. The sustainable yield of the Waialua groundwater control area is 100 MGD, and actual use in 1979 was reported at 71 MGD by the BWS. Thus, groundwater resources are available and additional development of resources should not adversely affect the Waialua aquifer. In all likelihood, an additional well, whether developed by the BWS or by the developer, will be required to meet the water demand for the project. This well will probably extract water from the Waialua aquifer.

Impact on Existing Water Users. Existing BWS consumers in the Pupukea Highlands and Sunset Hills subdivision who are serviced by the 892- and 600-foot reservoirs should not be adversely affected by the increase in water demand by the project's proposed water systems. Informal discussions with the BWS revealed the water systems in Pupukea are currently operating at one-fourth of their capacity. The systems were designed to handle the estimated additional water demand.

Impact of the Nonpotable Water Wells. In his report, "Groundwater Conditions, Pupukea-Paumalu, Oahu, "dated June 6, 1988, John Mink reports that groundwater flow beneath the golf course is directed toward the coast. The report also states that operation of the two wells proposed for nonpotable water development should have little, if any, adverse impacts on the BWS Sunset Beach wells. Percolation of irrigation water, consisting of nonpotable water and wastewater effluent, should not have a negative impact on the groundwater aquifer.

APPENDIX D

STORM DRAINAGE PLAN

FOR THE

PROPOSED LIHI LANI RECREATIONAL COMMUNITY

PUPUKEA, PAUMALU, KOOLAULOA, OAHU, HAWAII

Prepared by:

Engineering Concepts, Inc.
250 Ward Avenue, Suite 206
Honolulu, Hawaii 96814

December 1990

CONTENTS

TABLE

FIGURES

INTRODUCTION

Obayashi Hawaii Corporation is proposing to construct a golf course/residential development on the north shore of Oahu at Pupukea (TMK: 5-9-05:38 and 5-9-06:1, 18, 24). The 1,143-acre site is located mauka of Kamehameha Highway and Sunset Beach, surrounded by the COMSAT facility, forest reserve, and the Pupukea Highlands and Sunset Hills subdivisions (see Figure 1).

The objective of this report is to present preliminary engineering information pertaining to storm drainage for the proposed development. Specifically, this report will address--

1. Background information on the proposed project;
2. Identification of hydrologic parameters; and
3. Proposed drainage concepts.

PROJECT BACKGROUND

Proposed Project

The proposed Lihi Lani Recreational Community project will result in the development of approximately 598 acres within the 1,143-acre project site. Included is the proposed development of an 18-hole golf course with driving range and a clubhouse with banquet facilities; a tennis center, including a clubhouse with a snack shop and pro shop; an equestrian ranch with stables and riding trails; 120 estate-type residential home sites of one acre or larger; a 180-unit affordable housing complex; campground; several horse pastures (approximately 84 acres); and community facilities.

Topographic Features

Approximately 30 acres of the project site are situated along the coastal plain mauka of Kamehameha Highway and northeast of Sunset Beach Elementary School. The remaining

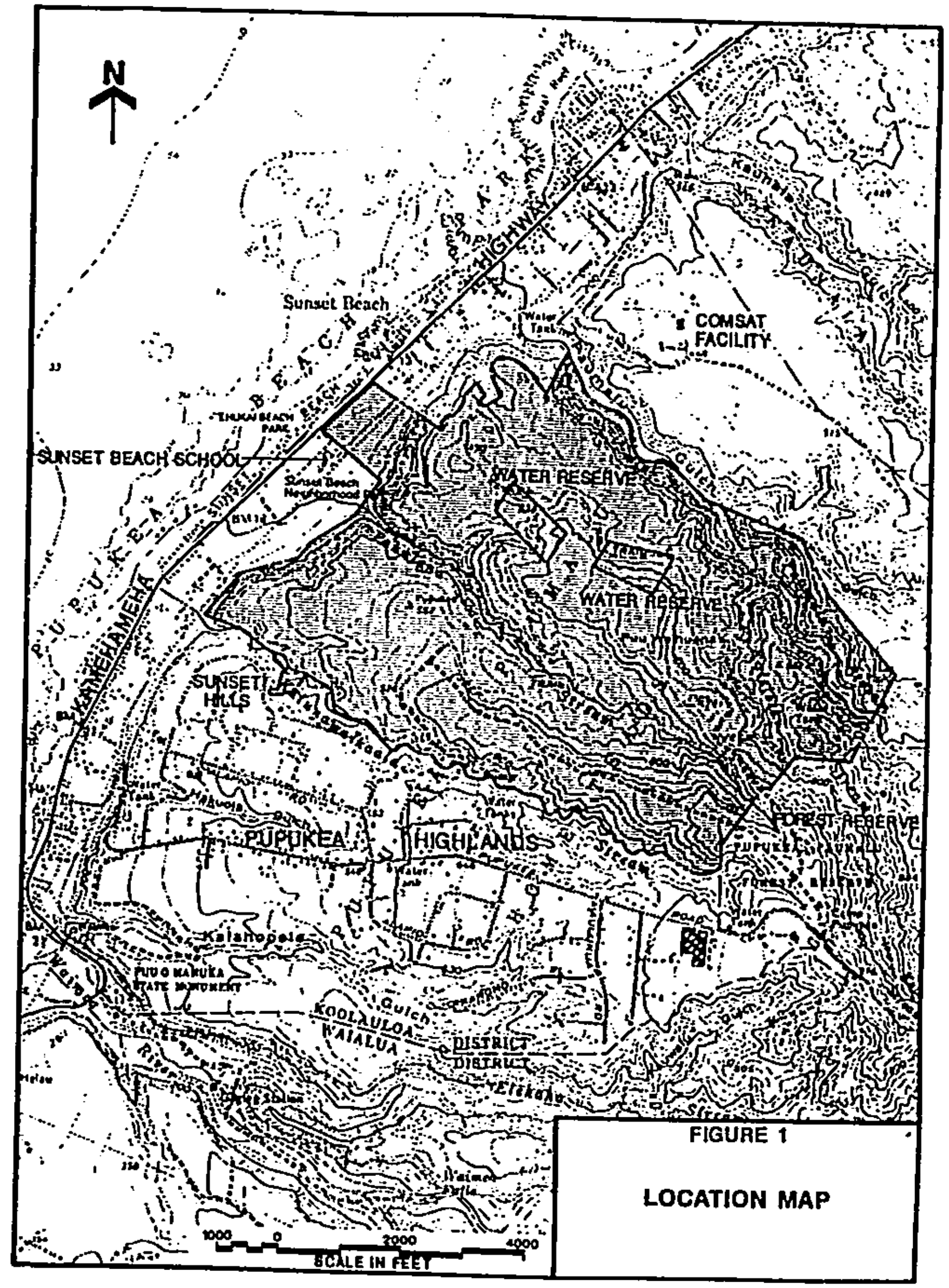


FIGURE 1

LOCATION MAP

area is located on an expanse approximately 6,000 feet wide and 8,000 feet in depth, separated from the coastal plain by a 200- to 400-foot high bluff.

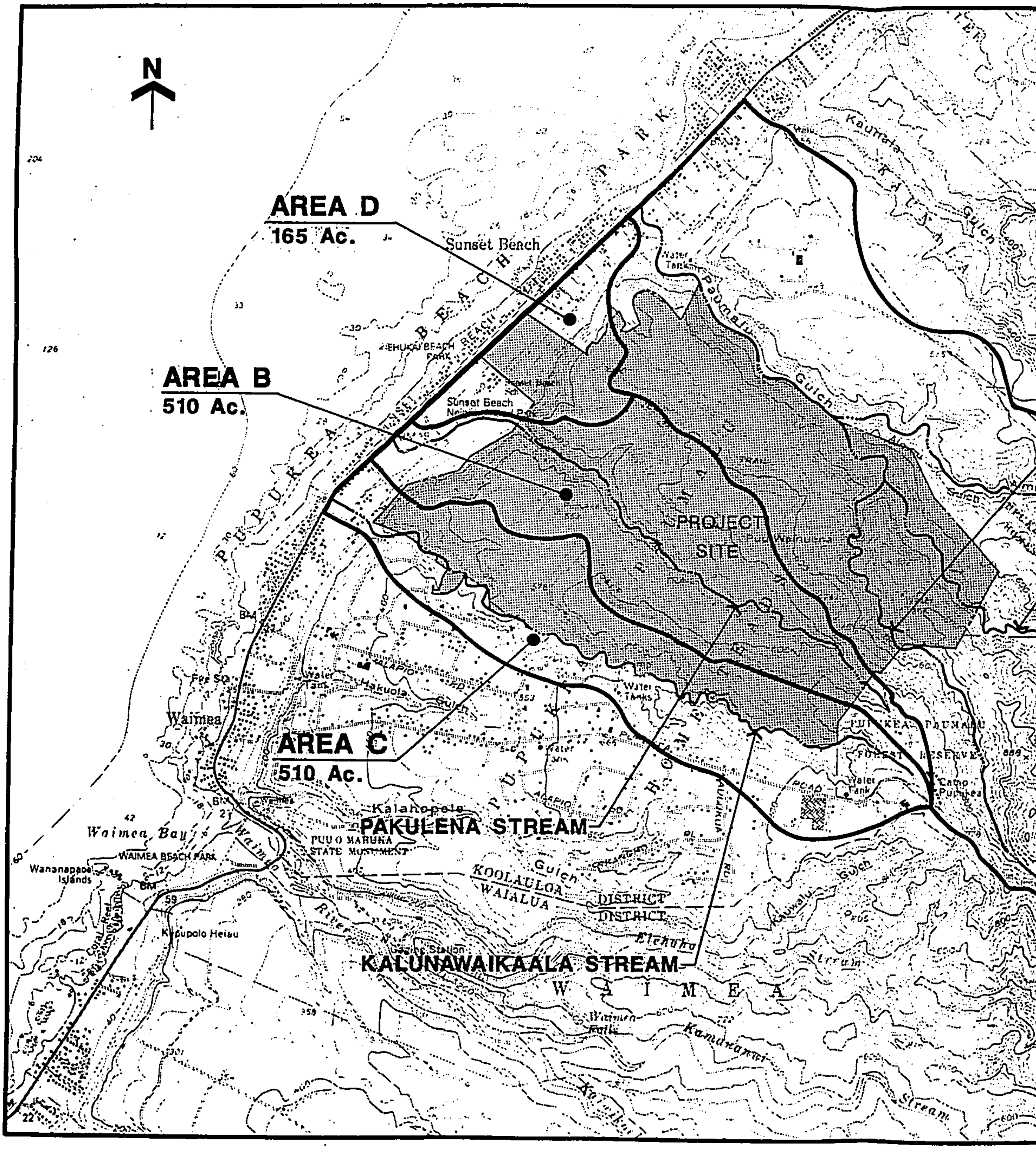
The site is isolated from neighboring properties on Kamehameha Highway by the bluff, and from neighbors on the northeast and southwest by the valleys of Paumalu Stream and Kalunawaikaala Stream respectively. Pakulena Stream bisects the site interior. The three streams flow intermittently, only during periods of heavy rain.

The elevation of the 30-acre coastal plain parcel varies from 20 feet to 75 feet while the elevation of major portions of the site varies from 200 feet to 840 feet in the mauka forest reserve region. Approximately one-fourth of the site slopes at less than 20 percent.

The property spans three major watersheds (Figure 2), the Paumalu Gulch watershed, the Pakulena Stream watershed, and the Kalunawaikaala Stream watershed. A portion of the property does not appear to drain to any of the watersheds, sloping directly toward Kamehameha Highway.

The Paumalu Gulch watershed is the largest of the three watersheds affected by the project. It encompasses approximately 1,970 acres and stretches almost 3.5 miles inland from Kamehameha Highway to the Pupukea-Paumalu Ridge. The Paumalu Gulch watershed contains three subwatersheds feeding Aimuu Gulch, Paumalu Stream, and Kaleleiki Stream, none of which are perennial.

The Pakulena Stream watershed covers approximately 510 acres, most of which fall on the project site. The Pakulena Stream watershed ends approximately 2 miles inland from Kamehameha Highway at an elevation of 960 feet above sea level.



N
AREA D
165 Ac.
Sunset Beach
AREA B
510 Ac.
PROJECT SITE
AREA C
510 Ac.
PAKULENA STREAM
KALUNAWAIKAALA STREAM
Waimea Bay
WAIMEA BEACH PARK
Wananapaoe Islands
Kupupolo Heiau
PUU O MAHUKA STATE MONUMENT
KOOLAULOA DISTRICT
WAIALUA DISTRICT
W A I M E A
Waimea Falls
Kamananui
Stream
Waimea
Sunset Beach Neighborhood Park
Paumalu Gulch
Kaunala Gulch
Hakuola Gulch

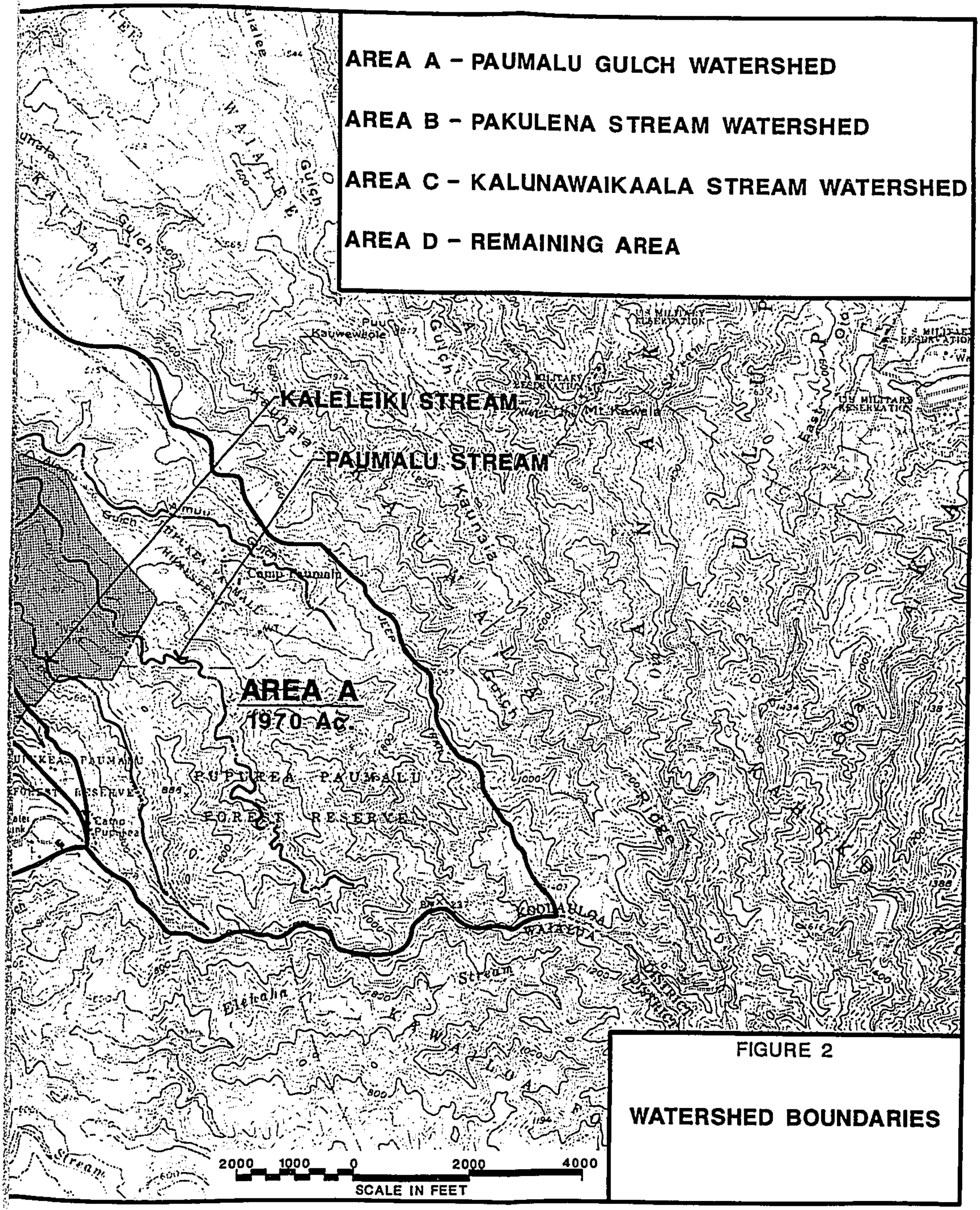


FIGURE 2

WATERSHED BOUNDARIES

The third watershed, Kalunawaikaala Stream watershed, also covers an area of approximately 510 acres. Portions of Sunset Hills and Pupukea Highland subdivisions fall within this watershed. The Kalunawaikaala Stream watershed converges with the Pakulena Stream watershed approximately 2 miles inland from Kamehameha Highway.

The three watersheds are characterized by steep gulches bordering relatively flat to rolling plateaus. The plateaus are covered with tall grasses, scrub brush, and trees, with the gullies having dense tree cover and moderately thick underbrush.

Climate

The median annual rainfall is 51.7 inches. Tradewinds from the sea average 8.9 mph, blowing slightly stronger during the day. The average temperatures in the summer are 83 degrees during the day and 69 degrees at night, while winter temperatures average 77 degrees during the day and 64 degrees at night. Relative humidity averages 74.6 percent during the day.

EXISTING CONDITIONS

Currently, there are no drainage improvements on the project site. Runoff flows overland to the three gulches and is conveyed to existing culverts at Kamehameha Highway. The culvert serving the Paumalu Gulch is located approximately 3,200 feet north of the property, with the culverts serving the Pakulena and Kalunawaikaala streams located approximately 2,200 feet and 3,800 feet south of the property respectively. The runoff from Area D (Figure 2) flows overland to Kamehameha Highway.

Flooding of the area is known to occur during heavy rains. Much of the flooding can be attributed to the many sump areas along Kamehameha Highway between the Paumalu and Pakulena stream crossings. A flood insurance study for the City and County of Honolulu was prepared by the U.S. Army Corps of Engineers in 1980. This report included the Sunset Beach area and mentioned that "...the principal flood problem in the area is the lack of

defined streams adequate to convey storm runoff to the oceans." The three streams serving the major watersheds become less defined as they move away from the bluffs. The report further mentions that flooding in the lower flat lands "...is due to the lack of adequate drainage systems and local depressions." Obstruction of the stream crossings at Kamehameha Highway may also contribute to the flooding of the area. The culverts were observed to be clogged with sand, rubbish, and vegetation, with the channels to the ocean filled with sand to the point of being barely discernible.

MODIFICATIONS AFTER DEVELOPMENT

The proposed development will spread across approximately 605 of the property's 1,143 acres; however, the actual area that will be affected by construction of the improvements will be less.

Proposed areas for the various land uses in each affected watershed and the remaining area are listed in Table 1.

Much of the unimproved areas consist of steep terrain along the slopes of the gulches or buffer strips separating the golf course fairways.

Drainage patterns are expected to remain similar to existing conditions, although some diversions of runoff through the golf course and internal roads are proposed. It is anticipated that the natural slopes and vegetation of most of the areas unaffected by construction of the improvements would be maintained.

IMPACT AND MITIGATION

The proposed development will increase the quantity of peak runoff generated onsite; however, the golf course and horse pastures provide a means of minimizing the impacts of the increased runoff. Runoff generated onsite will be routed through the golf course and horse pastures to dampen the peak runoff rate such that the runoff conveyed by the streams is expected to remain at the levels experienced with existing conditions. Detention features are planned to be incorporated in the golf course and horse pasture layouts. Sand traps, flat areas in and adjacent to fairways, local sumps and basins, and other golf course features will aid in dampening the peak runoff. Ponding areas to provide detention will be constructed in the horse pastures.

The impact of the subdivision lots and affordable housing area on runoff is expected to be minimal. Many of the lots and much of the housing area will drain onto the golf course or horse pastures allowing the runoff to be routed through detention basins. The remaining areas are located along the edge of the bluffs, with runoff sheet flowing to the three drainageways. The dense, natural vegetation along the gulch is expected to dampen the runoff, minimizing the impacts of any increase in runoff. Although the subdivision lots are large, many lots have considerable areas that are not useable, falling on steep slopes. This condition limits the possible improvements that will also minimize increase in runoff. Detention basins and injection wells will be provided in the low-lying area adjacent to Kamehameha Highway to offset any increase in runoff due to improvements proposed for the community facilities, the main access road and the area immediately mauka of this site.

CONCLUSION

Due to the nature of the development with its large, open spaces, it is expected that the overall impact of drainage in the area will be minimal. Increases in runoff will be routed through the proposed golf course and horse pastures to dampen the peak runoff rate. Much of the natural vegetation along the gulches and undisturbed areas are expected to remain, further minimizing the impact of runoff from the project. Detection/retention features are planned to be incorporated in the design of the proposed golf course and horse pastures. Additional detention features will be provided, as necessary, in the low-lying areas adjacent to Kamehameha Highway. Actual sizes and locations of these features will be determined during the design stage of the project. Peak discharge rates to be used for design will be estimated in accordance with the latest City and County of Honolulu Storm Drainage Standards. Erosion conrol plans will be prepared for construction during the design stage in

TABLE 1

PROPOSED LAND USE WITHIN WATERSHED AREA

			Proposed Land Use (acres)					
Watershed	Total Watershed Area (acres)	Property (acres)	Residential	Golf Course	Horse Pasture	Other Uses	Roadways	Open Area
Paumalu Gulch	1,970	428	75	181	1	2	7	162
Pakulena Stream	510	430	44	5	77	50	24	230
Kalunawaikaala Stream	510	208	63	0	0	19	7	119
Remainder	165	77	7	10	6	21	6	27
TOTAL		1,143	189	196	84	92	44	538

accordance with the City and County of Honolulu Soil Erosion Standards & Guidelines.

APPENDIX E

Market Assessment for the Proposed Lihi Lani Master-planned Community

Pupukea, Oahu, Hawaii

Prepared for

OBAYASHI HAWAII CORPORATION

January 1991

LIHI LANI RECREATIONAL COMMUNITY

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LIHI LANI RECREATIONAL COMMUNITY

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LIHI LANI RECREATIONAL COMMUNITY

Table of Contents, Continued

I - EXECUTIVE SUMMARY

This chapter reviews the background and scope of the market assessment for Lihi Lani and summarizes the conclusions of our study. The detailed analyses and explanation of findings and conclusions are presented in the following chapters.

BACKGROUND

Obayashi is planning to develop Lihi Lani, a recreation-oriented community on about 1,143 acres of land located near Pupukea in the Koolauloa Census Division of the island of Oahu. The property is located on the mauka side of Kamehameha Highway, near the Boy Scout and Girl Scout camps and Sunset Hills subdivision and about 60 minutes by car from Honolulu and Waikiki. The property rises to an elevation of about 850 feet, providing panoramic views of Sunset Beach.

The property is planned as a residential community that would provide a wide range of recreational amenities such as a golf course, a tennis center, equestrian ranch, hiking trails, campgrounds and picnic areas. The residential element will consist of 120 lots and 180 affordable homes.

STUDY OBJECTIVE

The objective of this study is to evaluate the potential market support for the golf, tennis, horseback riding and residential elements of Lihi Lani and to project its anticipated market performance in terms of:

- Sales absorption or expected demand
- Pricing
- Usage

PROJECT OVERVIEW AND PROPOSED DEVELOPMENT PHASING

Lihi Lani is proposed to be a master-planned recreational and residential community, offering:

- 120 country-zoned lots
- 180 affordable homes
- Semiprivate Jack Nicklaus designed 18-hole golf course
- Golf clubhouse and amenities
- Driving range
- Equestrian ranch
- Tennis center
- Campgrounds
- Hiking and horseback riding trails
- Community parks

The phasing is planned to commence with the development of the golf course, clubhouse, equestrian ranch, campgrounds and a first increment of about 60 lots and 90 affordable homes by 1995. The tennis center and a second increment of about 30 lots and 50 affordable homes are expected to be completed in 1996. The last increment of about 30 lots and 40 affordable homes would complete the development of Lihi Lani by 1997. All homes are expected to be constructed by 2000.

GOLF COURSE MARKET ASSESSMENT

This section summarizes the planned facilities and anticipated market support for the proposed golf course.

Proposed Golf Course Facilities

The semiprivate course at Lihi Lani is expected to represent an important activity center for the development and members of the community. The golf course and clubhouse would offer:

- Breakfast, lunch and dinner restaurant with ocean views
- Cocktail lounge
- Indoor/outdoor snack bar
- Swimming pool
- Tennis courts
- Driving range

Membership Pricing Structure

Because of the golf course's location about 60 minutes away from Honolulu, and the out-of-state market for private memberships, it is anticipated that the course could support up to about 500 members without jeopardizing the quality of the course or of play. Initiation fees are proposed to be slightly below those of the older, more established clubs of Oahu, and could range as follows:

Proposed Membership Initiation Fees
at the Golf Course

(1990 dollars)

Full golf	$ 25,000 - 30,000
Limited golf	15,000 - 20,000
Social	4,000 - 6,000

Monthly dues for residents and nonresidents of the state are proposed to be competitive with those offered by other private clubs, as explained in Chapter IV.

Projected Utilization Pattern

The course is projected to support about 47,500 rounds of play per year, or an average of about 130 per day. Players could include local residents, members and visitors, with a stabilized market mix in the fifth year of operations as follows:

Projected Rounds of Play at the Golf Course

1999

	Average rounds of play	Percent distribution
Local players	60	46%
Members	50	39
Oahu visitors	20	15
Total	130	100%

Projected Green and Cart Fees

Green and cart fees for nonmembers are projected to be approximately as follows:

Projected Average Nonmember Green and Cart Fees at the Proposed Golf Course

(1990 dollars)

	Total fees(1)
1995	$ 75
1996	75
1997	80
1998	85
1999	85

(1) Per person, assumes two persons per cart.

Due to their membership fees and dues, members are expected to pay only a cart fee at the time of play and this is projected to be about $7.00.

TENNIS MARKET ASSESSMENT

This section reviews the proposed facility, projected target markets, recommended marketing, proposed fee structure and projected utilization patterns.

Proposed Tennis Facilities Concept

The Lihi Lani Tennis Center is proposed to be developed as a complete tennis club with:

- 12 tennis courts, including two to three clay or grass courts
- Clubhouse, including two to four indoor racquetball courts
- Swimming pool
- Walkways, landscaping, entry road and other infrastructure

The total of 12 tennis courts would make Lihi Lani the largest private tennis facility on Oahu.

Projected Target Markets

Based on the review of the users of private tennis facilities, the tennis center could be marketed to several different segments, including:

- Lot owners at Lihi Lani
- Golf club members
- Residents from the North Shore and Koolauloa communities
- Other Oahu residents and visitors

Recommended Marketing of the Tennis Center

The Lihi Lani Tennis Center could be marketed as a family-oriented tennis facility:

- The tennis center could provide an alternative activity center for nongolf-playing golf club members, homeowners and their families.

- Tennis-only members would have a membership at a stand-alone tennis center competitive with any other tennis facility in the state in terms of courts, amenities and services. The family-oriented facility could offer a full schedule of activities and events such as organized tennis camps, family-oriented doubles, junior player (under 18 years old) development, age group competitions and the traditional tennis ladders for club champions in men's, women's, doubles and mixed doubles categories. The club could also sponsor grass court, clay court, hard court and all-surface club championships.

- Daily fee tennis players could primarily be attracted by the opportunity to reserve court times, play on one or more surfaces and to visit the recreational community. Family aspects could include having other members participating in group clinics or lessons, horseback riding or golfing.

- Junior development programs including tournaments and adequate access to facilities for teenagers in the North Shore and Koolauloa areas could have positive long-range implications for the community. In the long run, a tennis development program creates exposure for the sport and a junior development tennis program would help to make Lihi Lani a contributing part of the overall North Shore and Koolauloa communities.

Proposed Tennis Membership and Daily Fee Structure

Based on the current private tennis club's membership fee structures and the preliminary facilities concept of the proposed Lihi Lani Tennis Center, a proposed tennis membership could be structured, as follows:

Proposed Lihi Lani Tennis Center
Membership and Daily Fee Structure

(1990 dollars)

Type of membership	Initiation fee	Monthly dues	Guest fees(1)
Golf social and tennis club(2)	$6,000	$25 - $100	$10(3)
Tennis club(4)	5,000	60 - 80	10(3)
Daily fee play:			
Hard courts	-	-	8(5)
Clay courts	-	-	12(5)
Grass courts	-	-	15(5)

(1) Includes daily fee players.

(2) Includes tennis membership and discounts at the equestrian center, but no golf course privileges.

(3) Per guest per day.

(4) Includes discounts at the equestrian center.

(5) Per person per hour usage.

It should be noted that all of the golf club categories, except for the social-only memberships, will also have tennis center privileges.

Projected Utilization Patterns

Tennis court usage tends to occur in the early morning and late afternoon hours during weekdays and throughout the day during weekends. The different market segments could be managed to have complementary utilization patterns of play as follows:

- Local daily fee and club members would generally desire the prime time hours of early morning and late afternoon. A well-managed reservation system with a three- to five-day advance reservation privilege for members and one- to two-day advance reservation system for nonmember daily fee users should be able to accommodate both market segments.
- Visiting daily fee players, retirees, junior players and other community residents with more flexible schedules could be targeted for nonprime time hours on the weekdays with group clinics, individual instruction or possibly lower daily fee rates for play. This could help to enhance playing time during nonpeak hours.

In addition, lighted courts extend the peak late afternoon and early evening playing period for several hours, thus accommodating more of the membership and daily fee players.

EQUESTRIAN MARKET ASSESSMENT

This section presents the proposed facilities concept of the Lihi Lani Equestrian Ranch, and the recommended marketing strategy, proposed fee structure and expected utilization patterns.

Proposed Equestrian Ranch Facilities Concept

The proposed equestrian ranch is planned to include:

- Two to three barns with stables for up to 100 horses
- Covered arena area
- Two paddocks
- Feed and maintenance structure
- Horse trailer parking
- Riding trails, entry road, buffer and other areas
- Turnout pastures for exercise
- Jumping equipment for training
- Grooming, washing and hospital stalls
- Extensive trails
- Manager's office

The equestrian ranch site would have access to excellent riding trails that would run throughout the Lihi Lani community.

Projected Target Markets

Based on the market overview of equestrian facilities and users, the Lihi Lani Equestrian Ranch could target two segments: the Lihi Lani community and other Oahu residents that wish to stable their horses at the facility for recreational riding and equestrian training.

Recommended Marketing of the Equestrian Ranch

Based on the target markets and projected demand for services of these markets, several marketing methods could be utilized:

- Offer full service, state-of-the-art equestrian facilities.
- Create activity in family-oriented activities.
- Offer trails and wide-open pastures.
- Provide training facilities.

The ranch would also help to differentiate Lihi Lani from other Oahu developments by offering an equestrian atmosphere to the community.

Proposed Equestrian Stable Rates and Projected Utilization Patterns

Based on current fee structures at Oahu equestrian facilities and the preliminary facilities concept of the equestrian ranch at Lihi Lani, proposed stable fees range between $150 and $400 per month. Stable fees would depend on services provided, with the lower range reflecting lease rates with minimal services and the higher range including feeding of horses and maintenance of stalls.

Horse boarders are expected to be primarily Lihi Lani community and surrounding North Shore and Koolauloa residents. About 70% of the riders are expected to be from these regions.

CABIN MARKET ASSESSMENT

Twelve cabins are planned to be completed in 1995 at Lihi Lani's campground. The cabins are expected to be used primarily on the weekends with year-round weekend occupancy expected to be between 30% and 35%. The rates are expected to be about $75 per weekend (Friday and Saturday nights) in 1990 dollars.

RESIDENTIAL MARKET ASSESSMENT

This section reviews development concepts, target markets, pricing and sales absorption of the proposed lots and briefly reviews the pricing of the proposed affordable homes.

Development Concept

The residential portion of the development is planned to be a fee simple lot subdivision of 120 one-acre and larger lots and 180 affordable homes. Lot purchasers could be granted reduced price memberships and fees in the private golf club, tennis center and equestrian ranch in order to further integrate the residential and recreation elements of the development and to encourage a stable resident base for the recreational facilities. The affordable homes are planned to be developed in accordance with county guidelines.

Target Markets for Lots

The market for residential lots is expected to be composed principally of those seeking a primary residence or future retirement home, and secondly of couples or families seeking a second or vacation home. Obayashi plans to offer the lots to Hawaii residents prior to other potential buyers, thus giving state residents an advantage in purchasing lots. The expected buyer market mix is summarized as follows:

Projected Lihi Lani Lot Buyer Market Mix

Primary place of residence	Full-time	Part-time	Total
State of Hawaii	45%	35%	80%
Other	5	15	20
Total	50%	50%	100%

Proposed Lot Pricing

Initial lot sales prices are estimated to range as follows:

Projected Typical Lot Sales Prices at Initial Marketing

(1990 dollars)

Lot view orientation	Low	High
Prime ocean view	$ 375,000	425,000
Distant ocean/golf	325,000	375,000
Golf course	275,000	325,000
Other	180,000	220,000

Anticipated Lot Sales Absorption

There are currently no firm plans for competitive second home and golf-oriented large lot subdivisions on Oahu. Thus, due to the growing population of the island and the strength of the second home market in Hawaii, it is anticipated that sales absorption of the project could be fairly rapid. Based on the above prices and current market conditions, the 120 lots could be expected to be completely sold within three years of marketing, or by about 1997, as follows:

Projected Lot Sales Absorption

1995 to 1997

	1995	1996	1997
Annual lot sales	60	30	30
Cumulative lot sales	60	90	120

The above projected lot sales absorption assumes that:

- The project would be professionally and aggressively marketed at prices in the ranges indicated.
- All residential-related infrastructure and the lot subdivision would be completed according to the development schedule described previously.

- A golf course would be available for play within the first year of marketing.
- A model home would be completed within the first year of marketing.

Affordable Housing Pricing

Due to the strong demand for affordable homes on Oahu, absorption of this part of the development is expected to be rapid. The affordable housing units at Lihi Lani are projected to be developed in compliance with county policies on such development, which relate home prices to county median household incomes. However, this is subject to the county's approval.

Four-member households that earn from 80% to 100% of the Oahu median income are expected to be able to afford to purchase homes within the $90,000 to $120,000 range, in 1990 dollars. Households earning 120% to 140% of the Oahu median income are expected to be potential buyers of homes within the $135,000 to $165,000 range, also in 1990 dollars.

II - PROJECT OVERVIEW AND REGIONAL SETTING

This chapter describes the planned development at Pupukea and reviews economic and demographic trends for the island of Oahu, and in the North Shore and Koolauloa areas on Oahu, as pertinent to the outlook for development in this area.

PROJECT OVERVIEW

This section reviews the preliminary development plans for the master-planned community and characteristics of the project site.

Preliminary Development Concept

Obayashi plans to develop a recreational community on about 1,143 acres of land at Pupukea in the Koolauloa region on the island of Oahu, located as shown in Exhibit II-A.

The development would be a recreation-oriented community with a variety of products and amenities situated as shown in Exhibit II-B, and described as follows:

- 120 country-zoned lots
- 180 affordable homes
- Semiprivate Jack Nicklaus-designed 18-hole golf course
- Golf clubhouse and amenities
- Driving range
- Equestrian ranch
- Tennis center
- Campgrounds
- Hiking and horseback riding trails
- Community parks

The golf course, tennis center, equestrian ranch, campgrounds, trails and parks would be available to the local and visitor markets.

The golf course, clubhouse, equestrian ranch, campgrounds and a first increment of about 60 lots and 90 affordable homes are expected to be constructed by 1995. The tennis center and a second increment of about 30 lots and 50 affordable homes are expected to be completed in 1996. The last increment of about 30 lots and 40 affordable homes would complete the development of Lihi Lani by 1997. All homes are expected to be constructed by 2000.

Site Description

The project site is located on the mauka (mountain) side of Kamehameha Highway, near to the Boy Scout and Girl Scout camps and the Sunset Hills subdivision in the Pupukea area of Oahu, about 60 minutes from Honolulu and Waikiki. The property is distinguished by two plateaus and three valleys. The site rises from the highway to about 850 feet above sea level, offering spectacular sunset and ocean views.

LIHI LANI RECREATIONAL COMMUNITY

Proposed Site Plan

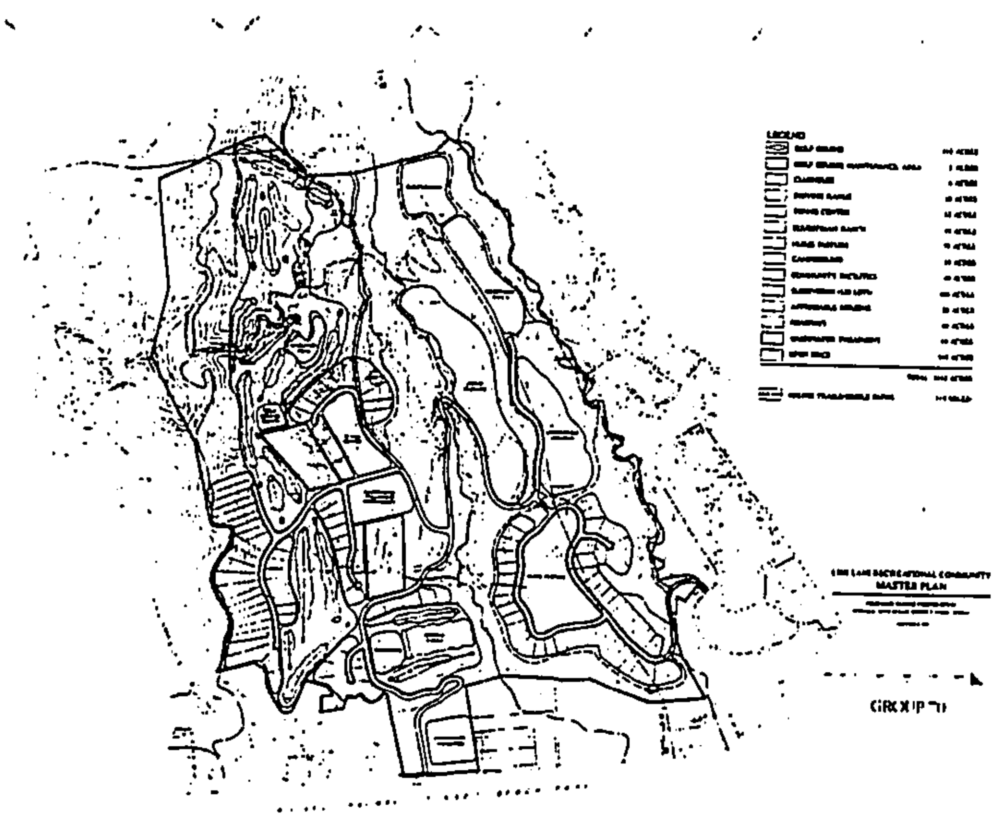

Exhibit II-B

LIHI LANI RECREATIONAL COMMUNITY

Location Map of the Proposed Lihi Lani Recreational Community

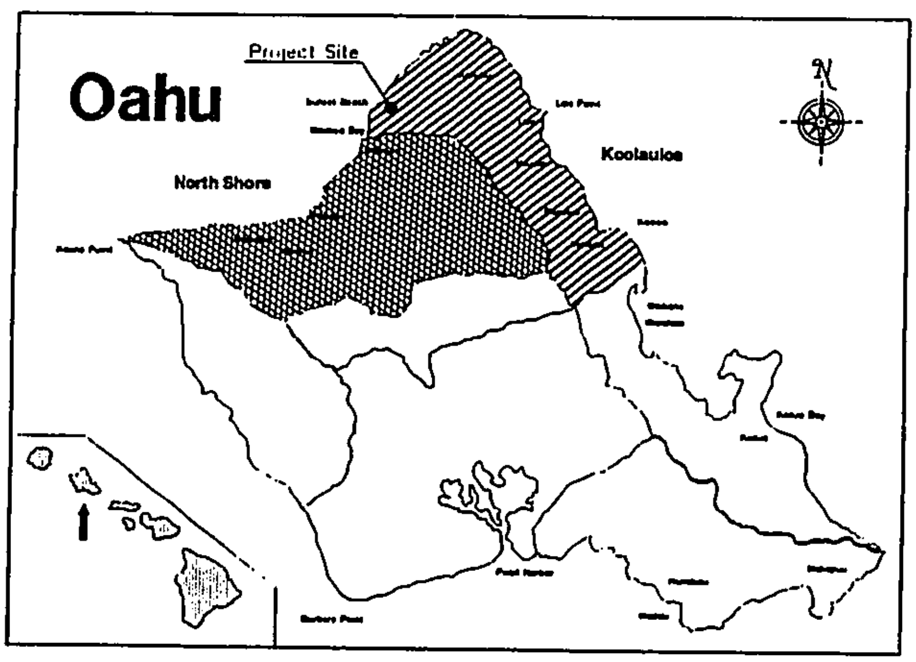

Exhibit II-A

REGIONAL SETTING

Oahu is the third largest island in Hawaii, covering a land area of 618 square miles. Oahu is the center of business and government for the state of Hawaii. This section briefly reviews the characteristics of Oahu and its Koolauloa and North Shore regions.

Oahu Resident Population

In 1989, Oahu contained about 76% of Hawaii's resident population, although it comprises only about 10% of the state's land area. During 1989, Oahu was estimated to have a population of 841,600, including military personnel.

The growth rate of the resident population is projected by the Hawaii State Department of Business and Economic Development (DBED) to decrease from the 1.1% per annum rate of growth experienced from 1987 to 1990, to 0.7% per annum through 2000.

Definition of Koolauloa
and North Shore Regions

The subject site is located near the North Shore edge of the Koolauloa region which is defined as the U. S. Census Divisions 101, 102.2 and 102.1. The area constitutes the northern half of Oahu's windward coast, bounded by the north end of the Koolau Mountains and extends from Kaaawa Stream to Waimea Bay. Kamehameha Highway is the main roadway linking this area with the adjacent North Shore region. Residential communities bordering the highway include Kaaawa, Punaluu, Hauula, Laie, Kahuku, Sunset Beach and Waimea.

The Koolau and Waianae mountain ranges and the areas from Waimea Bay to Kaena Point form the main boundaries for the traditionally rural communities of the North Shore. The primary land uses in this region have traditionally been agricultural. Coastal residential areas are concentrated at Mokuleia, Waialua, Haleiwa, and Kawailoa. The area is defined as U. S. Census Divisions 99.01, 99.02 and 100.

Koolauloa and North Shore Economy

The opening of the Kuilima Resort area in 1972 has had the most significant economic impact for the area with an estimated 500 jobs created by the resort since its inception. It is estimated that the total job count for Kuilima could grow to 3,000 by the time all phases of the resort are completed. Development plans at Kuilima include the addition of a 383-room luxury hotel, an additional 18-hole championship golf course and new clubhouse, a 60,000 to 100,000 square foot commercial center, a tennis center which will add 10 courts to the resort and proposed multifamily developments phased in over the next 10 years.

The North Shore and Koolauloa Districts could have increased tourism and drive-through visitors in the years ahead as Kuilima Resort expands and as attractions such as professional surfing events continue to attract visitors. In addition, the Polynesian Cultural Center (PCC), located in Laie, is Hawaii's largest paid tourist attraction according to state tourism statistics.

Koolauloa and North Shore
Resident Population

The 1980 resident populations of the North Shore and Koolauloa regions were 9,800 and 14,200, respectively, as shown in Exhibit II-C. This represented an annual compounded growth rate of 0.6% and 3.0% from 1970 to 1980 for the North Shore and Koolauloa regions, respectively.

The 1989 resident populations of the North Shore and Koolauloa districts were estimated at 11,500 and 14,200, respectively, by the state. This represented an annual compounded growth rate of 1.8% and 2.2% from 1980 to 1989 for the North Shore and Koolauloa, respectively.

Exhibit II-C

LIHI LANI RECREATIONAL COMMUNITY

Resident Population of the
North Shore and Koolauloa Regions of Oahu

1970 to 1989

	North Shore(1)	Koolauloa(2)	Total
Historical:			
1970	9,200	10,600	19,800
1980	9,800	14,200	24,000
Estimated(3):			
1989	11,500	17,200	28,700
Compounded annual percentage increase:			
1970 to 1980	0.6%	3.0%	1.9%
1980 to 1989	1.8	2.2	2.0

(1) Defined as census tracts 99.01, 99.02 and 100.

(2) Defined as census tracts 101, 102.02 and 102.01.

(3) Based on July 1, 1989 estimates by State of Hawaii, Department of Business and Economic Development for census areas. County estimates are 14,000 and 12,400, respectively, for the North Shore and Koolauloa Development Plan areas as of June 1989.

Sources: U. S. Bureau of the Census, 1972 and 1989; City and County of Honolulu, Department of General Planning, 1990; State of Hawaii, Department of Business and Economic Development, 1990.

Exhibit III-A

LIHI LANI RECREATIONAL COMMUNITY

Age Profile of the U. S. Golf Market

1988

Age	Number of Golfers (millions)	Percent of all golfers	Golf participation rate(1)
5 - 19	2.6	11.0%	11.7
20 - 29	6.2	26.5	15.0
30 - 39	5.2	22.4	12.9
40 - 49	3.6	15.2	12.2
50 - 59	2.4	10.3	11.2
60+	3.4	14.6	18.0
Total	23.4	100.0%	N/A

N/A Not applicable.
(1) Golfers as a percent of total U. S. population.

Source: National Golf Foundation, August 1989.

III - GOLF COURSE MARKET OVERVIEW

This chapter reviews the national and Hawaii golf market trends pertinent to the market assessment of the planned golf course. In addition, the Oahu private golf markets are reviewed.

NATIONAL GOLF MARKET REVIEW

This section describes trends in the overall U. S. golf market in terms of golfer demographics and financial performance.

Demographics of Golfing

According to the most recent National Golf Foundation statistics, 23.4 million U. S. golfers played 420 million rounds of golf in 1988. This represented an 8% increase in golfers over the previous year and an increase in the number of rounds played. On the national level, several demographic trends are projected to favor the golf market:

- Rapid increases in the 60+ year-old age group, which currently has the highest golf participation rates, as shown in Exhibit III-A.
- The fastest growing golf segment is the female market. In 1983 only 21% of all new golfers were estimated to be women. In 1988 this figure increased to 41%.

Golf Course Financial Performance

Golf courses have traditionally been considered facilities that indirectly enhanced room, food and beverage revenues. However, current trends suggest golf courses are evolving from loss-leader facilities to profit centers. Factors that have allowed golf courses to become better revenue producers include:

- Improved management and marketing.
- Ability to obtain higher green and cart fees. Green and golf cart fees have escalated 12 to 15% annually during the past several years.
- Ability to achieve high average golf rounds per year (40,000 rounds or more).
- Mandatory use of golf carts is becoming more common.
- Pro shop rentals and sales are significantly higher, due in part to sales of sportswear items and a high demand for rented clubs and shoes.

Golf courses in residential communities are also being viewed as an amenity that can add value as well as supporting real estate values.

HAWAII GOLF MARKET OVERVIEW

This section focuses on the Hawaii golf market, reviewing golf market segments and existing and proposed golf courses on Oahu.

Golf Market Segments

Golfers in Hawaii represent both local residents and visitors to the island. The local resident golf market can be segmented into two main categories:

- Local recreational players use daily fee and municipal courses, usually as small social golfing clubs or foursomes. These players tend to be flexible in time of play, often utilizing early morning tee-times, and tend to be more price sensitive than other golfer segments.
- Country club players have golf memberships at a private club. Golfers in this segment have demonstrated a willingness to pay a premium for a private golf club with its various amenities and associated prestige.

The visitor golf market is expected to be less significant at the subject project due to its location.

Oahu Golf Course Inventory

Oahu has 30 resort, municipal, daily fee, private and military golf courses as shown in Exhibit III-B. Public access is available on 17 of these courses, representing three resort, five municipal and nine daily fee golf courses. The four private courses and their characteristics are described in a later section.

Characteristics of Municipal Golf Courses

Municipal golf courses are owned and operated by a local municipality. On Oahu, the City and County of Honolulu operates four 18-hole golf courses and one 9-hole course, as also shown in Exhibit III-B. Municipal golf course characteristics include:

- Open to the general public with starting tee-times usually on a first-come, first-served basis.
- Tend to be designed to accommodate volume rather than challenging or exciting play.
- Rounds of play are typically fast due to the familiarity of the course by local golfers.
- Higher average number of rounds due to shorter intervals between starting times and greater skill of golfers at the particular courses.
- Green and cart fees range from $3 to $31, with an average of $19 to $31 as shown in Exhibit III-C.

Exhibit III-B

LIHI LANI RECREATIONAL COMMUNITY

Existing Golf Courses on Oahu

1990

Type	Name	Holes	Location
Resort	Makaha Resort and Country Club	18	Makaha Valley
	Kuilima Resort	18	Kahuku
	Ko Olina Resort	18	Ewa
Private	Waialae Country Club	18	Waialae/Kahala
	Oahu Country Club	18	Nuuanu
	Mid-Pacific Country Club	18	Lanikai/Kailua
	Honolulu International Country Club	18	Salt Lake
Municipal	Ala Wai Golf Course	18	Honolulu
	Kahuku Golf Course	9	Kahuku
	Ted Makalena Golf Course	18	Waipio/Waipahu
	Pali Golf Course	18	Kaneohe
	West Loch	18	Ewa
Daily fee	Bay View Golf Center (Par 3)	18	Kaneohe
	Hawaii Country Club	18	Kunia
	Hawaii Kai Championship Golf Course	18	Hawaii Kai
	Hawaii Kai Executive Golf Course (Par 3)	18	Hawaii Kai
	Makaha Valley Country Club	18	Makaha Valley
	Mililani Golf Course	18	Mililani
	Moanalua Golf Course(1)	9	Moanalua
	Olomana Golf Links	18	Olomana/Kailua
	Pearl Country Club	18	Pearl City/Aiea
Military	Barbers Point Golf Course	18	Barbers Point NAS
	Hickam Golf Course	18	Hickam AFB
	Kalakaua Golf Course	18	Schofield Barracks
	Kaneohe Marine Golf Course	18	Kaneohe MCAS
	Leilehua Golf Course	18	Schofield East Range
	Navy Marine Golf Course	18	Aliamanu
	Fort Shafter Golf Course	9	Fort Shafter
	Hickam (Par 3)	9	Hickam AFB
	Ford Island Golf Course	9	Ford Island NAS

(1) Course is open for public Mondays through Fridays only.

Source: Based on published information.

Exhibit III-C

LIHI LANI RECREATIONAL COMMUNITY

Fees at Selected Oahu Golf Courses

1990

	Total green and cart fees	
	Weekdays	Weekends
Resort courses:		
Makaha Resort and Country Club:		
Resort guests	$ 60	$ 60
Hawaii residents	55	55
Others	125	125
Kuilima Resort:		
Turtle Bay Golf Course(1):		
Resort guests	63	63
Hawaii residents	36	41
Others	81	90
Range	36 - 125	41 - 125
Private club (guest fee):		
Waialae Country Club	51 - 71	51 - 71
Oahu Country Club(1)	26 - 75	26 - 75
Mid-Pacific Country Club(2)	38 - 150	31
Honolulu Country Club	50	65
Range	26 - 150	26 - 75
Daily fee courses:		
Hawaii Country Club	21 - 45	30 - 50
Hawaii Kai Championship Golf Course	32 - 60	36 - 60
Mililani Golf Course	30 - 60	35 - 70
Olomana Golf Links	29 - 65	35 - 65
Pearl Country Club	32 - 50	36 - 60
Range	21 - 65	30 - 70
Municipal courses:		
Ala Wai	19 - 29	23 - 31
Pali	19 - 29	23 - 31
Ted Makalena	19 - 29	23 - 31
Kahuku (9 holes)	3 - 14	4 - 14
Range	3 - 29	4 - 31
Total range	$ 3 - 150	$ 4 - 125

(1) $75 green and cart fee for unaccompanied nonmember.
(2) $150 green and cart fee for unaccompanied nonmember, weekdays only.

Source: Compiled by KPMG Peat Marwick based on interviews with golf club representatives.

Characteristics of Daily Fee Courses

The daily fee course is the most common type of golf course on Oahu with nine courses, as previously shown in Exhibit III-B. These facilities are typically owned by individuals, partnerships or corporations on a "for-profit basis." Daily fee course characteristics include:

- Open to the general public with starting times on a first-come, first-served or a telephone reservation basis.
- Generally designed to be more challenging than municipal courses.
- Landscaping and maintenance are more extensive than municipals and natural viewpoints are taken into consideration in planning of the course.
- Similar to municipals in average rounds played and number of golfers accommodated at one time.
- Overall appearance of the golf course, clubhouse and facilities allow for higher green fees. Green and cart fees range from $21 to $65 on weekdays to $30 and $70 on weekends, as shown in Exhibit III-C.

Proposed Golf Courses on Oahu

Approximately 38 additional golf courses have been proposed by Oahu. Of these developments, only six have obtained the permits necessary to begin construction in the near future. These courses are listed in Exhibit III-D. In addition to Lihi Lani's golf course, the North Shore and Koolauloa areas include six planned golf courses, with one currently under construction:

- A second Kuilima Resort course, an 18-hole resort course that will be designed and managed by the Arnold Palmer companies, is now under construction and expected to be completed in 1991.
- Malaekahana golf course, an 18-hole semiprivate course planned by Asahi Jyuken.
- Mokuleia golf courses, an 18-hole daily fee course and an 18-hole private course planned by Mokuleia Land Co.
- Punamano golf courses, three 18-hole daily fee golf course planned by Campbell Estate.

Five of the six proposed projects have indefinite completion dates and/or are on hold due to various development considerations.

OAHU PRIVATE GOLF COURSE MARKET REVIEW

This section reviews private golf courses on Oahu in regards to their inventory, general characteristics, fee structure and memberships.

LIHI LANI RECREATIONAL COMMUNITY

Proposed Golf Course Developments on Oahu

1990

	Location	Type	Holes	Status
Under construction:				
Ewa (Hawaii Price) Golf Course	Ewa Beach	Semiprivate	27	Expected to be operational in 1991
Kapolei Golf Course	Kapolei Village	Municipal	18	Expected to be operational in 1991
Kuilima Resort Golf Course 2	North Shore	Resort	18	Expected to be operational in 1991
Makakilo Golf Course	Makakilo	Semiprivate	18	Expected to be operational in 1991
Minami Golf Course	Kaneohe	Semiprivate	18	Expected to be operational in 1991
Royal Hawaii Country Club 1	Maunawili	Semiprivate	18	Expected to be operational in 1991
Proposed:				
Bay View Expansion	Windward	Semiprivate	18	Pending City Council approval
Ewa Gentry Golf Course	Ewa	Semiprivate	18	Pending City Council approval
Ewa Marina	Ewa	Semiprivate	27	Preliminary, no official submittals
Haleiwa Golf Course	Haleiwa	Semiprivate	9	Preliminary, no permit applications filed
Heeia Golf Course	Windward	Semiprivate	18	Preliminary, no permit applications filed
Kailua Drive-In	Windward	Semiprivate	18	Preliminary, needs SMP
Kipapa Ridge Estates	Central	Municipal	9	Preliminary, no permit applications filed
Ko Olina Resort Course 2	Ewa	Resort	18	Preliminary, no permit applications filed
Kunia Golf Course	Central	N/K	18	Development plan admendment proposed, rezoning required
Lihi Lani	North Shore	Semiprivate	18	Needs development plan amendment
Maili Kai	Ewa	N/K	18	Prelimininary, no permit applications filed
Makaha Valley Country Club	Ewa	Daily fee	9	Pending City Council approval
Malaekahana Golf Course (Asahi Jyuken)	Laie	Resort	18	Original proposal rejected. Not yet resubmitted
Malu Lani Golf Course	Windward	Semiprivate	18	Needs environmental impact study
Mokuleia Golf Course	North Shore	Daily fee	18	Pending City Council approval
Mokuleia Golf Course 2	North Shore	Private	18	Pending City Council approval
Ohikilolo	Ewa	N/K	18	Preliminary, no permit applications filed
Puuloa	Ewa	Semiprivate	18	Pending City Council approval
Royal Hawaiian Country Club 2	Maunawili	Semiprivate	18	Approval pending performance of first course
Royal Kunia Golf Course 1	Central	Semiprivate	18	Pending City Council approval
Royal Kunia Golf Course 2	Central	Semiprivate	18	Pending City Council approval
Waianae Kai	Waianae	Semiprivate	27	Pending City Council approval
Waiawa Golf Course	Central	N/K	36	Development plan approval, rezoning required
Waihee Valley Golf Course	Windward	Municipal	18	Preliminary, no permit applications filed
Waikane Golf Course (Pan Pacific)	Windward	Semiprivate	27	Development plan pending
Waikane Golf Course (Hoyu)	Windward	Semiprivate	18	Development plan pending
Waikele Golf Course	Waikele	Semiprivate	18	Waiting for grading permit
West Loch/Ewa Villages Course 2	Ewa/West Loch	Municipal	18	Preliminary, no permit applications filed

N/K Not known

Inventory and General Characteristics

Private golf courses are generally member-owned, nonprofit entities. Use of the course is usually restricted to members and their guests, with starting times given preferentially to full members, then to limited, intermediate and social members. Courses are designed to be challenging and exciting, with natural viewpoints and extensive landscaping. The four private clubs on Oahu are:

- Waialae Country Club in Kahala
- Oahu Country Club in Nuuanu
- Mid-Pacific Country Club in Lanikai
- Honolulu Country Club (HCC), in the Salt Lake area

All of these private clubs are member-owned, except for HCC which is operated as a business entity.

Membership Fee Structure

Private country clubs on Oahu have several common characteristics regarding membership and fee structure:

- Acceptance into the club is determined by the membership.
- Several levels of membership, ranging from a social membership with no, or severely restricted golf privileges, to regular membership with unrestricted privileges.
- Except among Japanese memberships at HCC, unwanted memberships must be returned to the club rather than sold or traded to nonmembers.
- An initiation fee is collected upon acceptance into the club with monthly dues assessed to cover club expenses and overhead:
    - Initiation fees range from $26,000 to $33,000 for regular members, as shown in Exhibit III-E.
    - Monthly dues range from $150 to $175 for regular members.
    - No green fees are charged to members
- Nonresident membership is $40,000 at Waialae Country Club, $50,000 at Mid-Pacific Country Club, and about $172,400 at HCC. At HCC, all but about $34,500, can be refunded to the nonresident member after 10 years.

LIHI LANI RECREATIONAL COMMUNITY

Membership Fees at Oahu Private Golf Courses

Name	Type of membership	Initiation fee	Monthly dues Resident	Monthly dues Nonresident	Comments
Honolulu International Country Club	Regular golf	$ 27,000	$ 175		Only for U. S. citizens; 10 persons on the waiting list
	Weekday golf	17,000	100		Only for U. S. citizens
	Social	4,000	40		Only for U. S. citizens
	International	25 M yen(1)		1,000 yen	20 million yen is refundable after 10 years
Waialae Country Club	Regular golf	$ 26,000	175		Full use of all facilities
	Limited golf	22,000	131		Full use of all facilities; weekday golf only
	Nonresident regular golf	40,000		$ 275	Same as regular golf
	Nonresident limited golf	30,000		231	Same as limited golf
	Social	6,500	73		Clubhouse and swimming pool use only
	Nonresident social	7,000		161	Same as social membership
Oahu Contry Club	Regular	33,000	175	N/A	No membership for nonresidents currently available
	Limited regular	20,000		N/A	$7,000 is refundable for regular and limited membership
	Social	7,000		N/A	
	Ladies golf	6,000		N/A	
Mid-Pacific Country Club	Proprietary	26,000	150		$225 quarterly minimum charge for F & B
	Social/awaiting Propriety	20,000	150		Waiting list for the above; limited golf use
	Nonresident	50,000		225	
	Ladies	10,000	75		Use of golf and club house, $113 quarterly minimum except golf course use, $150 minimum
	Social	300	38		

(1) Based on an exchange rate of 145 yen to $1.00, 25 M yen is about $172,400.

Exhibit III-E

IV - TENNIS AND EQUESTRIAN MARKET OVERVIEW

This chapter reviews selected tennis and equestrian facilities in Hawaii and overviews their different market segments, membership profiles, utilization patterns, membership fee structures and general success factors. Based on this review, an assessment of the planned tennis and equestrian facilities at the Lihi Lani Recreational Community is presented in Chapter V.

TENNIS FACILITIES OVERVIEW

This section presents a review of facilities at Oahu municipal and selected private tennis developments in the state.

Characteristics of Oahu Municipal Tennis Facilities

A recent survey of municipal tennis courts on the island by the City Department of Parks and Recreation listed 174 public courts on Oahu. The most recent addition to Oahu's municipal facilities was the 200-seat Diamond Head Court stadium facility completed in mid-1989. Of the total inventory, 108 or about 60% of the courts have lights for night-time play and 25 of the facilities have backboards for hitting practice, as shown in Exhibit IV-A. The distribution of the courts by region indicate that:

- The North Shore and Koolauloa area of Oahu has only six public tennis courts or about 4% of the inventory, two at Sunset Elementary School and four at Waialua Recreational Center.
- Windward Oahu has about 20 courts or about 12% of the overall municipal court inventory.
- Central and West Oahu have 29% and 8% of the public courts on Oahu, respectively.
- Honolulu, with 83 total or about 48% of the public courts, has the largest percentage of the total Oahu municipal tennis court inventory.

Thus, the distribution shows that there are relatively few public courts on the North Shore and Koolauloa regions as compared to Honolulu and Central Oahu.

Currently, there are no fees to play on municipal tennis courts. A major issue for the City and County of Honolulu's Department of Parks and Recreation will be the possibility of charging user fees, just as golf players at public golf courses pay a nominal fee for usage of municipal facilities.

Characteristics of Private Tennis Facilities

The private tennis facilities selected for review reflect different market orientations, including private tennis clubs and tennis facilities at private golf clubs.

The selected private tennis club facilities on Oahu include:

Exhibit IV-A

LIHI LANI RECREATIONAL COMMUNITY

Oahu Municipal Tennis Court Inventory

1990

Location/name	Number of courts	Lighted courts	Practice backboard
North Shore and Koolauloa:			
Sunset Beach Park	2	2	1
Waialua Recreation Center	4	4	1
Subtotal	6	6	2
Windward:			
Kailua Rec Center	8	4	1
Kaneohe Park	6	6	-
Maunawili Park	2	2	-
Waimanalo Park	4	-	1
Subtotal	20	12	2
Central Oahu	51	24	10
West Oahu	14	12	2
Honolulu	83	54	9
Total	174	108	25

Source: City and County of Honolulu, Department of Parks and Recreation, 1990.

- Maunalua Bay Club, with an oceanfront site in Aina Haina and six lighted courts, was developed by the owners of the Kahala Hilton primarily as an amenity for their guests and secondarily as a private tennis club for Hawaii residents.

- Oahu Club in Hawaii Kai has a tennis and fitness orientation that includes six lighted tennis courts, a teaching tennis professional, Olympic-sized swimming pool and professional weight and fitness trainers.

- Kailua Racquet Club has the largest private facility on Oahu with nine tennis courts. The club emphasizes family and junior development, and except for tennis, does not offer any other major amenities or sports.

- Waialae Iki 5 Tennis Club is the smallest private facility surveyed with four tennis courts. The club membership is limited to lot owners at the Waialae Iki 5 subdivision.

General facility characteristics of the private tennis clubs, as shown in Exhibit IV-B, are summarized as follows:

- All have all-weather hard tennis courts, lights for night-time play, a pro shop and a teaching tennis professional who offers lessons on an individual or group basis.

- All except for the Waialae Iki 5 Tennis Club offer food and beverage services, usually a snack bar. The manager of the Maunalua Bay Club indicated a desire for an indoor or outdoor restaurant to take advantage of the club's ocean views and frontage.

- The Maunalua Bay and Oahu clubs also offer weight/exercise rooms, sauna or jacuzzi, swimming and aerobics or fitness instruction.

- The Kailua Racquet and Waialae Iki 5 clubs generally have only tennis with no supporting major amenities.

- The Maunalua Bay Club and Waialae Iki 5 tennis facilities tend to have windy conditions that can sometimes hinder play. Members and the manager of one of the clubs suggested that careful planning of the location of the courts and appropriate wind breakers could help to minimize windy playing conditions.

Private golf clubs on Oahu that include tennis facilities are:

- Waialae Country Club, with three omni-turf synthetic grass courts.

- Honolulu Country Club, with four all-weather hard courts.

General characteristics of the tennis facilities, as shown in Exhibit IV-C, include:

Exhibit IV-B

LIHI LANI RECREATIONAL COMMUNITY

Selected Oahu Private Tennis Club
Facility Characteristics

1990

Facilities	Maunalua Bay Club	Oahu Club	Kailua Racquet Club	Waialae Iki 5 Tennis Club
Tennis courts	6	6	9	4
Lighted courts	6	6	3	2
Surface	Plexi-pave(1)	All-weather	Plexi-pave(1)	Plexi-pave(1)
Pro shop	Yes	Yes	Yes	Yes
Restaurant	No	No	No	No
Snack bar	Yes	Yes	Yes	No
Clubhouse	Yes	No	Yes	No
Locker room	Yes	Yes	Yes	No
Weight/exercise room	Yes	Yes	No	No
Tennis instruction	Yes	Yes	Yes	Yes
Tennis leagues	Yes	No	Yes	Yes
Children's programs	No	No	Yes	Yes
Sauna/jacuzzi	Both	Jacuzzi	No	No
Massage	Yes	No	No	No
Other sports	Swimming Aerobics	Swimming Fitness	No -	No -
Other amenities	Valet parking	-	Spectators pavilion	Meeting pavilion
Tournaments	Various club tournaments	Hawaii Grand Prix Open	Men's Night Doubles	Satellite pro events

(1) Plexi-pave is an all-weather hard court surface.

Source: Compiled by KPMG Peat Marwick based on discussions with managers and tennis professionals at the respective clubs, 1990.

LIHI LANI RECREATIONAL COMMUNITY

Tennis Facility Characteristics
at Private Golf Clubs on Oahu

1990

Facilities	Waialae Country Club	Honolulu Country Club
Tennis courts	3	4
Surface	Omni-turf(1)	All-weather
Pro shop	Yes	Yes
Restaurant	Yes(2)	Yes(2)
Clubhouse	Yes(2)	Yes(2)
Locker room	Yes(2)	Yes(2)
Weight/exercise room	Yes(2)	Yes(2)
Tennis instruction	Yes	Yes
Sauna/Jacuzzi	Jacuzzi(2)	Jacuzzi(2)
Massage	No	Yes
Other sports	Golf Swimming	Golf Swimming
Tournaments	Waialae Senior Doubles	HCC Junior Open Championships

(1) Omni-turf is a synthetic grass surface.
(2) Incorporated with overall golf club facilities.

Source: Compiled by KPMG Peat Marwick based on discussions with managers and tennis professionals at the two clubs, 1990.

- The omni-turf synthetic grass courts at Waialae tend to be softer and easier on the legs than the standard all-weather hard courts. This has made the surface popular with many members, especially some of the older players.

- These two tennis facilities are treated as amenities to golf-oriented clubs, and provide the necessary basics for tennis such as well-maintained courts, a pro shop, tennis instruction and club or local tournaments.

- Many of the extra amenities provided for the membership, such as restaurant, locker room, weight/exercise room, Jacuzzi and other amenities or services are located in the main golf clubhouse rather than in the tennis complex.

Proposed Major Tennis Facilities on Oahu

Kuilima Resort plans include a 20-court Nick Bollettieri Tennis Academy, including a stadium with up to 3,000 seats, to be completed by spring 1992. The planned facilities will replace the existing 10-court complex.

PRIVATE TENNIS CLUB MARKET REVIEW

This section reviews the tennis club membership, utilization patterns, fee structure and success factors for the different types of private tennis facilities reviewed in this chapter.

Membership Profile

Different types of facilities tend to have different membership profiles due to their orientation as either a tennis club or golf club facility, as shown in Exhibit IV-D.

The characteristics of members in the different tennis club segments include:

- Membership size of the different types of tennis facilities ranges from:
  - About 140 to 400 members for Oahu private tennis clubs.
  - About 1,100 to 3,500 total club membership, most with tennis privileges, at golf-oriented private country clubs on Oahu.

- Kailua Racquet Club has a waiting list of about 13 potential new members.

- Private tennis club members tend to be in their 30's and younger while private golf club members are typically 50 plus years old.

- Members' primary places of residence were typically within the general location of the club itself. The private tennis facilities had 80% or more of their local members from the neighborhood of the club.

Utilization Patterns

The tennis facilities surveyed showed similar utilization patterns. On weekdays, tennis players typically play from early morning to about 10:00 or 11:00 a.m. and then after 3:00 p.m. to closing. These peak hours are generally times that are before or after work for many individuals and also avoid the hot mid-day sun. On weekends, utilization is typically high throughout the day though the cooler early morning and late afternoon hours are still the most desired times to play.

Other characteristics of facility utilization include:

- At the Haunalua Bay Club, which was developed by the Kahala Hilton, nonmember hotel guest play ranges from 10% to 40% depending on the seasonality of the tourism market.
- The Oahu Club, owned by Mainichi Sports Kikaku of Japan, has exchange privileges with several Tokyo swimming clubs. The Oahu Club also provides tennis and swimming lessons to tour groups of about 20 to 30 people, typically Japanese college students, about once every two months.
- The Kailua Racquet Club is primarily a tennis-only club and most of the play is by its members. The general manager estimated that only about 10 to 15 guest players per week are registered to play at the club.

The utilization of the tennis facilities was in most part influenced by each club's orientation, membership and guest composition.

Membership Fee Structure

The various types of private tennis facilities have different policies in terms of fee structure and nonmember play. Fee structures, as shown in Exhibit IV-E, include:

- The private tennis clubs generally include an initiation fee, monthly dues and nonmember guest fees. The Haunalua Bay Club has the highest fee schedule with a $7,500 initiation fee and $150 monthly dues.
- Nonmember guest fees range from $3 per day for weekday players at Kailua Racquet Club to $20 per hour per court for hotel guests at the Haunalua Bay Club.
- Waialae Country Club has the most expensive tennis membership initiation fees of $11,000. Monthly dues for the tennis memberships is $130 per month.
- Honolulu Country Club's tennis membership's initiation fee is $1,200 for couples and $1,000 for singles. Monthly dues are $125 and $100.

As shown by the review, the Haunalua Bay Club is the highest priced tennis-oriented club surveyed. The club has attracted 140 members and has temporarily suspended new memberships and started a waiting list.

LIHI LANI RECREATIONAL COMMUNITY

Tennis Club Membership Characteristics

1990

Name	Number of members	Number on waiting list	Typical age group	Members' primary place of residence	Comments
Tennis clubs:					
Maunalua Bay Club	140	-(1)	Late 30's	East Honolulu (90%+)	Developed by Kahala Hilton for guests and tennis members.
Oahu Club	400	None	40's	Hawaii Kai (80% to 85%) Honolulu, Kahala and Kailua (15% to 20%)	Owned by Mainichi Sports Kikaku.
Kailua Racquet Club	272	13	Over 30	Kailua (80%) Honolulu and Hawaii Kai (20%)	Main emphasis is family and junior development, does not offer amenities or other sports.
Waialae Iki 5(2)	150	None	Late 30's and 40's	Waialae Iki and Waialae/Kahala (90%+)	Provided as amenity to lot purchasers.
Golf-affiliated country clubs:					
Waialae Country Club	1,100(3)	N/A	62	N/A	Prestigious golf-oriented private country club.
Honolulu Country Club	3,500(4)	N/A	Mid-50's	N/A	Golf-oriented private country club.

N/A Not available.
(1) Membership is closed. A waiting list exists.
(2) Members must be lot owners, buyers of the remaining 50 lots will become members.
(3) Totals are for entire club, tennis only membership is 50.
(4) Total is for entire club.

Exhibit IV-D

Success Factors

Club managers and tennis professionals were asked about the attributes of their club that contributed to the success of their operations. Several success factors were considered important by different club representatives, including:

- Maintenance and high quality facilities are assumed for a private tennis facility. With over 170 municipal courts, private tennis clubs must offer superior courts, convenient access, well maintained facilities and services.
- Compared to public facilities, clubs also offer organized social and tennis events, supportive facilities, customized services and coaching.
- Court availability during prime playing times and an efficient reservation system to minimize waiting for an open tennis court are also key considerations.
- Quality of service and professionalism of the club staff are considered very important in tennis-only clubs that cannot offer a wide range of amenities.
- Reasonable initiation fees and monthly dues are considered important at most of the clubs. However, higher-end clubs like the Maunalua Bay Club can charge significantly more for new facilities and high levels of service.
- Junior development programs for younger school age children and inexpensive group clinics for older players support the social aspects of clubs and provide reasons to join as a family.
- Ball machines and video taping for stroke analysis are popular additional equipment for tennis players.
- Nationally, diverse recreational facilities for aerobics, swimming and fitness training are becoming more prevalent at some of the newer clubs. This is also evident at the Oahu and Maunalua Bay Clubs where extensive weight training and/or aerobics programs are major facets of the overall club.

The success of the local clubs have much to do with their facilities, club orientation and level of service offered. A well-rounded club could incorporate some of these successful attributes reviewed in order to enhance its own marketability.

EQUESTRIAN FACILITIES OVERVIEW

This section presents general information about the Oahu equestrian market and a review of selected private equestrian facilities on Oahu. Based on this review, an equestrian market assessment will be presented in Chapter V.

LIHI LANI RECREATIONAL COMMUNITY

Membership and Daily Usage Fees for Selected Tennis Facilities

1990

Name	User categories	Initiation fee	Monthly dues	Nonmember daily fee(1)
Tennis clubs:				
Maunalua Bay Club	Members	$ 7,500	$ 150	No fee(2)
	Hotel guests	-	-	$20 per hour per court
Oahu Club	Members:			
	Family	900	85	$7.50 adults, and $5.00 children(2)
	Couple	750	68	$7.50 adults, and $5.00 children(2)
	Single	600	49	$7.50 adults, and $5.00 children(2)
Kailua Racquet Club	Members:			
	Full	2,000(3)	56	$3/weekdays, $6/weekends(2)
	Juniors	150	15	$3/weekdays, $6/weekends(2)
Waialae Iki 5(3)	Members	-	N/A	No fee, guest policies currently under review
Private country clubs(4):				
Waialae Country Club	Tennis membership	11,000	130	No fee(2)
Honolulu Country Club	Couples	1,200	125	No fee(2)
	Singles	1,000	100	No fee(2)

N/A Not available.
(1) Per person per day unless otherwise stated.
(2) Daily fee player must be accompanied by a club member.
(3) Initiation fees are soon to be raised to the $2,500 - $2,800 range.
(4) Tennis privileges are also part of golf memberships.

Exhibit IV-E

Equestrian Market Overview

Oahu equestrian activities and facilities tend to be away from the primary urban center of Honolulu and are generally in areas of the island with wide open spaces and good riding trails. General characteristics of the market include:

- Most of the equestrian activity on Oahu is centered on the Windward side of the island, with several of the major equestrian facilities in the Waimanalo area, as listed in Exhibit IV-F. One equestrian facility manager reports that a recent survey found that about 80% of the horses on Oahu are stabled in the Windward region.

- The Hawaii Polo Club's matches at Mokuleia field are the best known equestrian activity on the North Shore. Polo activity is seasonal and typically runs from spring through the summer. Other activities such as recreational horseback riding are also popular on the North Shore. Competitive equestrian activities and training are not as prevalent in the area as in the Windward area, where many of the competitive events are held.

- One of the main issues in the equestrian field has been the problem of rising liability insurance premiums. Some equestrian facilities have stopped offering daily fee or rental rides due to the high insurance premiums.

- Three facilities that do offer daily fee rides are resort-oriented facilities at the Kuilima and Makaha Resorts or the visitor-oriented Kualoa Ranch. These facilities have blanket or umbrella coverage for the whole resort or ranch complex, rather than just coverage for daily fee riders.

In general, rental ride and other daily fee equestrian activities on Oahu has been a market that has been phased out by stables that board and/or train horses for competition leaving this market essentially to visitor-oriented facilities.

Characteristics of Selected Oahu Equestrian Facilities

The stables surveyed are oriented towards boarding, recreational and competitive riding and do not provide daily fee rentals. These facilities, as shown in Exhibit IV-G, include:

- Circle Z Ranch in Waimanalo, considered the best facility on Oahu, currently has about 100 horses in its stables.

- Maunawili Farms, located in a hilly area of Maunawili in Kailua, has about 80 horses stabled. Situated on land owned by Kaneohe Ranch, the operation is currently on a month-to-month lease.

- Crobar Ranch in Mokuleia and owned by Mokuleia Land Co. has about 90 horses in paddocks and pastures.

Exhibit IV-F

LIHI LANI RECREATIONAL COMMUNITY

Selected Oahu Equestrian and Stables Inventory

1990

Name	Location	Boarding	Training	Rental rides
North Shore:				
Crobar Ranch	North Shore	Yes	No	No
Turtle Bay Hilton stables	North Shore	No	No	Yes
Windward:				
A-Tri-K Stables	Waimanalo	Yes	Yes	No
Circle Z Ranch	Waimanalo	Yes	Yes	No
Hilltop Ranch	Waimanalo	Yes	Yes	No
Maunawili Farms	Maunawili/ Kailua	Yes	Yes	No
Kualoa Ranch	Kualoa	No	No	Yes
Other areas:				
Barbers Point Riding Club	Barbers Point	Yes	Yes	No
Koko Crater Stables	Hawaii Kai	Yes	Yes	No
Sheraton Makaha stables	Makaha Valley	No	No	Yes

Source: Compiled by KPMG Peat Marwick based on discussions with equestrian facility managers, 1990.

General characteristics of these facilities, as also shown in Exhibit IV-G, include:

- With the stabling of horses being the primary source of revenue, these facilities have between 80 and 100 horses. Circle Z and Maunawili are at full capacity with waiting lists.
- Stable-oriented facilities also have more amenities involving training or exercise areas. Circle Z, Maunawili and Crobar include:
  - Turnout pastures for exercise
  - Polo, hunt or other fields for training
  - Indoor and/or outdoor arenas with jumps for training
  - Access to trail rides for recreational riding
- Supporting amenities in this type of equestrian facility generally include:
  - Grooming, washing and hospital stalls
  - Storage areas
  - Tractor barn
  - Trailer parking
  - Manager's office or residence

EQUESTRIAN MARKET REVIEW

This section reviews the equestrian market in terms of types of users, fee structure and success factors associated with the stable facilities.

User Profile and Utilization Patterns

General characteristics, as shown by Exhibit IV-H, include:

- Circle Z Ranch and Maunawili Farms, which do not offer daily fee rides, generally found that most of their stable renters came from the Windward area with the remainder from Honolulu.
- About half of Crobar's renters are from the North Shore area with the remainder from rest of the island.
- More women appear to ride horses than men. At Circle Z, women were generally interested in recreational riding, English, western, combined training and dressage. Men were primarily interested in polo and hunting with some interest in dressage. Polo players also tended to keep more than one horse, as the sport generally requires at least two horses for a match.
- Maunawili Farms has a family-oriented facility that includes a significant number of school-age children from 10 to 18 years of age.
- Due to the Crobar's location near polo fields, about half of the riders are polo players and the remainder are primarily trail and dressage riders.

LIHI LANI RECREATIONAL COMMUNITY

Selected Oahu Private Equestrian Facility Characteristics

1990

Facilities	Circle Z Ranch	Maunawili Farms	Crobar Ranch
Stables:			
Stalls (units)	56	80	5(1)
Size of stalls (feet)	12 x 16, 30 x 40	12 x 12, 14 x 14	12 x 10, 12 x 14
Horses stabled (number)	100	80	90
Paddocks (number)	40	N/A	22
Riding areas	4	2	3
Full-time employees (number)	7	3	2
Other facilities	Polo field Hunt field Outdoor arena Outdoor track Covered arena (100 x 200 feet) Storage area Grooming Grooming stalls Jumps Exercise tracks	Turnout pasture Hunt field and trails Grooming stalls Tractor barn Resident manager's home Jumps Equipment storage Hospital stalls Trailer parking	Five pastures Jump course Trails Feed barn Tack room
Comments	Considered the best stable on Oahu	Currently on a month-to-month lease from Kaneohe Ranch	Owned by Mokuleia Land Co.

N/A Not available.
(1) Only hospital stalls; horses are kept in the paddocks and pastures.

Exhibit IV-G

Fee Structure

The general fee structure of the different equestrian operations, as shown in Exhibit IV-I, include:

- Circle Z Ranch charges between $300 to $400 per month for stables, depending on size, which also includes feed and maintenance of the individual stalls.
- Maunawili Farms charges from $100 to $125 per month for stables and about $140 per month for paddocks. Fees are lease rates only and do not include feed or stall cleaning, which is usually taken care of by the owner or an independent contractor hired by the owner.
- Crobar Ranch charges $100 per month for paddocks and some pastures. Renters of the paddocks must provide or pay for the feed and feeder. For one distant pastures, typically used by polo horses during the off season, the charge is $50 per month.

In summary, the fees for stable rentals can vary widely according to the level of services offered.

Success Factors

Key factors to success in equestrian facility operations included:

- Circle Z caters to the rider who takes equestrian competitions seriously and who is willing to pay for a full service equestrian center with training grounds, skilled workers and modern facilities.
- Maunawili Farms has managed to keep costs down, charging relatively low stable fees and letting owners handle all the extra services required to maintain a horse by themselves or through independent contractors.

LIHI LANI RECREATIONAL COMMUNITY

Selected Oahu Equestrian Facility User Profile

1990

Type of user	Circle Z Ranch	Maunawili Farms	Crobar Ranch
Stable renters' typical place of residence	1. Windward 2. Honolulu	Windward (80+%) Honolulu	North Shore (50%)
Typical riders	Polo (men in their 30's and 40's) Dressage (both men and women) Hunting (50+% men)	School children from 10 to 18 years old and families	Polo (men in their 30's and 40's) Dressage (both men and women) Trail rides (both men and women)
Comments	Manager sees great demand for daily fee rides due to daily inquiries regarding rentals.	Active clientele, typically like to be involved with other sports, including golf and tennis.	About half of the clientele are polo players.

Exhibit IV-H

V - RECREATIONAL FACILITY MARKET ASSESSMENT

This chapter assesses the market potential for the recreational facilities proposed at Lihi Lani, based on the reviews of comparable facilities and markets presented in the previous chapters. The sections below present recommendations and conclusions relating to potentially competitive facilities, the proposed project concept, project characteristics and expected market performance.

RECREATIONAL COMMUNITY CONCEPT

Lihi Lani's recreational facilities are conceived as mutually-supportive components that together provide a full-range of activities, amenities and attractions for families and individuals. The three major facilities would be the golf course, the tennis center and the equestrian ranch. The three components would support one another by providing:

- A variety of activities and types of environments, with appeal to family members of all ages.
- More extensive food and beverage facilities than are available at competitive tennis- or equestrian-only facilities in the state.
- Lessons and competition events for adults and children for golf, tennis and equestrian activities.

The homes could also support the facilities and activities planned. Those living at Lihi Lani would be the core group for the various activities and, in turn, the golf course, tennis center and equestrian ranch would help market the lots by attracting potential lot buyers to visit the project.

Lihi Lani could appeal to both Oahu residents and to visitors using individual facilities, as well as half-day and day activity packages. Packages could be designed in various combinations for one, two or more activities.

GOLF COURSE MARKET ASSESSMENT

This section discusses Lihi Lani's golf course's development concept, identifies its primary competitors, reviews the recommended facilities, membership absorption, course utilization and fees.

Golf Development and Market Concepts

Golf is an established and expanding sport in Hawaii, as indicated in Chapter III. Nationally as well as in Hawaii, golf is growing rapidly in popularity among seniors and women. Furthermore, due to the aging of the baby boomers, the number of people in age groups most likely to golf will continue to grow more rapidly than other age groups. Golf is additionally popular in Hawaii due to the state's:

- Year-round favorable playing weather
- High exposure of residents to the sport

LIHI LANI RECREATIONAL COMMUNITY

Selected Facilities Usage Fees

1990

Usage/fees	Circle Z Ranch	Maunawili Farms	Crobar Ranch
Stables ($/month)	$300 to $400	$100 to $125	N/A
Other fees	$3 to $5 day for turnouts(1)	$140 per month for paddocks	$50 or $100 per month for pasture $100 per month for paddocks
Comments	Stable fees include feed and maintenance of stalls	Stable fees are land lease rates only. Users must build a new stable or buy an existing one, and maintain stall and horse.	Users of paddocks must provide feeding.

N/A Not applicable.
(1) Turn-outs are usually done by independent contractors not employed by Circle Z Ranch.

Source: KPMG Peat Marwick based on interviews with facility managers or other representatives, 1990.

Exhibit IV-1

- Active resident population
- Availability of attractive courses and outstanding sites
- Strong development programs and tournaments
- Significant visitor and part-time resident populations

Due to factors such as these, the golf market in Hawaii is expected to remain strong for the forseeable future.

Within this strong marketplace, the Lihi Lani course is expected to be distinguised by its natural attributes and development strategies, including the following:

- Uplands location in Pupukea, with tremendous view planes and terrain.
- A master-planned development, with proximity to a major resort area and white sandy beaches.
- Approximately the same accessibility from Honolulu and Waikiki as the Makaha and Kuilima courses.
- Extensive project facilities and related recreational amenities.
- Inclusion of a single-family lot development.

Development plans include an 18-hole semiprivate golf course designed by Jack Nicklaus. The course will be open to the public; however, memberships will be offered.

Potentially Competitive Courses

Numerous golf courses are proposed for development on Oahu over the next several years, but not all of these courses are expected to be completed in the near future. The projects that, if developed, could be most competitive with Lihi Lani would include:

- Kuilima Resort second course, an 18-hole resort course that will be designed and managed by the Arnold Palmer companies, expected to be completed in 1991.
- Malaekahana golf course, an 18-hole semiprivate course planned by Asahi Jyuken.
- Mokuleia golf courses, including an 18-hole daily fee course and an 18-hole private course planned by Mokuleia Land Co.
- Punamano golf courses, three 18-hole daily fee golf course planned by Campbell Estate.

The second Kuilima Resort course is anticipated to be completed in the fall of 1991, while the other projects have indefinite completion dates and/or are on hold due to various development considerations.

Facilities and Amenities

Supportive facilities and amenities of the golf course would be of high quality. Because the majority of users could be expected to be day visitors to the project, there could be more emphasis on providing daytime and casual afternoon and sunset activities. In addition to serving users of the golf course, the facilities associated with this course could become a destination for nongolf visitors to the North Shore and Koolauloa areas and a dining alternative for residents of the community. The clubhouse and golf course could offer:

- Breakfast, lunch and dinner restaurant with ocean views
- Cocktail lounge
- Indoor/outdoor snack bar
- Swimming pool
- Tennis courts
- Driving range

Membership Pricing Structure

Due to the tremendous facilities and amenities of the club and golf course, the membership price schedule would have to be competitive with the local private golf course.

Fees and memberships could be structured with prices slightly less than at existing Oahu private golf courses, as shown in Exhibit V-A.

Full and limited golf memberships could also include privileges at the tennis ranch and discounts at the equestrian center. Membership discounts are also expected to be provided to Lihi Lani residents.

Projected Membership Sales Absorption

Due to the golf course's location about 60 minutes away from the majority of Oahu residents and expected utilization patterns of members, it is expected that the golf course could accommodate about 500 memberships over a five-year marketing period, as shown in Exhibit V-B.

Projected Utilization Patterns

Daily fee golf courses on Oahu have desired maximum rounds of 35,000 to 60,000 rounds per year, or 100 to 165 rounds per day. This range permits comfortable rates of play for golfers who are familiar with the courses. Total rounds played at Lihi Lani are expected to increase from about 27,400 in 1995, the first year of operations, to a stabilized rate of about 47,500 rounds in 1999, the fifth year of operation, as shown in Exhibit V-C.

The anticipated demand for use of the course can be segmented into three submarkets:

- Local recreational players
- Member players
- Visitor golfers

Exhibit V-A

LIHI LANI RECREATIONAL COMMUNITY

Proposed Membership Fees and Monthly Dues

1990 Dollars

Type	Initiation(1)	Monthly dues	Comments(2)
Full membership	$ 25,000 - 30,000	130 - 160	All privileges(3)
Limited membership	15,000 - 20,000	100 - 130	Limited golf(4)
Social	4,000 - 6,000	40 - 60	Use of golf clubhouse facilities, pool and tennis courts.

(1) Initiation fees could be discounted for members who are Lihi Lani residents.

(2) Includes corporate and family memberships. For corporate memberships, membership could be transferable to another employee at the corporation's discretion.

(3) Unlimited usage of private course, tennis ranch facilities, and discounts at activities and or/monthly charges at equestrian center.

(4) Unlimited usage of golf clubhouse, tennis ranch facilities, and discounts at activities and or/monthly charges at equestrian center; use of golf course limited to weekdays and one weekend per month.

Exhibit V-B

LIHI LANI RECREATIONAL COMMUNITY

Projected Membership Sales Absorption at the Proposed Golf Club

1995 to 1999

	1995	1996	1997	1998	1999	Total
Lihi Lani lot owners	20	30	20	10	-	80
Other Oahu residents	60	65	60	55	55	295
Out-of-state residents	30	30	25	20	20	125
Annual total	110	125	105	85	75	N/A
Cumulative total	110	238	340	425	500	500

LIHI LANI RECREATIONAL COMMUNITY

Projected Rounds of Play at the Proposed Golf Course

1995 to 1999

	1995	1996	1997	1998	1999
Average daily rounds:					
Nonmember Oahu residents(1)	30	30	40	50	60
Members	15	30	40	50	50
Visitors(1)	30	30	25	25	20
Total	75	90	105	125	130
Average annual rounds	27,400	32,900	38,300	45,600	47,500
Percentage:					
Nonmember Oahu residents(1)	40%	33%	38%	40%	46%
Members	20	33	38	40	39
Visitors(1)	40	33	24	20	15
Total(2)	100%	100%	100%	100%	100%

(1) Includes guests of private members.
(2) May not add due to rounding.

Projected Green and Cart Fees

Green and cart fees for nonmembers at private Oahu country clubs ranged from $26 to $120, while at Oahu resort courses they range from $36 to $125, and at Oahu daily fee courses from $21 to $70.

Achievable green and cart fees for nonmembers at the proposed golf course are projected to increase from about $75 initially, to $85 within four years, in 1990 dollars, as shown below:

Projected Average Nonmember Green and Cart Fees at the Proposed Golf Course

1995 to 1999

(1990 dollars)

	Total fees(1)
1995	$ 75
1996	75
1997	80
1998	85
1999	85

(1) Per person, assumes two persons per cart.

Due to their membership fee and dues, only cart fees are typically charged to members at the time of play. Based on the cart fee at Oahu's private courses the cart fee is projected to be about $7.00.

TENNIS MARKET ASSESSMENT

This section reviews the proposed facility concept of the Lihi Lani Tennis Center and recommends the necessary facility characteristics based on projected target markets, recommended marketing of the tennis center, proposed fee structure and utilization patterns.

Proposed Tennis Facilities Concept

The Lihi Lani Tennis Center is proposed to be developed as a complete tennis club with:

- 12 tennis courts, including 2 to 3 clay or grass courts
- Clubhouse, including two to four indoor racquetball courts
- Swimming pool
- Walkways, landscaping, entry road and other infrastructure

The total of 12 tennis courts would make Lihi Lani the largest private tennis facility on Oahu. The proposed tennis center site would encompass a total of about 12 acres.

Projected Target Markets

Based on the review of the users of private tennis facilities, the tennis center could be marketed to several different segments, including:

- Lot owners at Lihi Lani
- Residents from the North Shore and Koolauloa communities
- Golf club members
- Other Oahu residents and visitors

Recommended Facility Characteristics

With the tennis facility serving up to four distinct market segments, it could be appropriate that a tennis facility of 12 tennis courts could be supported by the end of a ten-year period.

The potential demand for the facility has been based on several factors:

- U. S. Tennis Association (USTA) guidelines of one court per 750 residents was calculated with the projected full-time North Shore and Koolauloa population, estimated at 28,700 in 1989. This would be the equivalent of about 38 courts serving the existing North Shore populations, not including any of the day visitor or part-time resident population, thus, making the estimate a fairly conservative one. Factoring out the existing six municipal and ten resort-oriented courts in the regions, the guideline would indicate at least 22 more tennis courts could be accommodated immediately.
- Demand by lot owners is further basis for additional courts. Based on Waiae Iki 5 residential development ratio of one tennis court to 50 lots, an additional demand of two to three courts is expected.
- Demand by tennis-only club members, based on the ULI ratio of 30 players per court, would be subject to the projected number of tennis-only members of the club. Based on an assumed 100 to 200 tennis-only memberships, the facility could require between two or three additional courts.
- Demand by daily fee players could be accommodated since many tennis clubs in Hawaii have available court times during the late morning and early afternoon time periods. This opportunity for play could accommodate North Shore and Koolauloa residents with flexible work schedules, retirees, junior development after-school programs and visitors to the community.

The facility could be developed in phases, with between six and eight lighted courts initially. This should allow for facilities that could accommodate the developing target markets of golf members, homeowners, tennis members and daily fee players. Further expansion with four to six courts in a second phase could be based on higher demand for tennis and as the golf club and tennis memberships expand.

With a fairly extensive facility of six to eight courts, up to a proposed total build-out of 12 courts, it could be advantageous from a marketing standpoint to have two to three courts with different playing surfaces, rather than the standard all-weather hard courts, to differentiate the club from other tennis facilities.

In addition, supportive facilities recommended for the tennis club include:

- Tennis pro shop
- Men's and women's locker rooms
- Manager's office space
- Aerobic and fitness areas
- Jacuzzi, sauna and/or furo
- Snack bar or restaurant area

Recommended Marketing of the Tennis Center

The Lihi Lani Tennis Center could be marketed as a family-oriented tennis facility:

- The tennis center can provide an alternative activity center for nongolf playing golf club members, homeowners and their families.
- Tennis-only members would have a membership at a stand-alone tennis center competitive with any other tennis facility in the state in terms of courts, amenities and services. The family-oriented facility could offer a full schedule of activities and events such as organized tennis camps, family-oriented doubles, junior player (under 18 years old) development, age group competitions and the traditional tennis ladders for club champions in men's, women's, doubles and mixed doubles categories. The club could also sponsor grass court, clay court, hard court and all-surface club championships.
- Daily fee tennis players could primarily be attracted by the opportunity to reserve court times, play on one or more surfaces and to visit the recreational community. Family aspects could include having other members participating in group clinics or lessons, horseback riding or nine holes of golf as part of a multisport activity.
- Junior development programs including tournaments and adequate access to facilities for teenagers in the North Shore and Koolauloa areas could have positive long range implications for the community. In the long run, a tennis development program creates exposure for the sport and a junior development tennis program would help to make Lihi Lani a contributing part of the overall North Shore and Koolauloa communities.

Proposed Tennis Membership and Daily Fee Structure

Based on the current private tennis clubs' membership fee structures and the preliminary facilities concept of the proposed Lihi Lani Tennis Center, tennis membership fees could be structured as follows:

Proposed Lihi Lani Tennis Center
Membership and Daily Fee Structure

(1990 dollars)

Type of membership	Initiation fee	Monthly dues	Guest fees(1)
Tennis club and golf social(2)	$6,000	$75 - $100	$10(3)
Tennis club(4)	5,000	60 - 80	10(3)
Daily fee play:			
Hard courts	-	-	8(5)
Clay courts	-	-	12(5)
Grass courts	-	-	15(5)

(1) Includes daily fee players.

(2) Includes tennis membership and discounts at the equestrian center but no golf course privileges.

(3) Per guest per day.

(4) Includes discounts at the equestrian center.

(5) Per person per hour usage.

It should be noted that all of the golf club categories, except for the social-only memberships, will have tennis center privileges, as was presented earlier in this chapter.

Projected Utilization Patterns

Most tennis court usage occurs in the early morning and late afternoon hours during weekdays and throughout the day during weekends. The different market segments could be managed to have complementary utilization patterns of play:

- Local daily fee and club members would generally desire the prime time hours of early morning and late afternoon. A well-managed reservation system with a three- to five-day advance reservation privilege for members and one- to two-day advance reservation system for nonmember daily fee users should be able to accommodate both market segments.
- Visiting daily fee players, retirees, junior players and other community residents with more flexible schedules could be targeted for nonprime time hours on the weekdays with group clinics, individual instruction or possibly lower daily fee rates for play. This could help to enhance playing time during nonpeak hours.

In addition, lighted courts extend the peak late afternoon and early evening playing period for several hours, thus accommodating more of the membership and daily fee players. The club could also create activity on one or more nights a week such as round robin doubles, club matches and other tennis- or social-oriented activities.

EQUESTRIAN MARKET ASSESSMENT

This section presents the proposed facilities concept of the Lihi Lani Equestrian Ranch, recommends the necessary facilities based on the projected target markets, recommended marketing strategy, proposed fee structure and expected utilization patterns.

Proposed Equestrian Ranch Facilities Concept

The proposed equestrian ranch is planned to include:

- Two to three barns with stables for up to 100 horses
- Covered arena area
- Two paddocks
- Feed and maintenance structure
- Horse trailer parking
- Riding trails, entry road, buffer and other areas
- Turnout pastures for exercise
- Jumping facilities
- Training equipment
- Grooming, washing and hospital stalls
- Extensive trails
- Manager's office

The total equestrian ranch site would encompass about 19 acres and would have access to riding trails that would run throughout the Lihi Lani community.

Projected Target Markets

Based on the market overview of equestrian facilities and users, the Lihi Lani Equestrian Ranch could target two segments, the Lihi Lani community and other Oahu residents that wish to stable their horses at the facility for recreational riding and equestrian training.

Recommended Marketing of the Equestrian Ranch

Based on the target markets and projected demand for services of these markets, several marketing methods could be utilized:

- Create activity by emphasizing family-oriented recreational riding, lessons and training and sponsorship of an equestrian show or championship. These activities could be key marketing programs targeted at attracting horse owners to Lihi Lani Ranch.
- Target horse owners who are interested in state-of-the-art facilities with well-managed stabling services for their horses.
- Offer a variety of trails and wide open spaces to the riders who enjoy trail riding in a country environment.
- Provide extensive training facilities to accommodate the riders interested in developing their horses.

The ranch would also help to differentiate Lihi Lani from other developments in the area by offering an equestrian atmosphere to the community.

Proposed Equestrian Stable and Projected Utilization Pattern

Based on current fee structures at Oahu equestrian facilities and the preliminary facilities concept of the equestrian ranch at Lihi Lani, proposed stable fees would range between $150 and $400 per month. Stable fees would depend on services provided with the lower range reflecting lease rates with minimal services with the higher range including feeding of horses and maintenance of stalls.

Horse boarders are expected to be primarily from Lihi Lani community and surrounding North Shore and Koolauloa residents. About 70% of the riders are expected to be from these regions.

CABIN MARKET ASSESSMENT

Twelve cabins are planned to be completed in 1995 at Lihi Lani's campground. The cabins will be used primarily on the weekends with year-round weekend occupancy expected to be between 30% and 35%. The rates are expected to be about $75 per weekend, Friday and Saturday nights, in 1990 dollars.

VI - RESIDENTIAL LOT MARKET REVIEW

This chapter reviews residential lot market trends pertinent to the planned lot development at Lihi Lani. The chapter considers two related areas of the single-family lot market, including:

- One-acre and larger lot developments throughout the state
- Selected North Shore and Koolauloa region residential lot sales

HAWAII ONE-ACRE AND LARGER LOT REVIEW

Several subdivisions in the state offer lots ranging between one and ten acres in size. The market performance of two such recent subdivisions can be viewed as potential indicators of the characteristics and depth of support for this market. These are as follows:

- Kohala Ranch
- Hauna Olu

This section describes the market and buyer characteristics at the selected lot developments, which may be compared to Lihi Lani in terms of location, views and the acreage offered.

Project Characteristics

Characteristics of the selected projects are summarized in Exhibit VI-A. The projects are master-planned subdivisions that range from 186 to 2,700 acres in total and offer a range of lot sizes, prices, infrastructure/amenities and view orientations, as shown in the exhibit. These two projects were selected based on the following criteria:

- Availability of one-acre or larger lots
- Lots priced at about $100,000 or more
- First marketed after 1985
- Over 100 lots offered in total
- Recent sales experience

Buyer Profiles and Purchase Motivations

Primary residences are planned for 45% to 50% of the lots as shown in Exhibit VI-B. The remaining 50% to 55% of the buyers are assumed to be motivated by second home and/or investment considerations. A brief description of demographic and life-style characteristics of the buyers is also shown in the exhibit.

Major purchase motivations and considerations for the primary home market are generally as follows:

- Low prices and good values
- Proximity to employment
- Preference for approximately one-acre over multiacre lots
- Less restrictive design standards

LIHI LANI RECREATIONAL COMMUNITY

Summary of Buyer Characteristics at Selected
One-Acre and Larger Lot Subdivisions in Hawaii

Subdivision and location	Intended uses	Demographic characteristics	Life-style characteristics	Main attractions to project
Kohala Ranch (North Kohala, Island of Hawaii)	Primary residence, 45% Second home, 40% Investment, 15%	40% in 30 to 39 age group. 25% from California (mostly Southern California); 40% in-state (mostly Hawaii island); average income about $500,000; 30% actively involved in real estate. Majority are independent entrepreneurs or professionals.	Entrepreneurs with freedom of location.	Good security, value and ocean/coastal views and amenities. Property sales increased substantially after the infrastructure was in place.
Mauna Olu (Makaha Valley, Oahu)	Primary residence, 50% Second home, 30% Investment, 20%	Oahu residents represented about 75%. California and Japan represented 25% of the buyers. Some local contractors bought for primary or secondary residences.	Buyers tended to be knowledgeable about real estate (such as contractors) and some were able to pay cash.	Buyers attracted by resort proximity, ocean views and one-acre lot sizes. Similar to neighbor island agricultural lot projects while located on Oahu.

Source: Compiled by KPMG Peat Marwick based on interviews with project managers and sales representatives.

Exhibit VI-B

LIHI LANI RECREATIONAL COMMUNITY

Summary of Project Characteristics at Selected
One-Acre and Larger Lot Subdivisions in Hawaii

Subdivision and location	Total project size (acres)	Phase	Number of lots	Lot size (acres)	Price range	Infrastructure/amenities	Views/comments
Kohala Ranch (North Kohala, Island of Hawaii)	2,700	1 2	223 154 377	3, 5 and 10 3 and 5	$ 300,000 - 500,000 300,000 - 425,000	Roads, cesspool, electricity, underground utilities, water, 24-hour security and manned gates. Amenities include gazebos, stables and trails, tennis, golf (planned).	Roads and boundary lines positioned to maximize view and privacy. Developer financing cash purchase incentives and build-out incentives offered along with other promotions. Elevations from sea level up to 3,000 feet.
Mauna Olu (Makaha Valley, Oahu)	186	1 2	94 12 106	1 to 2.5	$ 97,000 - 214,500	Roads, underground utilities, water, sewer, security gate.	Lot subdivision located in Makaha Valley with views of the ocean, the Sheraton Makaha Resort and the two golf courses.

Sources: Compiled by KPMG Peat Marwick based on interviews with project representatives and published sales information from the respective projects.

Exhibit VI-A

The second home market purchase motivations and considerations generally concern:

- Security and privacy
- Views of the ocean
- Master-planned subdivision
- Larger lot sizes

Sales Absorption and Prices

The marketing of high quality, master-planned single-family lot subdivisions is a concept that has found good market acceptance in Hawaii. Sales absorption is also affected by the number and types of developer-financing packages and incentives being offered, with Kohala Ranch being the most innovative in these areas.

Average annual absorption since the first marketing of the comparable projects has ranged from about 36 lots per year at Mauna Olu to an equivalent 100 lots per year at Kohala Ranch, as shown in Exhibit VI-C. Mauna Olu, the only Oahu comparable lot project, was able to sell approximately 43 out of the 94 Phase I lots offered on the first day of marketing and 50 more lots within about a month. Twelve additional lots were offered for sale in April 1988, and all sold within a month.

KOOLAULOA AND NORTH SHORE LOT REVIEW

This section reviews the sales trends on Oahu of residential lots from one to five acres in size and located in the Koolauloa and North Shore regions of Oahu. The Pupukea area in Koolauloa, where Lihi Lani is located, is reviewed in detail.

Sales Absorption

Sales and resales of vacant one- to five-acre lots in the two regions increased from 11 in 1983 to a high of 73 in 1987, as shown in Exhibit VI-D. Sales as of November 1990 represent 30 lots in the year. By size, the 2- to 3.9-acre lots had the highest percentage of sales in 1986 and 1987. However, during the first 11 months of 1990 the one-acre lots were the majority of sales. All but one of the remaining lots sold during the first 11 months of 1990 were 2 to 3.9 acres.

The Koolauloa and North Shore regions both showed increasing sales from 1983 to 1988. Recent sales have since declined to 19 lots sold in 1989 and 30 lots in the first 11 months of 1990. This is partially due to the lack of available inventory and the fact that current sales involve resales of improved lots.

Sales Prices

Sales prices for 1- to 1.9-acre lots ranged from $12,500 to $725,000 in 1990 and averaged $320,000, as shown in Exhibit VI-E. In terms of price per acre, the one-acre lots have shown a strong increase in prices since 1987, nearly doubling in value from 1989 to 1990.

Exhibit VI-C

LIHI LANI RECREATIONAL COMMUNITY

New and Resales Absorption at
Selected One-Acre and Larger Lot Subdivisions in Hawaii

1986 to November 1990

Subdivision	Total lots	Marketing start date	Number of lots sold(1) 1986	1987	1988	1989	1990(2)	Total	Average annual absorption
Kohala Ranch	377	January 1986	40	128	70	162	103	503	100
Mauna Olu	106	August 1987	-	93	12	-	3	108	36

(1) Based on sales, resales or reservations as reported by representatives of the specific projects.
(2) Through November 1990.

Source: Based on data provided by the THK database.

LIHI LANI RECREATIONAL COMMUNITY

Average Sales Prices of Vacant One- to Five-Acre Lots in the Koolauloa and North Shore Regions by Lot Size

1983 to November 1990

	1983	1984	1985	1986	1987	1988	1989	1990(1)	Compound average annual percent increase
1 to 1.9 acres:									
Low	$ 53,000	70,000	12,500	18,000	102,500	85,000	85,000	12,500	
High	250,000	125,000	220,800	135,000	155,000	320,000	250,000	725,000	
Average	151,000	98,700	104,500	103,800	129,900	157,300	160,000	320,600	
Average/acre	93,800	94,400	84,800	89,700	100,129	132,700	120,900	223,800	13.2%
2 to 3.9 acres:									
Low	194,000	70,000	48,500	75,000	95,000	10,000	195,000	60,000	
High	207,000	260,000	150,000	270,000	385,000	1,700,000	400,000	1,500,000	
Average	198,300	159,300	120,900	132,900	165,300	599,300	275,900	519,200	
Average/acre	99,200	65,700	56,900	62,300	75,323	261,400	118,800	213,100	11.5%
4 to 5 acres:									
Low	190,000	25,200	75,000	152,000	145,000	N/S	225,000	383,000	
High	190,000	185,000	270,000	210,000	145,000	N/S	695,000	383,000	
Average	190,000	155,600	132,900	189,900	145,000	N/S	460,000	383,000	
Average/acre	45,640	32,900	62,300	44,100	30,300	N/S	98,400	79,800	8.3%

N/S No sales.
(1) Sales recorded through November 1990.

Source: Based on data provided by the THK database.

Exhibit VI-E

Exhibit VI-D

LIHI LANI RECREATIONAL COMMUNITY

Sales Absorption of Vacant One- to Five-Acre Lots in the Koolauloa and North Shore Regions

1983 to November 1990

	1983	1984	1985	1986	1987	1988	1989	1990(1)
Number of sales:								
By lot size:								
1 to 1.9 acres	7	5	14	11	17	32	8	16
2 to 3.9 acres	3	9	8	36	53	10	9	13
4 to 5 acres	1	16	3	4	3	5	2	1
Total	11	30	25	51	73	47	19	30
By region:								
Koolauloa(2)	2	7	6	24	34	43	16	22
North Shore(3)	9	23	19	27	39	4	3	8
Total	11	30	25	51	73	47	19	30
Percent distribution of sales:								
By lot size:								
1 to 1.9 acres	64%	17%	56%	22%	23%	68%	42%	53%
2 to 3.9 acres	27	30	32	70	73	21	47	43
4 to 5 acres	9	53	12	8	4	11	11	4
Total	100%	100%	100%	100%	100%	100%	100%	100%
By region:								
Koolauloa(2)	18	23	24	47	47	91	84	73
North Shore(3)	82	77	76	53	53	9	16	27
Total	100%	100%	100%	100%	100%	100%	100%	100%

(1) Sales recorded through November 1990.

(2) Koolauloa District, Tax Map Key #1-5. The THK Koolauloa District is co-terminus with the Koolauloa Census Division.

(3) Waialua District, Tax Map Key #1-6. The THK Waialua District is co-terminus with the North Shore Census Division.

Source: Based on data provided by the THK database.

The next category, 2- to 3.9-acre lots, has achieved high sales prices but lower prices per acre. In 1990, prices ranged from $60,000 to $1.5 million, averaging $213,000 per acre.

The 4- to 5-acre lots had insufficient sales in 1990 to analyze. The one lot sold for $383,000, or $79,000 per acre, which represented a decline from 1989, but more than twice the per acre price realized in 1987.

Overall, the relatively smaller lots showed the strongest price increases with the 1- to 1.9-acre category having the highest average price per acre, at $223,800. It would appear that lots sized at four acres or more tend to have less value for residential buyers who typically construct only one housing structure and do not necessarily require larger acreage lots.

Several trends emerge in the analysis of sales of lots by region, as shown in Exhibit VI-F. Koolauloa lots had the highest in average sales prices in 1990 with an average of $395,800. The average price per acre also showed the most rapid price increases from a 1985 low of $51,400 to $212,800 in 1990, representing a 12.6% compound annual rate of increase since 1983.

On the North Shore lot sales averaged $361,700 in 1990, 9% below the average Koolauloa lot price. Segmenting the North Shore price trends further, the Pupukea area has performed well. In Pupukea, the average sales price per acre has increased from below $100,000 in 1985 to $275,000 in 1990. Within Pupukea, the higher prices are partly attributable to the Sunset Hills subdivision, where vacant lot prices reached a high of $1,700,000 in 1988. One sale in 1990 was $450,000, a decline from 1989 sales but high compared to pre-1988 sales.

OTHER REGIONAL DEVELOPMENT PLANS

Koolauloa/North Shore landowners with significant development plans include Campbell Estate, Castle & Cooke, Hokuleia Land Co. and Bishop Estate. Their respective development concepts are presented below.

Campbell Estate

Three projects have been planned for Campbell Estate lands in and around Kahuku but none of these plans include significant competitive residential inventory:

- The Kahuku Village consists of 87 affordable housing units. The project is currently on hold pending local government approvals.
- The Industrial Service Park is also pending approvals. The project consists of 15 acres of committed park land subdivided into 28 industrial lots. This development is also reportedly on hold at this time.
- Four golf courses were originally planned; however, the necessary land use approvals were denied. Subsequently an amendment was resubmitted for three courses.

LIHI LANI RECREATIONAL COMMUNITY

Sales Price Indicators of One- to Five-Acre Lots in the Koolauloa and North Shore Regions by Location of Lot

1983 to November 1990

	1983	1984	1985	1986	1987	1988	1989	1990(1)	Compound average annual percent increase
Koolauloa region:									
Low	$ 120,000	25,200	27,400	18,000	56,000	10,000	85,000	12,500	
High	150,000	260,000	220,800	270,000	280,000	1,700,000	695,000	1,500,000	
Average	135,000	133,200	99,700	142,400	185,000	257,100	251,600	395,800	
Average/acre	92,600	65,400	51,400	63,100	78,500	191,000	114,200	212,800	12.6%
North Shore region:									
Low	53,000	70,000	12,500	100,000	60,000	96,000	195,000	60,000	
High	250,000	195,000	220,000	207,500	375,000	189,000	260,000	725,000	
Average	174,800	151,500	108,200	121,000	127,800	142,500	235,000	361,700	
Average/acre	90,500	49,200	72,700	70,000	70,600	72,900	112,300	177,700	10.1%
Pupukea area(2):									
Low	53,000	83,500	12,500	100,000	95,000	10,000	107,200	75,000	
High	250,000	125,000	122,500	135,000	150,000	1,700,000	325,000	450,000	
Average	168,200	102,900	92,900	122,400	118,300	256,100	222,600	275,000	
Average/acre	99,700	99,400	77,100	96,600	107,700	204,500	125,900	181,500	8.9%
Sunset Hills subdivision(3):									
Low	140,000	100,000	N/S	125,000	125,000	140,000	180,000	450,000	
High	250,000	125,000	N/S	125,000	125,000	1,700,000	325,000	450,000	
Average	205,000	112,500	N/S	125,000	125,000	478,000	261,500	450,000	
Average/acre	133,200	107,800	N/S	122,200	119,000	355,700	142,900	234,400	8.4%

N/S No sales.
(1) Through November 1990.
(2) Defined as Tax Map Key 1-5-9.
(3) Defined as Tax Map Key 1-5-9-29 and 30.

Source: Based on data provided by the TMK database.

Exhibit VI-F

Castle & Cooke

A private golf course was planned for development on Castle & Cooke lands on the North Shore, however, these plans are now on hold indefinitely.

Mokuleia Land Co.

Mokuleia Land Co. has North Shore residential development plans, however, they are behind the Lihi Lani project in terms of the necessary approvals and, therefore, not considered highly competitive at this time.

Among the plans considered for development are:

- Two 18-hole golf courses (1 private and 1 daily fee)
- 100 to 150 ranch-style lots of 1-2 acres
- Resort facilities including a mountain lodge and an oceanfront hotel
- Equestrian center

Bishop Estate

Bishop Estate is examining master-plan development concepts, however, nothing has yet been approved by the Trustees. Accordingly, no significant competing residential development exists at this time. However, there has been discussions regarding residential and golf course development on Bishop Estate lands in the region.

AFFORDABLE HOUSING PROGRAM

Absorption of the affordable housing portion of the development of Lihi Lani could be expected to be rapid due to the tight market conditions for affordable homes on Oahu. The market assessment conclusions with respect to this market segment are presented in the next chapter.

VII - RESIDENTIAL LOT MARKET ASSESSMENT

This chapter assesses the market potential for the proposed country lot subdivision at Lihi Lani and presents recommendations and conclusions relating to target markets, proposed development characteristics, marketing strategies and expected market performance of the lot sales program. The chapter also addresses pricing and development integration of the affordable housing component.

PROPOSED PROJECT CONCEPT

The residential portion of the development is proposed to be a fee simple residential subdivision of approximately 120 one-acre and larger country lots and 180 affordable homes. The project would offer:

- A master-planned recreation-oriented community, including golf, tennis, horseback riding, hiking trails and parks.

- Excellent sunset, ocean and coastline views, close proximity to the Kuilima Resort and North Shore and Koolauloa beaches, and a climate conducive to outdoor activities.

It is proposed that the lot purchasers be granted reduced price memberships and fees in the golf club, tennis center and equestrian ranch, in order to further integrate the residential and recreation elements of the development and to encourage a stable resident base.

A preliminary subdivision design prepared by Group 70 Architects and Planners was shown previously in Exhibit II-B. The design would place the 120 country lots around the golf course and other project amenities with an emphasis on providing outstanding ocean, golf and ravine views from the maximum number of lots. The 180 affordable homes would be developed in conjunction with other project elements, in accordance with county guidelines.

TARGET MARKETS

This section examines the buyer profiles of the comparable projects reviewed in earlier chapters and assesses the anticipated target markets for the planned development.

Buyer Origins

The previous chapter surveyed the buyer profiles at the following types of lot developments in the state:

- One-acre and larger lot developments
- North Shore and Koolauloa residential lot sales on Oahu

Origins of residential lot buyers vary considerably by type of project, as shown in Exhibit VII-A.

Oahu residents were the majority of purchasers of the acreage lots on Oahu and 10% of buyers at Kohala Ranch on the island of Hawaii. This reflects the strong and relatively large resident market base on Oahu and the preference of many Oahu residents to retain primary and/or secondary homes on the island. The largest in-state buyer segments were observed at:

- Oahu lot sales in the Koolauloa and North Shore regions (87% and 97%)
- Oahu lot sales in the Pupukea area and at the Sunset Hills subdivision (85% and 100%)

Western U. S. buyers typically ranged from 5% to 31% of the buyers of the selected project types. The most significant western U. S. buyer segment was observed at the Kohala Ranch with 31%.

Anticipated Target Markets

Based on interviews with project managers and sales representatives of one-acre and larger residential lots and on the data presented above, buyers seeking a full-time home can be expected to be the most significant segment, with vacation, secondary home and investor buyers making up the balance of buyers.

Based on buyer profiles observed at the comparable projects and taking into consideration the location and project characteristics of Lihi Lani, the market for lots in Lihi Lani is also expected to be principally composed of Hawaii resident couples or families seeking a primary or second/vacation home. The local resident market is also proposed to be encouraged by the developer's plan to market the lots first to Hawaii residents.

Actual market mix would be dependent on final prices established and the competitive market conditions at the time of marketing. However, in summary, the major markets and their potential purchase motivations could be anticipated to be approximately as shown in the following table and described in the sections below:

Projected Lihi Lani Lot Buyer Market Mix

Primary place of residence	Full-time	Part-time	Total
State of Hawaii	45%	35%	80%
Other	5	15	20
Total	50%	50%	100%

LIHI LANI RECREATIONAL COMMUNITY

Comparison of Typical Buyer Origins
for Selected Comparable Lot Developments in Hawaii

1989 to 1990

		Buyer origin								
		State of Hawaii								
	Typical price	Island of Oahu	Other	Total	Western U. S.	Other U.S.	Total	Foreign	Total
Equestrian development lots - Kohala Ranch	$ 400,000	10%	28%	38%	31%	17%	48%	14%	100%
Lihi Lani area lot sales:									
Koolauloa region	395,800	87	1	88	5	4	9	3	100
North Shore region	361,700	97	-	97	-	3	3	-	100
Pupukea area	275,000	85	-	85	7	4	11	4	100
Sunset Hills subdivision	450,000	100	-	100	-	-	-	-	100

Exhibit VII-A

Full-time Resident Market Segment

Full-time or primary resident buyers are expected to be motivated by several considerations:

- The attractiveness of a secure recreation-oriented community on the North Shore/Koolauloa area of Oahu for residents anticipating retirement.
- The location of the project in the Koolauloa division of Oahu, about 60 minutes away from the state's largest population and employment centers.
- The emerging visitor economy of the North Shore/Koolauloa areas and increasing telecommunications technologies, which could permit more working professionals to live in the region.
- The importance of the primary home market at other lot developments in the state.

Typical primary resident buyers may be Oahu families who wish to upgrade their current primary residence to a large custom built home or older couples seeking a potential retirement home. This market segment may be further represented as follows:

- Household head typically 40 to 65 years old.
- Employed in the North Shore/Koolauloa to Central Oahu areas, self-employed, retired and/or with flexible work schedules.
- Primary attractions to the project:
  - Recreation and family-oriented community
  - Tennis center, equestrian ranch and golf course
  - Master-planned subdivision
  - One- to two-acre lot sizes
  - Excellent ocean and coastline views

Vacation/Part-time Home Market Segment

The vacation/part-time home buyer could be attracted by the project's Hawaii and Oahu location, proximity and access to the planned golf courses, equestrian ranch and tennis center, excellent ocean views and privacy. This market may be further described as follows:

- Household head typically 40 to 55 years old.
- Personal and professional freedom to travel and make significant use of a second home.
- Primary attractions to the project:
  - Golf-oriented community located on Oahu.
  - Excellent ocean and coastline views.
  - Close proximity to a resort area and recreational opportunities.
  - 60-minute drive from urban centers of the state.

ANTICIPATED LOT PRICES

This section presents a pricing schedule for the development based upon comparable projects.

It is expected that lot sales prices at the new development could be positioned at or above those of the current Koolauloa and North Shore markets due to the unique qualities of the project. In establishing the sales price schedule, the following premiums are considered:

- View orientations, including:
  - Excellent ocean, coastline and sunset views
  - Golf course views
  - Ravine, forest and mountain views
- Other factors, including:
  - Golf, tennis and equestrian facilities
  - Well-designed master-planned subdivision
  - Location close to a resort area and renowned beaches
  - Ranch setting about 60 minutes from Honolulu

Very few other single-family lot developments have offered both excellent ocean and fairway views. Oceanview premiums at other acreage developments range from 80% to 230%.

At the project, typical initial lot prices are projected to range approximately as shown below:

Projected Typical Lot Sales Prices
at Initial Marketing

(1990 dollars)

Lot view orientation	Low	High
Prime ocean view	$ 375,000	425,000
Distant ocean/golf	325,000	375,000
Golf course	275,000	325,000
Other	180,000	220,000

These are suggested initial offering prices based on current market conditions, anticipated competition and expected project facilities and amenities. Once marketing for the project has begun, the initial prices could be adjusted depending on market conditions at the time.

PROPOSED MARKETING STRATEGIES

Possible marketing activities for the planned development could target two major objectives:

- Establish the market identity as a high-quality product and residential recreation-oriented community.
- Stimulate word-of-mouth advertising and attract site visits.

Market Identity

In order to establish the project as a high-quality development, marketing activities could feature the community's unique and attractive qualities, including:

- Its recreational amenities.
- The outstanding mountain, forest, ravine and ocean views throughout the community.
- The Hawaiian ranch atmosphere, within driving distance of urban Honolulu.

Establishing the project as a solid residential and recreational community could be directed at securing the attention of the Hawaii resident market. This could also stimulate markets by demonstrating the superior qualities and location over neighbor island lots.

Purchase Incentives

Potential strategies to establish initial market momentum could include:

- Hosting island activities such as golf or tennis tournaments and equestrian competitions or other events.
- Providing one or two model homes.
- Offering initial open houses for the model homes and golf course.
- Encouraging construction activity at the site through builder incentives or requirements.

A reduction in the price of the golf course memberships for purchasers of lots could also be a major market attraction, particularly for the sizable second home market anticipated for the development. In addition, a related selling point may be to emphasize the large sizes of the lots offered, relative to other golf-front lots in Hawaii, which are typically 9,000 to 20,000 square feet.

ANTICIPATED SALES ABSORPTION

Lot sales absorption of the selected comparable projects on the islands of Oahu and Hawaii was about 70 sales per year from 1986 to 1989, as shown in Exhibit VII-B.

Sales absorption at the lot subdivision could be affected by numerous factors, including:

- Effective marketing of the golf course that could give the development local, national and international recognition in the home buyer and golfing markets.

Exhibit VII-B

LIHI LANI RECREATIONAL COMMUNITY

Typical Lot Sales Absorption Rates for Selected Comparable Projects

1986 to 1989

	Average annual absorption per project
Oahu and Hawaii island selected lot subdivisions	70
Oahu lot sales:(1)	
Koolauloa region	29
North Shore region	18

(1) Sales absorption represents total annual recorded sales for the North Shore and Koolauloa districts of Oahu for vacant lots.

Source: Based upon discussions with project developers or realtors and data from the Multiple Listing Service.

- Promotion of the planned subdivision as the superior alternative to a neighbor island lot property due to its Oahu location and its competitive master-planned design and extensive amenities.
- The emergence of the North Shore/Koolauloa area as a major recreational area on Oahu for golf, ocean and other activities which will stimulate employment and income as well as name recognition of the area.
- Economic conditions during the sales period.

The anticipated sales absorption for the lots has been developed based upon the phasing of the lots, average annual sales of comparable projects, the buyer profile and product mix previously discussed and current market factors. Sales are projected to be completed by the third year of market availability or about 1997, as shown in Exhibit VII-C. The following assumptions have been made in deriving this absorption analysis:

- The schedule shown represents closed sales, assuming a reasonable marketing budget and that developer financing or other incentives are available as market conditions may require. Reservations and pre-marketing could accelerate the absorption rate while delays in completing infrastructure and/or amenities could have a negative effect.
- Infrastructure, subdivision and project amenities including the golf course are completed according to current development plans.
- A model home is completed on the property in the first year of market offering, in order to demonstrate the quality and potential of the development.

AFFORDABLE HOUSING DEVELOPMENT PROGRAM

This section discusses the affordable housing component of the project in terms of market assumptions and housing prices.

Assumptions

Home purchase and affordability for a family of four are based on median income estimates for Oahu, as prepared by the U. S. Department of Housing and Urban Development in 1990. Additional market assumptions are as follows:

- 30-year mortgage at 9.5% interest.
- 30% of gross household income available for mortgage principal, interest, real property tax and insurance payments.
- 30% of gross household income available for rent, including utilities and association dues, if applicable.

Affordable Housing Prices

Based on the home purchase and market assumptions, affordability as a function of household income is estimated in Exhibit VII-D and summarized as follows:

Exhibit VII-C

LIHI LANI RECREATIONAL COMMUNITY

Projected Country Lot Sales Absorption at Lihi Lani

1995 to 1997

	1995	1996	1997
Annual lot sales	60	30	30
Cumulative lot sales	60	90	120

Exhibit VII-D

LIHI LANI RECREATIONAL COMMUNITY

Home Purchase and Rental Affordability for Oahu Households

1990

	Percent of Oahu median household income			
	80%	100%	120%	140%
Household income:				
Annual(1)	$ 33,000	$ 41,200	$ 49,400	$ 57,700
Monthly	2,750	3,430	4,120	4,810
Home purchase assumptions:				
Maximum monthly payment(2)	$ 830	$ 1,030	$ 1,240	$ 1,440
Less real property tax and insurance	100	125	150	180
Maximum amount to principal and interest	730	905	1,090	1,260
Maximum mortgage amount(3)	$ 86,000	107,000	129,000	149,000
Down payment amount:				
At 5% of purchase price	$ 5,000	$ 6,000	$ 7,000	$ 8,000
At 10% of purchase price	$ 10,000	$ 12,000	$ 14,000	$ 17,000
Home purchase affordability:				
Maximum price at 5% down	$ 91,000	$ 113,000	$ 136,000	$ 157,000
Maximum price at 10% down	$ 96,000	$ 119,000	$ 143,000	$ 166,000
Maximum monthly rent(4)	$ 830	$ 1,030	$ 1,240	$ 1,440

(1) As established by the U. S. Department of Housing and Urban Development for Oahu in 1990, assuming a household size of four.

(2) Based on 30% of monthly income.

(3) Based on 30-year mortgage at 9.5% interest, with 30% of gross household income available for payment of mortgage principal, interest, real property tax and insurance.

(4) Assuming 30% of gross household income available for rent, including utilities and association dues, if applicable.

- 80% - 100% of median - This income bracket could be expected to afford housing priced from about $90,000 to $120,000 in 1990 dollars, assuming they qualify for federal and other programs enabling down payments of 5% to 10%.

- 120% - 140% of median - This income bracket could be expected to afford to purchase housing priced from about $135,000 to $165,000, assuming they qualify for federal and other programs enabling down payments of 5% to 10%.

APPENDIX F

AGRICULTURAL FEASIBILITY AND NEED FOR OHBAYASHI PUPUKEA PROJECT LANDS

PREPARED FOR
OHBAYASHI HAWAII CORPORATION

Coordinated by GROUP 70

Prepared by
Frank S. Scott, Jr.
Agricultural Economist

March 1988

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SUMMARY AND CONCLUSIONS

This report indicates that agriculture is not a viable option for utilizing Ohbayashi Pupukea Project lands. Findings are based on four criteria: ecological adaptation, sales potential, economic viability and intensity of production. Most of the area is ecologically infeasible for any type of crop production or grazing. Seventy-one percent of the land area, 801 acres, consists of soil types in very low SCS capability classifications of IVs to VIIIs. These areas are very badly eroded and most consist of steep, rocky gulches. The 176.4 acres of Class II (162.2 acres of LSB Class B) soils consist of many scattered small plateaus, surrounded by the steep, badly eroded gulches. This configuration prevents economies of scale and increases the cost of infrastructure for crop production.

Median annual rainfall is a moderately high 51.7 inches, but seasonal distribution is uneven and there is extreme variation for any given month from year to year. Any month may require almost complete dependence on irrigation during some years. The median annual supplemental irrigation requirement in the longrun is estimated at 190,000 gallons per acre at an annual per acre cost of $1,223, including both water and development costs. Twenty-five percent of the time, the annual water requirement would amount to and estimated 695,000 gallons at a cost of $1,349 per acre, including development costs. These costs are prohibitive for truck crop and tree fruit production. Because any month during a drought period may require almost complete dependence on supplemental irrigation, the water system must be capable of delivering 5,431 gallons per acre per day or 900,000 gallons per day for the approximately 200 acres ecologically adaptable to crop production. The existing system in Pupukea reportedly could supply about one-fourth of this amount. The remainder must be obtained from new project wells which may be too saline for salt sensitive crops and would be costly to develop.

Limited market potentials for crops that are ecologically adapted to the project and the inability to compete in the marketplace are major constraints. Analysis of the market supply, Oahu's ability to displace imports and the competitive disadvantage of Ohbayashi Pupukea in relation to alternative production areas, particularly on the Neighbor Islands, indicate that potential lack of a sales potential is an almost complete deterrent to the utilization of project lands for commercial agricultural production.

A final factor with respect to preserving project land for agricultural production is that the land is not needed for that purpose. A total of 141,849 acres of land on Oahu were zoned as Agricultural in 1986 by the State Land Use Commission. Acreage in cultivated crops, on the other hand, has steadily declined from 50,700 acres in 1977 to 40,700 acres in 1986. This decline can be expected to continue as economic viability of sugar declines and some diversified crops such as bananas and watermelons shift from Oahu to the Neighbor Islands, which have lower costs of production.

A substantial amount of the land area being withdrawn from agriculture on Oahu consists of Class I soil types, of which Ohbayashi Pupukea has only 6.4 acres, if irrigated. Sugar plantations with good soils would be the most feasible units for commercial production of alternative crops to sugar for which economies of scale are essential. As of now, there has been no breakthrough in the search for alternative crops for sugar lands. With an excess of good land on Oahu in relation to its demand for crop production, there is no substantive agricultural demand for the inferior gulch lands or poorly configurated plateaus in the project area.

Not only do the criteria used in the analysis indicate that the Ohbayashi Pupukea Project Property is infeasible for commerical agriculture, but also that any agricultural use would likely accelerate the already very serious erosion problem.

AGRICULTURAL FEASIBILITY AND NEED FOR OHBAYASHI PUPUKEA PROJECT LANDS 1/

INTRODUCTION

This report investigates the agricultural feasibility of the Ohbayashi Pupukea Project lands and the probable effects on Hawaii agriculture as a consequence of rezoning the project lands from Agricultural to Urban for use as golf courses.

Determination of agricultural feasibility is based on four appropriate criteria which are specified in the following section of the report. The agricultural need for lands in the project area that are ecologically adaptable to crop production is based on the relationship of the availability of good agricultural lands on Oahu to trends in crop production and the quality of project lands in relation to other available agricultural lands on Oahu. Projections of land needed for agricultural production on Oahu consider possible shifts in crop production to Neighbor Islands.

Project lands are currently idle, except for occasional grazing. No crops have been grown in the area for several decades.

AGRICULTURAL FEASIBILITY CRITERIA

Determination of agricultural feasibility of Ohbayashi Pupukea Project lands for crop production and/or grazing is based on the following criteria:

1. Ecological Adaptation, including soil type, configuration, accesibility, rainfall, availability of supplemental irrigation water, temperature, wind, light intensity and insect and disease problems, if applicable.
2. Sales Potentials based on comparative advantage in competing for market potentials for crops ecologically adaptable to the project area, including comparative costs of production.
3. Economic Viability based primarily on ability of Hawaii production to compete with imports.
4. Intensity of Production based on net returns per acre, if applicable.

NEED FOR AGRICULTURAL ZONING OF PROJECT LANDS

A crucial consideration with respect to retaining the project lands in agricultural zoning is whether they are needed for that purpose. This analysis considers the acreage zoned Agricultural on Oahu, trends in crop production on Oahu, the competitive position of crop

1/ Coordinated by Group 70; prepared by Frank S. Scott, Jr., Agriculatural Economist.

production on Oahu in relation to Neighbor Islands and the quality and configuration of land in the project area in relation to other lands available for crop production on Oahu.

ALISH CLASSIFICATIONS

ALISH Classifications (Agricultural Lands of Importance to the State of Hawaii) of the Hawaii State Department of Agriculture for the Ohbayashi Pupukea Project are shown in Figure 1. A total of 328.2 acres of Prime Agricultural Land is distributed in 8 parcels throughout the project. Likewise, scattered throughout the project are 10 parcels constituting 237.9 acres of Other Agricultural Land. A total of 563.4 acres of land, consisting primarily of steep, rocky, eroded gulches, is unclassified.

CITY AND COUNTY OF HONOLULU LAND USE DESIGNATIONS

All land in the project area is zoned AG-2 (General Agricultural District) by the City and County of Honolulu.

SOILS AND TOPOGRAPHY

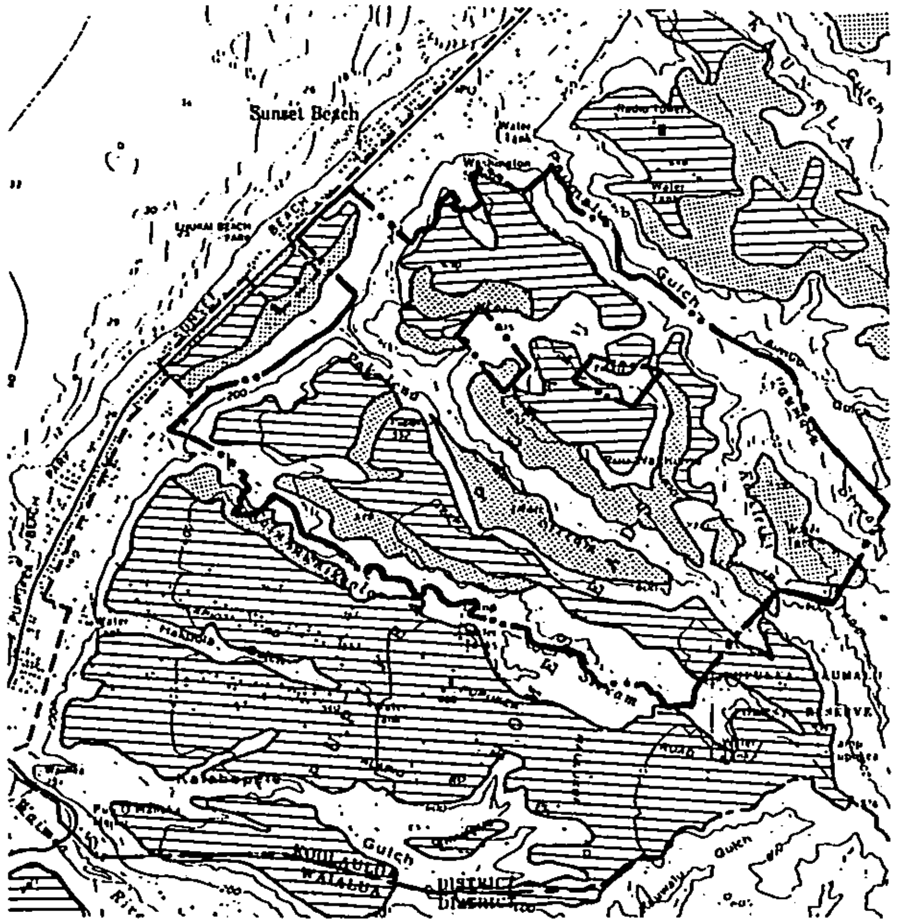
Soil capability classifications for agriculture in this report are based on soil surveys by the USDA Soil Conservation Service (10) and the University of Hawaii Land Study Bureau (8) plus on-site observations by the subcontractor.

SOIL CONSERVATION SERVICE CLASSIFICATIONS (SCS)

SCS soil capability classifications are based on soil profile, topography, water holding capacity, drainage, erosion hazard, pH, workability and depth of root penetration. SCS soil capability classifications range from I to XIII, with I being the best. Class I soils have no more than minimal limitations that restrict crop production and Classes IV to VIII are unsuitable for crop production, with Class VIII having the most severe limitations. SCS capability classifications are delineated in Figure 2 and are described as follows:

Helemano Series

This series consists of steep to extremely steep well drained soils on alluvial fans and colluvial slopes on the sides of gulches. The only soil in this series is Helemano Silty Clay, 30 to 90 Percent Slopes (HLMG). There are 80.6 acres of this soil type in the project area, stretching from near the makai boundary to the mauka boundary along the South border. This unit is given a very low capability classification of VIIe because of extreme steepness and severe erosion. It is unsuited to any type of cultivated crop production, but some areas are marginally useful for pasture.

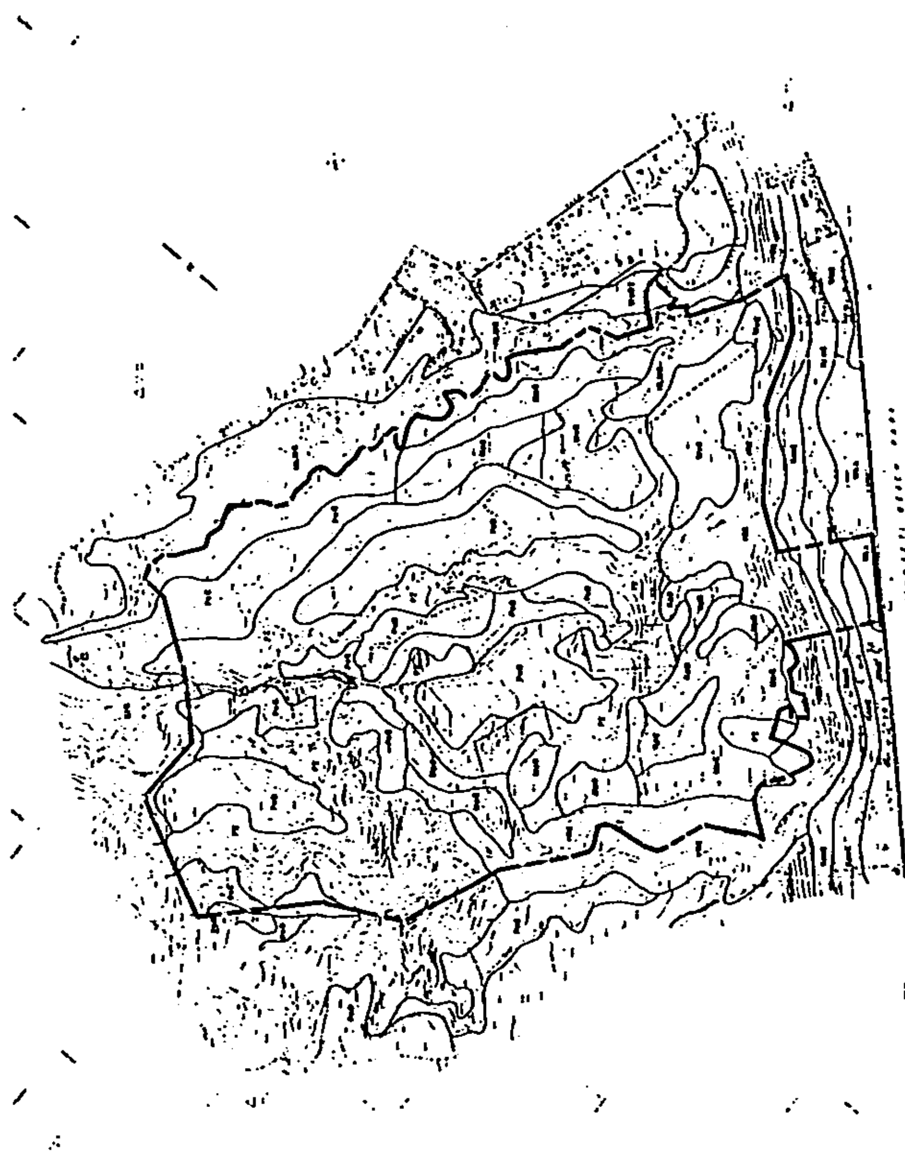


LEGEND

- PRIME AGRICULTURAL LAND
- OTHER IMPORTANT AGRICULTURAL LAND
- UNCLASSIFIED

AGRICULTURAL LANDS OF IMPORTANCE
TO THE STATE OF HAWAII (ALISH)
OHBAYASHI PUPUKEA PROJECT

FIGURE 1



SOIL CAPABILITY CLASSIFICATIONS
OHBAYASHI PUPUKEA PROJECT

SOURCE: U.S. DEPARTMENT OF AGRICULTURE,
SOIL CONSERVATION SERVICE

FIGURE 2

Kaena Series

The Kaena series encompasses 12.4 acres in two narrow strips stretching over the width of the project near the makai boundary (including 6.7 acres of KaeC and 5.7 acres of KanE). The series consists of very deep, poorly drained soils on alluvial fans and talus slopes. The soils developed in alluvium and colluvium from basic igneous material. The soils are gently sloping to steep and are commonly stony.

Kaena Stony Clay, 6 to 12 Percent Slopes, KaeC (6.7 acres).

The topsoil in this subseries is very dark gray clay about 10 inches thick. The subsoil is dark-gray and dark grayish-brown clay 36 to 48 inches or more in thickness. The substratum is weathered gravel. The soil is very sticky, very plastic and mottled. Runoff is slow to medium and the erosion hazard is slight to moderate. The soil is slightly acid to neutral. The water holding capacity is good at 1.4 inches per foot in the topsoil and 1.7 inches per foot in the subsoil. Workability is difficult because of moisture and rocks. The shrink-swell potential is very high and in some areas the soil is affected by seepage. The capability classification is IVw if nonirrigated and IIIw if irrigated with severe limitations for crop production because of excess water. This soil is not recommended for truck crops or orchards but could be used for grazing.

Kaena Very Stony Clay, 10 to 35 Percent Slopes, KanE (5.7 Acres)

This soil has a profile like KaeC, except that there are many stones in the profile and on the surface. Runoff is medium to rapid and the erosion hazard is moderate to severe. Workability is difficult because the soil is stony, steep, very sticky and very plastic. Small areas of rock outcrop and stony land are included. This subseries is given a low capability classification of VIs because of stoniness and unfavorable texture. It is not adaptable to cultivation and is marginal for pasture.

Kapaa Series

This series is represented by 5.6 acres of Kapaa Silty Clay, 40 to 100 Percent Slopes (KlG), located in the North-mauka corner of the project. These soils developed in material weathered from basic igneous rock. The topsoil consists of dark yellowish-brown silty clay, most of which has been removed by erosion. The subsoil is yellowish-red and yellowish-brown silty clay. The substratum is soft weathered rock. About 25 percent of the area consists of rock outcrop, steep stony land, rough broken land, eroded land and rough mountain land. This subseries is given a very low SCS capability classification of VIIe because of extreme erosion and is not suited to crop production or grazing.

Kemoo Series

This series contains 43.5 acres in the North-makai section of the project above the rocky cliffs. The area includes parcels of three subseries: KpB, 6.3 acres; KpC, 17.4 acres; and KpD, 19.8 acres. The series consists of well drained soils on uplands, which are gently sloping to very steep. The topsoil is very dusky red to dark reddish-brown subangular blocky silty clay about 12 inches in depth. The subsoil is dark reddish-brown to dusky-red silty clay of a subangular block structure about 55 inches thick. The substratum is soft, weathered rock. The topsoil is slightly acid and the subsoil is slightly acid to neutral. Permeability is moderate to moderately rapid. The water holding capacity is 1.4 inches per foot. Runoff and erosion hazard vary by subseries as described below.

Kemoo Silty Clay, 2 to 6 Percent Slopes, KpB (6.3 Acres)

For this subseries, runoff is slow to medium, the erosion hazard is slight to moderate and workability is easy. The SCS capability classification is IIe, with moderate limitations for crop production because of the slight erosion hazard. This soil is good for sugarcane, truck crops and orchards, but the small size of the parcel makes it infeasible for sugarcane production.

Kemoo Silty Clay, 6 to 12 Percent Slopes, KpC (17.4 Acres)

This subseries is the same as KpB, except that runoff is medium and the erosion hazard is slight to moderate. The SCS capability classification is downgraded to IIIe because of the erosion problem. This unit is fairly well adapted to sugarcane and truck crops if properly managed to prevent erosion. The comparatively small area of this soil and the fact that it adjoins rocky cliffs limits its use for commercial crop production.

Kemoo Silty Clay, 12 to 20 Percent Slopes, KpD (19.8 Acres)

This subseries is similar to Kemoo soils of lesser slopes, except that runnoff is medium and erosion hazard is moderate. Workability is somewhat difficult because of the slope. This soil is downgraded to a capability classification of IVe because of the erosion problem. The soil is marginal for crop production because of the erosion problems and is not recommended for that use. It can be used for grazing, but this use is also limited because of the erosion problem.

Manana Series

There are several scattered parcels of the Manana Series in the makai section of the project above the ridge, amounting to a total of 147.7 acres. This series consists of well drained silty clay loam and clay loam soils on uplands developed from material weathered from basic igneous rock. The soils are gently sloping to steep. The topsoil is dark reddish-brown silty clay loam about 8 inches in depth. The subsoil is dusky-red, dark reddish-gray and dark reddish-brown silty clay with subangular blocky structure, containing a nonporous panlike sheet 1/8 to 1/4 inches thick at depths ranging from 15 to 50 inches. The substratum is soft, weathered basic igneous rock. The topsoil is very strongly acid and the subsoil is very strongly to extremely acid. The available water capacity is 1.2 inches per foot in the topsoil and 1.3 inches per foot in the subsoil. Roots penetrate to a depth of 15 to 30 inches and up to 4 feet where there are cracks in the panlike sheet.

Manana Silty Clay, 3 to 8 Percent Slopes, MpB (41.1 Acres)

For this subseries, runoff is slow, the erosion hazard is slight and depth to the panlike sheet is 30 to 50 inches. The capability classification is IIe, irrigated or nonirrigated, with the slight downgrading due to the vulnerability to erosion. This soil is well adapted to sugarcane, pineapple, truck crops and orchards. Commerical crop production is limited, however, because this unit consists of small noncontiguous parcels of 21.8, 11.8 and 7.5 acres, which are surrounded by soils of lower capability ratings. The small size of the parcels makes them infeasible for crops requiring economies of scale, such as sugarcane and pineapple.

Manana Silty Clay, 8 to 15 Percent Slopes, MpC (61.3 Acres)

This is the same as Manana silty clays of lesser slopes, except that runoff and the erosion hazard are increased to moderate. The soil is classified as IIIe and is fair for sugarcane, pineapple, truck crops and orchard production if erosion is properly controlled. It is located in two separate, isolated parcels of 49.3 and 12.0 acres.

Manana Silty Clay, 15 to 25 Percent Slopes, MpD (7.7 Acres)

This soil is the same as MpC, except that runoff is medium and the erosion hazard, although moderate, is somewhat more severe. This soil, which is classified IVe, is not usable for sugar, pineapple and truck crops because of the steep slopes and erosion hazard. It is submarginal for orchards.

Manana Silty Clay, 25 to 40 Percent Slopes, MpE (37.3 acres)

This subseries has rapid runoff and an erosion hazard of moderate to severe. The SCS cpability classification is VIe. It cannot be used for crop production and grazing is marginal. It consists of two isolated parcels of 30.2 and 7.1 acres.

Paaloa Series

This series consists of well drained upland soils developed in old alluvium and residium derived from basic igneous rock. It is represented by the subseries PaC in the project area.

Paaloa Silty Clay, 3 to 12 Percent Slopes, PaC (43.6 acres)

This parcel consists of a narrow strip paralleling the South-mauka border of the project and bounded by steep gulches. The topsoil is a mixture of dark brown and dark reddish-brown silty clay about 17 inches in depth. The subsoil is dark reddish-brown silty clay and clay with a subangular blocky structure about 43 inches thick. The substratum is soft, weathered rock. The soil is strongly acid to very strongly acid. Permeability is moderately rapid, runoff is slow to medium and the erosion hazard is slight to moderate. The water holding capacity is 1.2 inches per foot in the topsoil and 1.4 inches per foot in the subsoil. Roots may penetrate to a depth of 5 feet or more. Workability is slightly difficult because of the slope. The SCS land capability classification is IIIe. This land type is fair for truck crop and tree fruit production. It is not feasible for field crop production, such as sugarcane, because it is a small, isolated inacceesible parcel. These restrictions would also seriously limit use of the parcel for truck crops or orchards.

Paumalu Series

This series consists of well-drained silty clay soils on uplands. It is the predominant series in the project, encompassing 579.1 acres, including Paumalu badlands. The soils developed in alluvium and colluvium derived from basic igneous rock and are gently sloping to very steep. Both the topsoil and the subsoil are dark reddish-brown silty clay. The topsoil is about 9 inches in depth and the subsoil is 30 to more than 60 inches thick. The substratum is highly weathered gravel. The topsoil is strongly acid and the subsoil is medium acid. The available water holding capacity is about 1.3 inches per foot of soil. The roots may penetrate to a depth of 5 feet or more in some areas.

Paumalu Silty Clay, 3 to 8 Percent Slopes, PeB (46.7 Acres)

This is the best soil of the Paumalu series. Runoff is slow to medium, the erosion hazard is slight and workability is easy. The capability classification is IIe, irrigated or nonirrigated. Although it is ecologically adapted to sugar cane, truck crops and orchards, it's use for commercial agriculture is limited because of its isolation in the center of the project by steep gulches.

Paumalu Silty Clay, 8 to 15 Percent Slopes, PeC (13.2 acres)

This soil is the same as PeB, except that the erosion hazard is slight to moderate and workability is slightly difficult. The capability classification is IIIe, irrigated or nonirrigated. This soil type is moderately well adapted to crop production with proper erosion control. It has been used for sugar production in areas of larger acreages, but the use of this small isolated parcel is not feasible for that purpose. This soil is also fairly well adapted to truck crop production, but the small size of the parcel would limit its use for that purpose.

Paumalu Silty Clay, 15 to 25 Percent Slopes, PeD (138.5 acres)

This soil is the same as PeC, except that runoff is increased to medium and the erosion hazard is moderate. The capability classification is IVe, irrigated or nonirrigated, reflecting very severe limitation for crop production because of the steep slope and erosion problem.

Paumalu Silty Clay, 25 to 40 Percent Slopes, PeE (56.0 Acres)

The soils on these steep slopes are subject to a medium to rapid runoff and moderate to severe erosion hazard. Because of these conditions, the unit is downgraded to VIe and is not usable for cultivated crop production or recommended for pasture.

Paumalu Badland Complex, 10 to 70 Percent Slopes, PZ (324.7 Acres)

These soils, which constitute about 29 percent of the entire project area, predominate in the mauka section of the project where they consist of steep barren canyons that surround plateaus of somewhat better lands. Most of the soils have been removed from the badlands by wind and water erosion. About 25 percent of the area includes stony land, stony steep land, rock outcrop and rockland. This land has the lowest capability classification of VIIIe and is not adaptable to any type of crop production. Some of the less steep areas are marginal for grazing, but the erosion problem makes grazing impractical.

Rock Land, rRK (116.1 Acres)

A narrow strip of rock land forms steep cliffs surrounding the plateaus and canyons in the makai and Northern sections of the project. Exposed rock covers most of the surface and the remainder is very sticky and very plastic clay. The SCS capability classification is VIIIs because of the steep, rocky conditions. The land cannot feasibly be used for any type of crop production or grazing.

Wahiawa Series

Three soil types in the Wahiawa series comprising 89.9 acres are located in West-makai section of the property. These consist of 82.0 acres of WaB, 5.7 acres of WaC and 2.2 acres of W2D2.

The Wahiawa series consists of well drained soils in upland areas. The soils developed from residium and old alluvium derived from basic igneous rock. The topsoil consists of very dusky red and dusky red silty clay about 12 inches in depth. The subsoil is dark reddish-brown silty clay about 4.8 inches thick. The substratum is weathered basic igneous rock. The topsoil is medium acid and the subsoil is medium acid to neutral. The water holding capacity is good at 1.3 inches per foot in the topsoil and 1.4 inches per foot in the subsoil. Permeability is moderately rapid, runoff is slow to rapid and the erosion hazard is slight to severe, depending upon slope. Roots may penetrate to a depth of 5 feet or more.

Detailed descriptions of the three subseries are as follows:

Wahiawa Silty Clay, 3 to 8 Percent Slopes, WaB (82.0 Acres)

This subseries consists of two noncontiguous, but nearby parcels of 44 acres and 38 acres. Runoff is slow and the erosion hazard is slight. The unit is moderately downgraded to an SCS capability classification of IIe because of the need for erosion protection under tillage. This subseries is good for sugarcane, pineapple, truck crops, orchards and grazing. Truck crops and orchards are presently grown on the same soil type adjoining developed areas of Pupukea. Notwithstanding the good soil type, development for cultivated crop production is hampered because of the isolation of the small parcels which are surrounded by soils that are infeasible for crop production and limited accessibility.

Wahiawa Silty Clay, 8 to 15 Percent Slopes, WaC (5.7 Acres)

This subseries is similar to WaB, except that runoff is medium, the erosion hazard is moderate and some areas are stony and eroded. Because of potential serious erosion problems unless strictly managed under cultivation, this subseries is downgraded to IIIe, irrigated or nonirrigated. This small parcel of 5.7 acres is marginal for crop production but could be used for that purpose in conjuction with the 44-acre parcel of WaB which it adjoins, subject to the same extraneous limitation of WaB.

Wahiawa Silty Clay, 15 to 25 Percent Slopes, Eroded, W2D2 (2.2 Acres)

This subseries is similar to the better Wahiawa Silty Clays, except that most of the topsoil and part of the subsoil in some places has been lost through erosion. Weathered rock occurs at a depth of 2 to 3 feet and boulders occur on the surface in a few places. Runoff is medium to rapid and erosion is severe. Tillage is difficult. The soil is classifeid as IVe, with severe limitations for crop production. This small parcel of 2.2 acres is not considered feasible for crop production because of the low capability rating and isolation.

Waialua Series

This series, which includes 11 acres in the central-makai area of the project, consists of moderately well drained soils on alluvial fans. The soils developed from alluvium weathered from basic igneous rock. The topsoil is dark reddish-brown silty clay about 12 inches in depth. The subsoil is dark reddish-brown silty clay with a subangular blocky structure about 26 inches thick. The substratum is dark reddish-brown, mottled silty clay. The topsoil is neutral and the subsoil is slightly acid. Permeability is moderate. The available water capacity is a very good 1.8 inches per foot in the topsoil and 1.6 inches per foot in the subsoil. Roots may penetrate to a depth of 5 feet or more.

Waialua Silty Clay, 0 to 3 Percent Slopes, WkA (6.4 Acres)

This subseries is the same as described above. Runoff is slow and the erosion hazard is no more than slight. This unit is the only one in the project area with a capability classification of I, with essentially no physical limitations affecting its use for crop production and grazing. The soil is good for sugarcane, truck crops and pasture, disregarding configuration, but its proximity to the ocean and prevailing salt laden winds would seriously limit its use for truck crops. Proximity to salt water plus the salt laden winds make this unit infeasible for orchard crops. The fact that it is a small, isolated parcel would also restrict its use for agriculture.

Waialua Silty Clay, 5 to 8 Percent Slopes, WkB (4.6 Acres)

This soil is the same as WkA, except for the somewhat steeper slopes, for which it is slightly downgraded to a capability classification of IIe. The same limitations to crop production apply because of its proximity to the ocean and to salt laden winds.

LAND STUDY BUREAU CLASSIFICATIONS (LSB)

LSB classifies soils by land type in which classifications are provided for an overall crop productivity rating, with and without irrigation, and for selected crop productivity ratings for 7 crops, namely, pineapple, vegetables, surgarcane, forage, grazing, orchards and timber. The timber rating is not utilized in this report, since it is not concerned with agricultural crop production and grazing. Overall ratings range from A to E, with A being the best. Selected ratings for individual crop categories range from a to e, with a

being the highest. Ratings are generally comparable to those of SCS, but differ somewhat because of fewer categories (A to E for LSB and I to VIII for SCS) and some differences in evaluating soils in specific areas. Some differences also exist because of the use of somewhat different soil capability criteria. The use of both methods leads to a more thorough evaluation than can be obtained by one system, alone. LSB crop productivity ratings for the various parcels of the 1,129.5 acres in the project area are shown in Figure 3 and are described as follows:

A124

A small, isolated parcel of 0.2 acre of this land type is located in the extreme South-makai corner of the project. This unit has an overall productivity rating of A if irrigated and selected crop productivity ratings of b for pineapple and a for vegetables, sugarcane, forage, grazing and orchards. The unit is not considered feasible for commercial crop production, however, because of the small size of the parcel and the fact it is surrounded by rocky cliffs and urban developments.

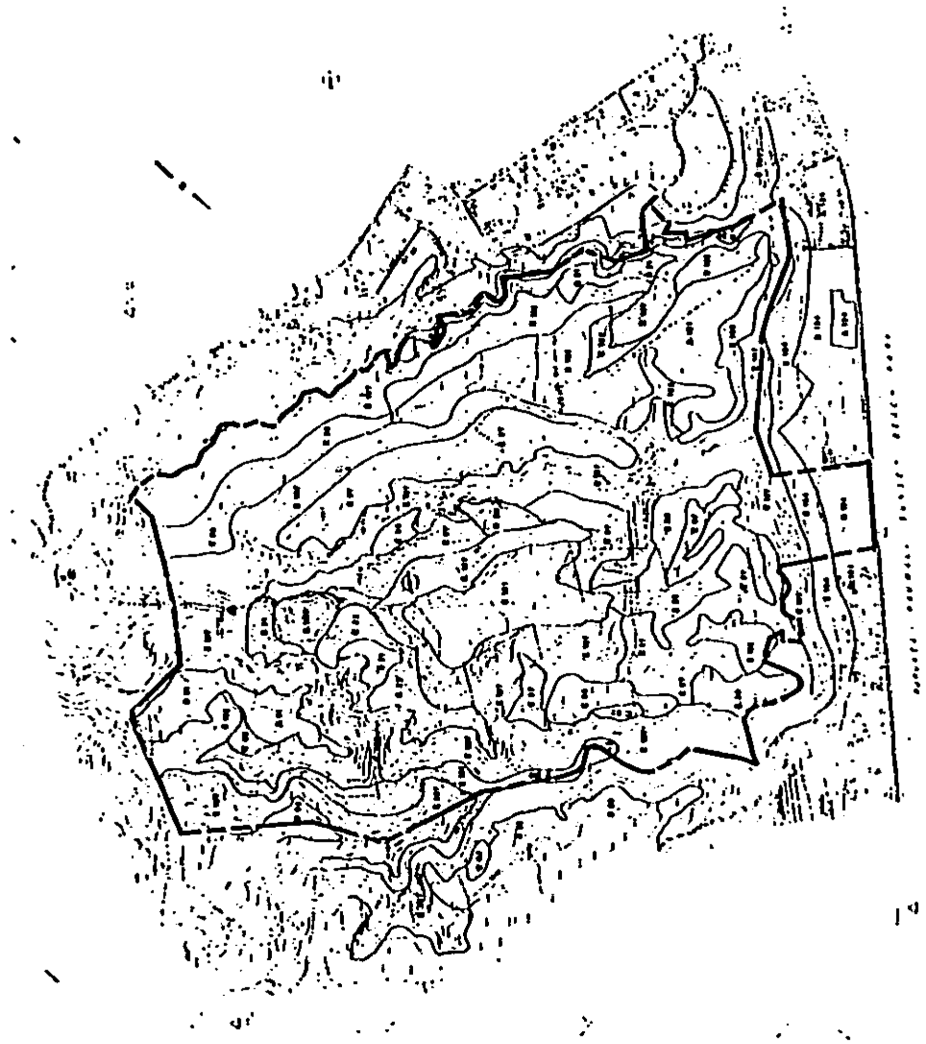
B21

This soil type totals 21.0 acres, consisting of isolated parcels of 7.8 acres near the South border and 3 parcels of 7.1, 5.9 and 0.2 acres in the central-mauka section of the project. This land type has an overall crop productivity rating of B without irrigation and A with irrigation and selected crop productivity ratings with irrigation of b for pineapple and a for all other crops. Because this unit consists of small isolated parcels surrounded by steep canyons it is not considered feasible for commercial crop production.

B121

This soil type encompasses 141.2 acres in the project, consisting of a long narrow plateau of 93.3 acres near the North central border and another plateau of 47.9 acres in the center of the project. This soil has an overall crop productivity rating of B if nonirrigated and A if irrigated. Selected crop productivity ratings if nonirrigated are a for pineapple, b for forage and grazing and c for vegetables, sugarcane and orchards. If irrigated, the selected crop productivity rating is a for all crops.

There is little potential for developing low cost irrigation water for these high plateaus, which is essential for truck crops and orchards. Thus the potential for these crops is marginal. Also, accessibility poses a problem, since these plateaus are isolated and surrounded by steep gulches.



DETAILED LAND CLASSIFICATION
OHBAYASHI PUPUKEA PROJECT

SOURCE: LAND STUDY BUREAU
FIGURE 3

C22

This unit consists of an isolated high plateau of 25.9 acres bounded by steep canyons in the North-mauka section of the project. The overall crop productivity rating is C if nonirrigated and B if irrigated. Selected crop productivity ratings if nonirrigated are b for grazing, c for pineapple, sugarcane and orchards and d for vegetables and forage. If irrigated, the ratings are a for grazing and orchards, b for vegetables and sugarcane, c for pineapples and d for forage. Because of the inability to obtain low cost irrigation water for this high plateau and because of its small size and isolation, the potential use for crop production is poor.

C90

Unit C90 totals 34.6 acres, including a long narrow plateau of 31.4 acres surrounded by canyons paralleling the South-mauka border and a small plateau of 3.2 acres bordering a steep canyon in the North-mauka area of the project. The overall crop productivity rating for these parcels is C, irrigated or nonirrigated. Selected crop productivity ratings, irrigated or nonirrigated, are d for pineapple and c for all other crops. These parcels are considered marginal for crop production based on crop productivity ratings. Considering the fact that the land areas are isolated high plateaus, they are submarginal for agricultural production.

C96

This unit has 32.0 acres in the project area, consisting of three small parcels of 14.5, 13.0 and 4.5 acres scattered through the central to North-makai areas of the project. As with most of the plateaus, these parcels adjoin or are surrounded by steep rocky gulches. Without irrigation the overall crop productivity rating is C and selected crop ratings are c for pineapple and b for all other crops. The unavailability of low cost irrigation water essential for truck crop production and the isolation of the small parcels would render this soil type submarginal for agricultural crop production.

C97

This series encompasses 156.8 acres, consisting of 7 plateaus of 57.1, 45.5, 21.4, 14.6, 9.8, 6.0 and 2.4 acres scattered through the central and North-central-makai areas of the project. Most areas of the plateaus are bounded by steep, rocky gulches. These soils are given an overall crop productivity rating of C, irrgated or nonirrigated. Selected crop productivity ratings if nonirrigated are c for pineapple, orchards and grazing and d for other crops. If irrigated the ratings are b for orchards and grazing, c for pineapple, vegetables and sugarcane and d for forage. Because of the low ratings without irrigation, the unavailability of low cost irrigation water and the isolation and difficult accessibility to the many small parcels, this unit is not considered feasible for commercial agricultural development.

C122

The 15.6 acres in this soil type are divided into two isolated plateaus of 9.9 and 5.7 acres in the South-makai section of the project. The overall crop productivity rating is C without irrigation and B with irrigation. Selected crop productivity ratings without irrigation are b for pineapple and grazing, c for sugarcane and orchards and d for vegetables and forage. With irrigation, the ratings are a for grazing and orchards, b for pineapple, vegetables and sugarcane and d for forage. These two parcels are contiguous to a 93.3 acre parcel of B121 and the combined parcels offer the best opportunity for commercial crop production insofar as size and soil type are concerned. However, low cost irrigation, which would be required for truck crop production is not obtainable. Thus the low selected crop rating of d without irrigation for vegetables prevails. Even this size of parcel is too small and isolated for pineapple or sugarcane production. Orchards would require irrigation during dry spells and, although feasible ecologically, are not feasible commercially because of market limitations.

D30

This unit forms a very narrow segmented strip of 8.2 acres along the South boundary of the project. Without irrigation, the overall productivity rating is D and selected crop productivity ratings are e for sugarcane and d for all other crops. With irrigation, the overall rating is A and the selected ratings are b for pineapple and a for all other crops. Because the area is an isolated, small narrow strip bounded by rocky cliffs or gulches, commercial development for agriculture is considered infeasible.

D58

This soil type is located on a small 6.7 acre parcel in the center of the project area, most of which is surrounded by steep, rocky gulches. The soil has an overall crop productivity rating of D, irrigated or nonirrigated. Both irrigated and nonirrigated selected crop productivity ratings are d for pineapple and sugarcane and e for vegetables and forage. The rating for grazing is b if nonirrigated and a if irrigated. The soil is stony and has poor machine tillability. It is not adaptable to any type of cultivated crop production.

D91

This soil type is located on an irregularly shaped, narrow plateau of 29.9 acres in the North-mauka corner of the property. It is surrounded by steep, rocky gulches. The overall crop productivity rating is D, irrigated or nonirrigated. Selected crop productivity ratings are c for sugarcane, grazing and orchards, d for vegetables and forage and e for pineapple. The soil is fairly well suited to machine tillability. Based on the productivity ratings, this soil is not recommended for crop production or grazing.

D92

This unit consists of a 3.9-acre parcel of poor soil located on the North border near the mauka border. The overall crop productivity rating is D, irrigated or nonirrigated. Selected crop productivity ratings are c for grazing, d for sugarcane and orchards and e for pineapple, vegetables and forage, irrigated or nonirrigated. This isolated parcel is not adaptable to crop production, but could be used for grazing, considering ecological criteria only.

D123

This 8.5-acre parcel is located above the makai cliff in the South-makai corner of the project. The overall crop productivity rating is D if nonirrigated and C if irrigated. Selected crop productivity ratings if nonirrigated are c for pineapple, forage and grazing, d for vegetables and orchards and e for sugarcane. Irrigated selected crop productivity ratings are b for pineapple and a for all other crops. Machine tillability is poor. Part of the parcel consists of a gulch, thus the nonirrigated ratings appear to better represent the crop poetential for the parcel. The parcel is, therefore, not recommended for cultivated crop production, but is ecologically adaptable to grazing.

D124

This unit consists of 17.1 acres in the small section of the property that extends makai to Kam Highway. The unit has an overall crop capability rating of D without irrigation and A with irrigation. Selected crop productivity ratings without irrigation are c for pineapple, forage and grazing, d for vegetables and orchards and e for sugarcane. With irrigation, the ratings are b for pineapple and a for all other crops. In spite of the high rating under irrigation, machine tillability is indicated to be poor. Ecologically this parcel is good for crop production. It has the disadvantage of being an isolated parcel surrounded by urban developments on three sides and is not a good candidate for commercial agriculture for that reason. Crops grown in this area would be subject to wind and salt damage because of its location near the shoreline on the Northwest shore.

E89

This unit consists of 35.0 acres, including two separate parcels of 23.7 and 11.3 acres in the North-makai corner of the project. The overall rating is E without irrigation and D with irrigation. Selected crop productivity ratings without irrigation are c for grazing and e for all cultivated crops. With irrigation, the selected ratings are b for grazing, d for orchards and sugarcane and e for all other crops. The eroded parcels consist of the sides of steep gulches. No crop production is ecologically adapted to this area. Grazing is submarginal and not recommended because of the erosion problem.

E104

This unit of 10.5 acres is located in the lower part of the steep makai cliffs and includes a 9-acre parcel in the North-makai corner and a 1.5 acre parcel in the South-makai corner of the property. Ratings are given only if non-irrigated for class E lands, since these lands cannot feasibly be irrigated. The overall crop productivity rating is E and the selected crop productivity ratings are d for grazing and e for all cultivated crops. This unit cannot be used for any type of agriculture.

E106

This unit encompasses 90 acres of steep rocky canyon walls, consisting of three, mostly elongated parcels near the North border and one parcel paralleling the South-makai border of the property. The overall rating is E and selected crop productivity ratings are b for grazing, d for orchards and e for all other crops. It consists of eroded and rocky lands not suited to machine tillability. It is not adaptable to any type of cultivated crop and is not recommended for grazing because of the erosion problem.

E107

This unit, which encompasses 479.8 acres, constitutes 44 percent of the entire land area in the project. It predominates along the border of the project and forms two long, narrow strips through the center of the project from the makai border to the mauka border. It consists of four parcels, which are broken up into numerous gulches that surround most of the better mesa lands of the project. The overall rating is E and selected crop productivity ratings are d for grazing and e for all cultivated crops. It cannot be used for any type of agriculture, including grazing.

E108

This soil type consists of a long, narrow rocky slope of 12.6 acres in the South-mauka section of the project. The overall rating is E and selected crop productivity ratings are d for grazing and orchards and e for all other crops. This unit is not ecologically feasible for crop production or grazing.

SUMMARY - SOILS AND TOPOGRAPHY

Crop capability classifications for project lands are summarized in Table 1 for SCS classifications and in Table 2 for LSB classifications.

Based on the SCS soil survey, only 176.4 acres or 15.6 percent of the total land area of 1,129.5 acres have crop capability classifications of I (6.4 acres) and II (170.0 acres) if nonirrigated and a slightly greater 187.4 acres or 16.6 percent if irrigated, (Table 1). These lands offer a good potential for crop production, considering soil type only. Another 152.2 acres or 13.5 percent of the land area if nonirrigated are considered marginal for crop production. Some of these lands are upgraded when irrigated, thus the land area in Class III decreases slightly to 147.9 acres or 13.1 percent if irrigated. A total of 800.9 acres or 70.9 percent of the project area is ecologically infeasible for crop production if nonirrigated. When irrigated, this decreases to 794.2 acres or 70.3% of the project area.

LSB classifications place 162.2 acres or 14.4 percent of the project area in crop productivity ratings of A and B under irrigation. This is comparable to the land area in SCS classifications I and II. With irrigation, however, the land area classed as A and B by LSB increases to 261.2 acres as compared to 187.4 acres in SCS classes I and II. Under LSB classifications, 264.9 acres are rated as C without irrigation. With irrigation, some of these lands are upgraded to A or B, thus reducing the number of acres in the C category to 199.9. Under LSB classifications without irrigation, 702.4 acres or 62.2 percent of the land areas is rated D through E and considered infeasible for crop production as compared to 800.9 acres or 70.9 percent under SCS classifications. This difference can be attributed largely to the fact that LSB has only 5 capability classifications (A to E) as compared to 8 for SCS (I to VIII). Thus, whereas LSB class A soil is comparable to SCS class I soil, LSB class B soils may be comparable to better SCS class II soils and less capable LSB class C lands fall into the SCS class IV category, which is considered infeasible for cultivated crop production. On-site inspection supports the more restrictive classifications of SCS.

The indication that about 70 percent of the land area in the project is infeasible for either cultivated crop production or grazing based on crop capability classifications fails to fully address limitations to agricultural development with respect to the site.

Table 1. Acreage of Each Land Type, Ohbayashi Corporation Pupukea Project, SCS Classifications

Soil Type	Acreage	Capability Classification Nonirrigated	Capability Classification Irrigated
KlMG	80.6	VIIe	VIIe[a]
KaeC	6.7	IVw	IIIw
KanE	5.7	VIs	VIs[a]
KIG	5.6	VIIe	VIIe[a]
KpB	6.3	IIe	IIe[a]
KpC	17.4	IIIe	IIIe[a]
KpD	19.8	IVe	IVe[a]
HpB	41.4	IIe	IIe
HpC	61.3	IIIe	IIIe
HpD	7.7	IVe	IVe
HpE	37.3	VIe	VIe[a]
PaC	43.6	IIIe	IIIe[a]
PeB	46.7	IIe	IIe
PeC	13.2	IIIe	IIIe
PeD	138.5	IVe	IVe
PeE	56.0	VIe	VIe
PZ	324.7	VIIIe	VIIIe[a]
rRX	116.1	VIIs	VIIs[a]
WaB	82.0	IIe	IIe
WaC	5.7	IIIe	IIIe
WaD2	2.2	IVe	IVe[a]
WKA	6.4	IIIe	I
WKB	4.6	IIIe	IIe
Total	1,129.5	1,129.5	1,129.5
Class I & II		176.4 (15.6%)	187.4 (16.6%)
Class III		152.2 (13.5%)	147.9 (13.1%)
Class IV-VII		800.9 (70.9%)	794.2 (70.3%)

a/ Classified only for nonirrigated. Thus irrigated is given the same classification.

Table 2. Acreage of Each Land Type, Ohbayashi Corporation Pupukea Project, LSB Classifications

Soil Type	Acreage	Capability Classification Nonirrigated	Capability Classification Irrigated
B21	21.0	B	A
B121	141.2	B	A
C22	25.9	C	B
C90	34.6	C	C
C96	32.0	C	B
C97	156.8	C	C
C122	15.6	C	B
D30	8.2	D	A
D58	6.7	D	D
D91	29.9	D	D
D92	3.9	D	D
D123	8.5	D	C
D124	17.3	D	A
E89	35.0	E	D
E104	10.5	E	E[a]
E106	90.0	E	E[a]
E107	479.8	E	E[a]
E108	12.6	E	E[a]
Total	1,129.5	1,129.5	1,129.5
Class A & B		162.2 (14.4%)	261.2 (23.1%)
Class C		264.9 (23.4%)	199.9 (17.7%)
Class D & E		702.4 (62.2%)	668.4 (59.2%)

a/ Classified only for nonirrigated. Thus irrigated is given the same classification.

Another severely limiting factor is that the limited land area in SCS classes I and II (LSB classes A and B) consists of small, noncontiguous plateaus surrounded by deep, badly eroded gulches. This prevents economies of scale, with the associated high costs of farming small parcels, causes costly and difficult access and increases the cost of providing an essential irrigation system. Although a limited amount of grazing has taken place on the better project lands, there has been no cultivated crop production for 70 years or more and commercial crop production under modern methods would not be feasible for the reasons indicated.

CROP SELECTION BASED ON SOIL TYPE AND SITE

Approximately 200 acres in the project area are adaptable to cultivated crop production, assuming that adequate good quality irrigation water could be made available at affordable rates and that good management would prevail, particularly with respect to erosion control. The fact that all arable land areas consist of small isolated plateaus surrounded by steep eroded gulches severely limits the types of crops that might be grown.

Sugarcane requires economies of scale, which are crucial to mechanization and advanced technology in order to even approach economic viability under current and forseeable prices. Even under plantation agriculture, sugar production on Oahu is reported to be uneconomic. Four hundred of 500 small sugarcane farms on the Hilo Coast, some as large as 700 acres, have gone out of business during the past 10 years. Thus sugarcane is certainly not a viable candidate for the project area, even though sugar was grown in nearby areas in an earlier era of labor intensive operations.

Pineapple was also grown in the developed part of Pupukea during an earlier labor intensive era, when foreign competition was a minimal threat. Pineapple is now a plantation crop in Hawaii and survival on Oahu is possible only under cost cutting measures resulting from economies of scale, advanced technology and excellent management. This crop cannot viably be grown on the small isolated plateaus of the project area.

Tree fruits, such as mangoes, citrus, lychees and avocados are grown in the developed areas along nearby Pupukea Road and would be adpatable to the project area insofar as ecology is concerned. However, mangoes are better adapted to a drier climate, such as Waianae and citrus, lychees and avocados can be grown more economically for commercial production on the island of Hawaii.

Bananas are ecologically adaptable to the project area, but would require substantial amounts of irrigation water during dry periods in order to assure adequate yields. Banana production, except for apple bananas, is moving from Oahu to the outside islands, particularly Hawaii, where producers depend entirely on rainfall and land is much cheaper than on Oahu.

Several varieties of floriculture and nursery crops could be grown in the project area with respect to ecological adaption, providing that low cost potable water is available at affordable rates. Among these are anthuriums, ginger, plumeria, orchids and poinsettias. The small size of parcels of better type soils would be a less serious problem for floriculture and nursery crops than for most other crops because of the intensity of production.

The only recent agricultural use of project lands has been for a minimal amount of grazing. Grazing is difficult to manage because of the mixture of small plateaus and steep, eroded slopes. Unless properly managed, overgrazing can contribute to erosion and deterioration of the entire project area. Also, intensive grazing would require fertilization and supplemental irrigation, which would be uneconomic because grazing offers the least productive use value of the land, with a prohibitively low net return per acre.

Several varieties of truck crops, such as bell peppers, snap beans, cucumbers, bitter melon, eggplant and sweet corn would adapt well to the better soils in the project area, assuming that an adequate supply of good quality irrigation water is available at affordable prices. Truck crop production would require good management and a sufficient volume to assure a competitive position in the market place. Competition for the limited sales potential for these products is a major limiting factor to utilization of the land for commercial truck crop production.

Crops best adapted to the project are primarily grown on small farms, where family labor is utilized and limited out-of-pocket expenses are incurred for labor and managment. These enterprises would not be attractive to the project area for one large commercial farm. This is supported by the fact that there has been no cultivated crop production in the subject area for several decades.

RAINFALL AND WATER REQUIREMENTS

State Weather Station 896.00 (Pupukea farm), which is located near the project at an elevation of 670 feet, best approximates the mean elevation of the better soil types. Rainfall was recorded by HSPA at this station during 13 years of the period from 1932 to 1948. Median annual rainfall during the 13 recorded years was 51.7 inches (Table 3). During 75 percent of the time, annual rainfall did not exceed 68.2 inches and was less than 48.9 inches 25 percent of the time. The annual maximum was 75.5 inches and the annual minimum was 41.6 inches. Annual rainfall does not adequately indicate availability for crop production, since median seasonal distribution is uneven and the rainfall for any given month is extremely variable by year.

Table 3. Rainfall recordings at State Key Stations in the Vicinity of the Ohbayashi Pupukea Project

MONTHLY AND ANNUAL RAINFALL SUMMARY, OAHU

SKN: 895.00 NAME: WAIMEA-H PINE OBSV: HAWAIIAN PINE ELEV(FT): 565
DATA PERIOD: 1924-1949 NYRS: 25 READ: DAILY LAT: 21 36 58 LONG: 158 3 24

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
MAX	18.8	20.2	17.9	10.4	9.4	4.9	10.8	11.2	7.5	15.9	10.7	12.5	82.2
75%	8.3	8.2	8.3	5.0	3.4	3.0	5.4	4.9	3.1	7.1	7.3	9.4	66.2
MED	5.3	5.1	4.6	4.1	2.6	2.4	3.3	3.5	2.0	3.3	4.2	5.1	55.2
AVG	6.1	6.1	5.9	4.4	2.9	2.6	4.0	4.1	2.2	4.5	4.9	6.3	54.3
25%	2.6	2.9	2.7	2.4	1.6	1.4	1.9	2.0	1.3	2.0	3.1	3.4	39.1
MIN	0.8	0.6	1.7	1.3	0.3	0.5	0.8	0.9	0.1	0.7	1.2	2.4	26.2

SKN: 896.00 NAME: PUPUKEA FARM OBSV: USDA ELEV(FT): 670
DATA PERIOD: 1932-1948 NYRS: 13 READ: DAILY LAT: 21 38 54 LONG: 158 2 42

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
MAX	9.9	14.7	13.3	13.4	9.1	7.3	9.1	10.9	5.5	17.9	9.5	10.0	75.5
75%	7.5	7.4	9.8	6.0	5.5	4.1	5.1	6.6	3.5	8.5	5.3	7.8	60.2
MED	5.8	5.0	4.8	4.4	4.2	3.6	4.9	4.1	3.6	3.7	3.8	5.4	51.7
AVG	5.3	5.7	6.3	4.8	4.2	3.7	4.8	4.8	3.2	5.5	3.9	5.5	50.7
25%	2.4	3.3	3.9	3.2	2.4	2.6	2.9	2.9	2.1	2.4	2.4	2.7	40.7
MIN	0.7	1.3	1.3	0.4	0.2	2.0	2.3	1.1	1.3	0.9	0.3	2.2	41.6

SKN: 896.19 NAME: PUPUKEA OBSV: LIBBY ELEV(FT): 520
DATA PERIOD: 1906-1922 NYRS: 16 READ: DAILY LAT: 21 39 13 LONG: 158 3 4

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
MAX	18.6	16.9	12.6	14.0	12.9	7.5	5.9	8.2	6.9	7.3	19.5	15.6	97.5
75%	8.8	5.0	5.8	7.1	4.4	4.8	4.8	5.1	4.2	4.4	9.5	8.4	57.1
MED	4.9	3.3	3.7	4.4	3.0	3.3	3.4	2.9	2.9	3.5	6.1	5.0	52.5
AVG	6.3	4.1	4.6	5.4	3.6	3.5	3.7	3.8	3.3	3.6	6.4	6.4	52.5
25%	2.9	1.8	2.3	3.5	2.0	2.0	2.9	2.4	1.9	2.6	2.3	3.4	43.1
MIN	0.8	0.1	1.5	1.1	0.2	1.5	1.0	1.9	1.1	2.0	0.8	1.6	24.9

SKN: 896.20 NAME: PAUMALU CAMP OBSV: HAWAIIAN PINE ELEV(FT): 440
DATA PERIOD: 1924-1949 NYRS: 11 READ: DAILY LAT: 21 40 15 LONG: 158 2 9

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
MAX	13.1	18.3	16.9	8.6	17.6	9.3	7.4	10.5	7.7	12.6	13.6	20.8	90.6
75%	8.9	6.5	4.8	8.6	4.3	4.6	5.5	4.7	4.9	5.9	8.7	8.3	62.8
MED	6.3	4.2	3.7	2.9	2.6	3.4	4.0	3.1	2.6	3.4	5.8	4.6	52.4
AVG	6.4	5.9	4.8	3.9	4.3	3.7	4.2	3.9	3.3	4.8	6.1	7.1	56.9
25%	2.8	2.6	2.8	1.5	1.4	1.8	3.1	2.2	1.9	2.8	2.9	3.8	46.4
MIN	1.8	1.0	1.0	0.4	0.9	1.0	1.8	1.7	1.2	1.3	0.7	2.9	25.2

SKN: 896.30 NAME: WAIALEE LIVSTCK OBSV: UH LIVESTOCK FAR ELEV(FT): 33
DATA PERIOD: 1964-1979 NYRS: 14 READ: DAILY LAT: 21 41 25 LONG: 158 1 30

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
MAX	12.1	12.8	7.5	8.1	11.0	5.6	6.1	3.8	3.2	7.9	17.3	13.1	67.8
75%	7.3	7.3	4.5	5.5	4.0	2.4	2.9	2.5	2.4	3.7	6.1	5.5	45.4
MED	3.5	4.1	3.2	3.8	1.6	2.0	1.9	1.9	2.0	2.2	4.2	3.7	42.6
AVG	5.0	4.5	3.3	4.0	3.1	2.0	2.4	1.9	2.0	2.3	5.8	4.5	41.2
25%	2.3	1.9	1.9	2.2	0.9	1.2	1.5	1.3	1.3	1.9	2.8	2.1	30.7
MIN	1.8	0.5	0.5	1.5	0.5	0.8	1.0	0.5	0.9	1.7	1.2	0.7	28.2

SKN: 896.80 NAME: PUPUKEA-LARSON OBSV: LARSON PL ELEV(FT): 540
DATA PERIOD: 1969-1983 NYRS: 14 READ: DAILY LAT: 21 38 54 LONG: 158 2 1

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
MAX	17.5	12.1	19.3	16.4	15.6	8.8	8.9	9.7	5.2	11.4	12.8	8.8	87.1
75%	9.6	8.3	7.8	10.0	6.0	5.2	6.0	4.6	3.7	5.5	7.7	6.9	67.5
MED	6.9	4.8	6.3	5.6	3.5	3.7	4.5	3.0	3.0	4.1	6.0	4.7	57.8
AVG	7.1	5.6	6.4	7.1	5.1	4.0	4.7	3.8	3.1	4.9	6.2	5.1	60.9
25%	2.8	2.8	3.3	3.9	2.7	2.2	3.0	2.4	2.6	3.2	4.1	3.9	53.4
MIN	1.6	0.8	1.2	2.1	1.9	1.8	1.9	1.9	1.0	2.5	2.1	1.1	46.3

SKN: 897.00 NAME: WAIMEA MAUKA OBSV: HAWAIIAN PINE ELEV(FT): 920
DATA PERIOD: 1926-1960 NYRS: 34 READ: WEEKLY LAT: 21 37 4 LONG: 158 2 0

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
MAX	16.3	25.5	19.8	10.1	19.9	12.9	12.1	12.6	11.3	21.4	20.2	22.9	136.5
75%	9.9	9.7	10.9	7.6	7.5	5.9	6.4	7.1	5.4	7.2	10.3	11.6	85.1
MED	7.3	6.4	6.7	6.0	4.5	4.3	4.8	6.1	3.7	4.9	8.4	7.8	78.8
AVG	7.7	8.2	8.1	6.0	5.7	4.9	5.4	5.6	4.4	6.0	8.0	9.5	80.0
25%	4.0	3.9	4.9	4.1	3.6	3.3	3.6	3.6	2.8	3.2	4.8	5.6	69.3
MIN	0.6	1.9	1.9	1.4	0.8	2.0	1.9	1.6	1.4	1.9	1.6	3.6	48.6

SKN: 897.30 NAME: WAIMEA 25 #2 OBSV: WAIALUA AG ELEV(FT): 990
DATA PERIOD: 1962-1983 NYRS: 18 READ: WEEKLY LAT: 21 36 24 LONG: 158 1 46

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
MAX	29.9	15.0	18.3	21.5	12.8	10.3	14.0	10.3	6.2	17.3	21.6	18.0	99.0
75%	10.9	8.5	11.7	11.9	8.8	5.3	7.2	5.5	4.1	6.1	11.8	7.0	88.1
MED	9.6	5.8	6.0	6.9	4.9	3.5	6.5	4.3	3.5	5.2	6.8	4.8	74.8
AVG	7.3	6.5	7.4	8.3	5.4	4.1	6.0	4.5	3.5	5.7	9.1	5.9	76.0
25%	2.3	3.7	2.6	4.3	1.9	2.5	3.1	2.9	2.4	3.2	5.3	3.4	66.4
MIN	1.1	0.7	0.9	1.9	1.1	1.4	1.4	1.9	1.5	1.3	2.4	0.4	62.6

Source: State of Hawaii, Division of Water and Land Development, Department of Land and Natural Resources

Vegetables and tree fruits, which are ecologically adaptable to the better soil types, require delivery of 4,500 gallons and effective use of 4,073 gallons of water per acre per day. Bananas, which could also be grown in the project, require delivery of 6,790 gallons per acre per day for effective use of 5,431 gallons per acre per day. Only January, February, July and December provide median rainfall of 4,500 gallons or more per acre per day (4.9 acre-inches per month). The other 8 months would require supplemental irrigation ranging from 0.1 acre inch in March to 1.3 acre inches in September, totalling 7.0 acre-inches for the 8-month period.

Analyses based on long term median rainfall underestimate the problem. Twenty-five percent of the time, supplemental irrigation is needed during all 12 months, although all dry months would not likely occur during the same year. Based on the 25 percent of the time factor, annual rainfall amounts to 33.2 inches as compared with an annual requirement of 58.8 acre inches for truck crops. On this basis the annual need from supplemental irrigation is 25.6 acre inches (695,142 gallons) per acre.

In addition to water requirements, drilling of wells, construction of a reservoir and providing piping to project lands and within project lands is required. Estimated annual irrigation costs per acre for water and infrastructure for the estimated 200 acres of arable land in the Ohbayashi Pupukea project are presented in Table 4. The median annual cost would amount to $1,223.00 over a longterm amortization period, but 25 percent of the time the cost would amount to $1,349.00 or more per acre, not considering future inflation. The major cost would be the irrigation infrastructure, which is particularly high on a per acre basis because the cost of the water delivery system must be prorated among only 200 acres of scattered plateaus rather than among the entire 1,129.5 acres in the project. Application of this excessive cost of water to available budget analyses for truck crops and tree fruits would render the enterprises uneconomic. If the project were to incur these costs for water development, a higher use value than agriculture would be essential.

The projection of annual costs of irrigation per acre for truck crop production does not consider the required daily delivery system. The delivery system must take into consideration the fact that any month may require almost complete dependence on supplemental irrigation during a drought period for that month. The absolute recorded minimum rainfall ranges from 0.2 acre-inch in May to 2.3 acre-inches in July (Table 3). To accommodate these needs, an irrigation system would be required that could deliver 4,500 gallons per acre per day for truck crops. This amounts to 900,000 gallons per day for the estimated 200 acres in the project that are ecologically adapted to crop production. It is indicated that 225,000 gallons of potable water could be made available according to historical agreement from wells serving the developed area of Pupukea. This is only 25 percent of required maximum delivery. The other 75 percent would need to come from additional wells to serve

Table 4. Computations of Water Costs For Truck Crop Production, Ohbayashi Pupukea Project

Item	Total Cost	Amortization Period (yearly)	Annual Cost (Amortized)	Annual Cost Per Acre a/
Wells, Pumps, Trans. to Reservoir	$1,600,000	20	$80,000	$400.00
Reservoir	$500,000	20	$25,000	$125.00
Transmission to Plateaus	$2,000,000	20	$50,000	$500.00
Farm Irrigation System	$300,000	10	$30,000	$150.00
Sub Total	$3,400,000		$185,000	$1,175.00
Water (25% of time requirements) b/	695,140 gallons @ $.25 per 1,000 gallons			$173.79
Water (median requirements) b/	190,078 gallons @ $.25 per 1,000 gallons			$47.52
Total Annual Cost Per Acre 25% of time Median				 $1,222.52 $1,348.79

a/ Based on 200 acres of arable land.

b/ Estimated cost of pumping and maintenance of pumps and delivery system.

the project. Based on reports of an earlier well drilled in the area, an undetermined amount of salinity could be expected from potential sources. Most truck and tree fruit crops are sensitive or moderately sensitive to salinity. Yields for sensitive crops would be reduced by 20 percent at a total salt concentration of greater than 2.0 millimeters per centimeter or 1,280 milligrams per liter (9). Salinity analysis cannot be pursued further because the saline composition of potential wells will not be known until the wells are drilled.

In summary, the foregoing analysis indicates that the development of irrigation water for agricultural crop production in the project area is not economically feasible.

TEMPERATURE, WIND AND MICROCLIMATIC CONDITIONS

Temperature recordings at State Station 896.00 (Pupukea Farm) at the 670 foot elevation in Pupukea are considered representative of temperatures on the better lands in the project area. Average maximum and minimum monthly temperatures as shown in Table 5 are slightly lower than at lower elevations in the vicinity, but are near optimal for the production of warm climate truck crops, tree fruits and bananas.

Vine and bush type vegetables and fruit trees would be subject to wind damage in the project area, both from prevailing trade winds and Kona storms. Wind damage is reported to be somewhat less severe in Pupukea than in more exposed areas on Oahu, such as Kahuku, Waimanalo and the windward valleys.

Light intensity for maximum crop yields is moderately restricted in the project area because of cloud cover, particularly during the winter months.

Humidity is sufficiently high in the project area to encourage bacterial wilt for some crops, such as tomatoes, bell peppers and eggplant.

SALES POTENTIALS

Sales potentials in this analysis are relevant only for those crops which are ecologically adaptable to SCS class II (LSBC class B) soils and to some class III soils that are interspersed with class II soils. The acreage in class I soils is negligible. An estimated 200 acres of the 1,129.5 acres in the project area could be utilized for cultivated crop production, considering ecological restraints, only, and assuming that good quality irrigation water could be made available at affordable cost, which is not the case.

Crops considered best adapted to the area from a production standpoint are some varieties of vegetables, melons, bananas, papayas and tree fuits. Sugarcane and pineapple require large acreages to permit economies of scale and are not feasible for the

Table 5. Average Daily Maximum and Minimum Temperatures Recorded at State Key Station 896.00 (Pupukea Farm)

Month	Mean Daily Maximum (degrees F)	Mean Daily Minimum (degrees F)
January	75.3	62.7
February	75.3	63.1
March	74.8	63.0
April	77.3	58.4
May	79.5	65.7
June	81.0	68.0
July	82.0	69.3
August	82.2	69.6
September	82.3	69.0
October	80.3	68.5
November	77.6	66.8
December	75.2	64.7
Annual	78.8	65.5

Source: State of Hawaii, Division of Water and Land Development, Department of Land and Natural Resources.

many small, isolated plateaus that contain the better soils in the project. Cattle grazing constitutes the lowest use value for the subject lands. The limited returns from this enterprise are indicated to be inadequate to meet costs of pasture improvement, including irrigation and fertilization. Necessary erosion control through pasture management would be difficult or impossible, since the small parcels of good land are surrounded by steep, badly eroded gulches. Grazing cattle and horses in the area has been a subsistence type operation, with inadequate consideration for an economic return to the land or to profit maximization. LSB estimated that lands with a productivity rating of B (comparable to SCS II) provide average live beef cattle gains of 80 pounds per acre per year. At the 1986 Oahu price of 31.1 cents per pound live weight for beef cattle, class B soils would provide a gross return of only $25.00 per acre per year as compared to an average gross of $6,000 per acre per year for adaptable vegetables under good management.

The market potential for Hawaii production of truck crops, bananas and tree fruits is essentially the acreage required to displace imports. Sales potentials for Pupukea for the above crops plus papayas depend further on the ability to compete for the market against other Hawaii producing areas. For flowers and nursery products, the Pupukea sales potential depends upon the ability to compete with other growers both for the local market and for export.

Truck crops which can be grown in the project area with respect to ecology are snap beans, sweet corn, cucumbers, eggplant, green peppers, sweet potatoes and watermelons. Other truck crops are better adapted ecologically to other areas in the state. Onions, celery and head cabbage, for example, do best in more temperate areas, such as Kula and Waimea. Tomatoes are primarily grown in greenhouses in Hawaii and require a continuing source of high quality water, readily accessible locations and freedom from devastating winds. Irish potatoes are produced primarily in temperate climates.

The 1986 Hawaii market supplies and acreages required to displace inshipments of vegetables, melons and fruit crops which might be grown in the project area are shown in Table 6. The total of 793 acres required to displace imports considerably exceeds the 200 acres ecologically adaptable to the production of these crops in the project area. The next step is to determine the comparative advantage of the Ohbayashi Pupukea Project to supply the indicated market requirements. Trends in production, the competitive position of each county in supplying the market for each commodity and relevance to the Ohbayashi Pupukea Project are discussed in the following analysis.

The area devoted to snap bean production on Oahu declined from 60 acres in 1977 to 50 acres in 1986, with a proportionate decrease in marketings. Neighbor Island production also decreased and imports increased during the period. These trends indicate that it is highly unlikely that the Pupukea Project could provide the additional output required to displace imports.

Table 6. Hawaii Market Supply and Acreage Required to Displace Imports, Selected Fruits and Vegetables

Crop	Market Supply Hawaii	Market Supply Imports	Yield Per Acre	Acreage Required To Displace Imports
	(1,000 pounds)		(pounds)	(acres)
Beans, Snap	980	330	12,000	28
Corn, Sweet	1,040	767	8,000	96
Cucumbers	3,720	2,024	20,000	101
Eggplant	1,300	196	30,000	7
Peppers, Green	2,050	1,392	20,000	70
Sweet potatoes	2,000	676	30,000	23
Watermelons	14,300	831	25,000	33
Bananas	9,700	10,887	30,000	363
Avocados	1,300	576	8,000	72
TOTAL				793

Oahu is the major producer of sweet corn in Hawaii, but acreage declined from 345 acres in 1977 to 220 acres in 1986. Marketings during the same period declined from 1,345,000 pounds to 840,000 pounds. At the same time, imports increased from none in 1977 to 767,000 pounds in 1986, indicating that Hawaii is losing it's competitive position in sweet corn production for the local market. Thus, even if Ohbayashi Pupukea were competitive in relation to existing sweet corn production areas on Oahu, such as Waimanalo, it is not a likely candidate to displace imports.

Cucumber production in Hawaii has shown a slight decline during the past 10 years. Acreage declined from 260 acres for the state and 95 acres for Oahu in 1977 to 220 acres for the state and 75 acres for Oahu in 1986. Hawaii production declined from 4,300,000 pounds in 1977 to 3,720,000 pounds in 1986. During the same period, inshipments increased from 1,027,000 pounds to 2,204,000 pounds, indicating no opportunity under existing technology and costs to displace imports.

Hawaii is essentially self-sufficient in eggplant production. Thus it is not a candidate for acreage expansion.

Green pepper acreage in Hawaii expanded appreciably during the past 10 years from 70 acres in 1977 to 190 acres in 1986. But the major expansion in production has been on the outside islands, primarily Maui, Molokai and Kauai, where labor and land costs are lower than on Oahu. Oahu had only 13 acres in 1977, seven acres in 1985 and 15 acres in 1986. Hawaii production increased from 1,070,000 pounds in 1977 to 2,050,000 pounds in 1986. During the same period inshipments increased from 1,173,000 pounds in 1977 to 2,020,000 pounds in 1982, but decreased to 1,392,000 pounds in 1986. Thus it appears likely that Hawaii producers will plant an additional 70 or more acres, depending upon efficiency of production, to displace green pepper imports. But all expansion can be expected on the Neighbor Islands.

Sweet potato acreage increased from 95 acres in 1977 to 210 acres in 1986. But during the same period, Oahu acreage decreased from 60 acres to 30 acres. Hawaii production increased from 1,190,000 pounds in 1977 to 2,100,000 pounds in 1986. Imports did not change substantially during that period, amounting to 605,000 pounds in 1977 and 676,000 pounds in 1986. The data indicate that Hawaii production is expanding only in response to increased local demand. Imports consist of different varieties and qualities of sweet potatoes and substantial additional displacement is not likely. Contrary to the state trend, Oahu production might be expected to decline further.

Watermelon acreage in Hawaii approximately tripled during the 10-year period, from 210 acres in 1977 to 620 acres in 1986. Most of the increase took place in Maui County (mostly Molokai), where acreage increased from 60 acres in 1977 to 460 acres in 1986.

Oahu acreage during the same period increased from 90 acres to 120 acres. Hawaii production increased very substantially from 2,075,000 pounds in 1977 to 14,300,00 pounds in 1986. During the same period, inshipments decreased from 3,584,000 pounds in 1977 to 831,000 pounds in 1986 and Hawaii became almost self-sufficient in watermelon production. Only an estimated 33 acres would be required to displace the 1986 level of imports. Molokai has advantages over Pupukea in soils, climate and production costs. Thus, any further expansion in watermelon acreage is likely to take place on Molokai.

Harvested banana acreage in Hawaii increased from 550 acres in 1977 to 980 acres in 1986. Most of the increase was in the Puna district on Hawaii. Hawaii County harvested acreage increased from 105 acres in 1977 to 370 acres in 1986. During the same period, Oahu harvested acreage decreased from 445 acres to 425 acres. Most Hawaii County acreage consists of high yielding Williams bananas and the majority of Oahu production consists of low yielding, but higher priced, Brazilian (apple) bananas. Hawaii banana production increased from 5,800,00 pounds in 1977 to 9,700,000 pounds in 1986. During the same period, inshipments increased from 6,006,000 pounds to 10,887,000 pounds. Thus, whereas Hawaii production has been increasing, local producers have not been successful in displacing imports, which would require a very substantial additional 363 acres. There is good indication that Hawaii banana production will continue to expand, but this expansion is likely to take place in Hawaii and Kauai Counties and not on Oahu. Furthermore, the Pupukea Project is at a disadvantage in relation to other existing and potential banana producing areas on Oahu with respect to soil type, accessibility and cost and availability of irrigation water.

Avocado acreage in Hawaii increased substantially from 305 acres in crop and 145 acres bearing in 1977 to 540 acres in crop and 330 acres bearing in 1986. Most of the increase was in Kona, where labor and land costs are less than on Oahu and natural rainfall is sufficient in most production areas. Hawaii production increased from 940,000 pounds in 1977 to 1,300,000 pounds in 1986, with most of the increase being shipped to Canada and Alaska. Inshipments also increased, from 270,000 pounds in 1977 to 576,000 pounds in 1986. Since a segment of the population prefers the small California avocados and because of the need for inshipments for seasonal adjustments, further displacement of imports is not likely. Unless restrictions on shipments to the U.S. mainland because of presumed fruit fly infestations are eliminated, most expansion in marketing of Hawaii avocados will be directed to Canada and Alaska and Kona will be the likely supplier.

Papaya is a major export crop, but expected expansion of the industry has not been realized because of problems in developing an effective low cost fruit fly treatment, the high cost of air freight and failure to develop a satisfactory method to extend shelf life for surface shipments. Harvested acreage increased only minimally from 2,155 acres in 1977 to 2,355 acres in 1986. In spite of the

slight increase in acreage, utilized production decreased from 63,548,000 pounds in 1977 to 61,000,000 pounds in 1986. Most of the production is in Hawaii County where farmers depend primarily on natural rainfall, land is available to permit replanting for root rot control and labor rates are lower than on Oahu. Oahu acreage is very small and growth has been insignificant. There were 45 acres in 1977 and 56 acres in 1986. It is quite evident that the Pupukea project would not be an appropriate contender for the papaya market.

This analysis clearly indicates that market limitations and the inability to compete in the market place constitute an almost complete deterrent to the utilization of Ohbayashi Pupukea land for commercial agricultural production.

LAND REQUIREMENTS IN RELATION TO AVAILABILITY OF AGRICULTURAL LAND ON OAHU

The acreage in cultivated crops on Oahu has steadily declined during the past ten years from 50,700 acres in 1977 to 47,100 acres in 1981 and 40,700 acres in 1986 (6). The very marked decline of 6,400 acres in crop production between 1981 and 1986 exceeds that which has been converted to uses other than agriculture, resulting in a stockpile of unused agricultural land of good quality. Land zoned Urban by the State Land Use Commission increased by 2,646 acres from 1981 to 1986. Land zoned agricultural decreased by 1,706 acres during the same period, most of which was rezoned to urban. Most of the decline was in sugar and pineapple acreage. Some of this land offers a potential for expansion in diversified crop production with respect to ecology, but high land prices, market limitations and difficulties in obtaining agricultural subdivision permits from the City and County of Honolulu have prevented its use for agriculture.

The LSB classified 53,039 acres of land on Oahu outside urban areas as good agricultural land in 1972, of which 20,583 acres were given crop productivity ratings of A and 32,456 acres were rated as B. In addition, 17,837 acres were classified as C, which is marginal for cultivated crop production. This compares to a total of only 40,700 acres in cultivated crop production on Oahu in 1986, of which an undetermined number of acres in production had productivity ratings lower than B. These data indicate that the total acreage of good agricultural land (A and B) exceeds the total acreage in cultivated crop production of all classes of lands by 12,339 acres. With Class C land included, the availability of cultivatable land based on the 1972 data exceeds the 1986 acreage in cultivated crop production by 30,176 acres. However, some of excess good agricultural land has been converted to other uses and is no longer available for agriculture.

Land zoned urban by the State Land Use Commission increased by 9,797 acres from 1972 to 1986 (79,700 acres to 89,497 acres). During the same period land zoned Agricultural decreased by 7,051 acres (148,900 acres to 141,849 acres). It is conservatively estimated, based on a study of soils maps of urban areas approved for development during that period, that not more than half of the area zoned from agriculutral to urban consisted of A and B soils. On this basis, A and B lands available for agriculture would have decreased from 53,039 acres to 49,813 acres from 1972 to 1986. This would decrease the amount by which A and B lands outside urban areas exceed acreage in cultivated crops in 1986 from 12,339 acres to 9,113 acres. On the same basis, the excess of A, B and C lands outside of urban areas would have decreased from 30,176 acres to 26,950 acres for 1986.

The SCS classified 67,342 acres as good agricultural land in 1972, with 23,551 acres rated as I and 43,791 acres rated as II, with irrigation. Since an undetermined amount of this is in urban areas, the relationship of this acreage to acreage in cultivated crops cannot be determined without a detailed analysis of land use by land capability type, which is beyond the scope of this study. However, since SCS and LSB land productivity ratings are fairly comparable, a similar excess of 9,113 acres of good agriculutral land not in urban use over all land in cultivated crop production on Oahu is indicated.

The State Land Use Commission classified 141,849 acres of land on Oahu as Agricultural in 1986. These lands are, with some exceptions, restricted to agricultural use and are separate from lands zoned as Urban or Conservation. The land area zoned as Agricultural is far in excess of the 40,700 acres in culitvated crop production in 1986, the 53,039 acres classified as A and B by LSB (adjusted to 49,813 acres for 1986) and the 67,342 acres classified as I and II by SCS.

The large acreage zoned as agricultural is not only far in excess of the acreage of good agricultural land outside of urban areas, but increasingly exceeds the land needed for crop production on Oahu as the area in crop production declines. Another important consideration is that unused good agriculutral land is available at lower cost on the outside islands. Because of lower land cost and lower or no irrigation water cost, production centers for crops such as bananas, guavas and truck crops are moving to the outside islands. Oahu sugar plantations continue to convert less productive sugarlands out of sugar. Substantial areas of former pineapple fields lie fallow. Thus the supply of unused prime agricultural land on Oahu continues to increase as the agricultural need for it decreases.

NEED FOR AGRICULTURAL LAND IN THE PROJECT AREA

The previous section of the report indicated a substantial excess of prime agricultural land on Oahu over what is required for agricultural production. This excess continues to increase as crop

production declines. Much of the land area being withdrawn from agriculture consists of SCS Class I (LSB Class A) soil types. There are only 6.4 acres of Class I soils, if irrigated, and 176.4 acres of Class II soils if nonirrigated, or 187.4 acres of Class II soils, if irrigated, out of a total of 1,129.5 acres in the project area. Most of the land, 800.9 acres, consists of Class IV to VIII soils and is infeasible for any type of cultivated crop production or grazing. Project lands have the further disadvantage of consisting of small isolated, high plateaus surrounded by steep, severely eroded gulches. Project lands have not been used for any type of cultivated crop production for many decades. It is very unlikely that this situation would change, considering the increasing availability of good land on Oahu and the comparative disadvantage of the project area in competing with better lands, both with respect to quality and configuration. Utilization of the land for golf courses would not only result in a higher use value, but provide erosion control, which if not contained will render the Pupukea project lands unsuitable for any economic use.

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APPENDIX G

GROUNDWATER CONDITIONS

PUPUKEA-PAUMALU, OAHU

John F. Mink
June 6, 1988

The proposed golf course and ancillary development are located in the Pupukea-Paumalu region in the northern sector of Oahu between Waimea Bay and Kahuku. The nearest communities are Sunset Beach, which is strung along the coastal plain, and the house lots along Pupukea Road that reach all the way to the Forest Reserve. The parcel to be developed is unoccupied. Its northern boundary is Paumalu Stream and the southern boundary is along Kalunawaikaala Stream. The eastern (inland) boundary is the forest reserve line, while seaward most of the boundary is along the base of the ancient sea cliff at the inner edge of the coastal plain except for a rectangular portrusion that extends to the coastal highway.

The developable land starts at an elevation of about 400 feet at the top of the old sea cliff. Maximum elevation inland is 800 feet, but most of the useable property lies between 400 and 600 feet. Almost bisecting the property is Pakulena Stream. The interfluves between Pakulena and Paumalu on the north and Kalunawaikaala on the south are spacious and gently sloping, and the valleys, though steep, are accessible.

None of the three major streams in or on the margins of the property -- Paumalu, Pakulena and Kaluawaikaala -- are

perennial. Their channels lie too high above the water table to receive seepage of groundwater. Only during substantial rains do the streams flow. The sole developable water resource in the region is groundwater.

Hydrogeology

The recently completed Aquifer Classification study (Univ. Hawaii Water Resources Research Center, Tech. Rep. 179) places Pupukea-Paumalu in the North Sector of Oahu in the Kawailoa Aquifer System and identifies the Aquifer Type as unconfined, basal in lavas of the Koolau volcanic series. The Aquifer Code is 30403111. The Kawailoa Aquifer System extends from the Anahulu River near Haleiwa to the Koolau rift zone at Waialee. The principal aquifer in the system is a thin basal lens of fresh to brackish water floating on sea water. This basal lens is the least robust in northern Oahu, having a head of less than 3 feet at a distance of 1 to 2 miles from the coast. On the Waialua side of the Anahulu boundary the basal head is about 10 feet, while in the dike aquifers of the rift zone at Waialee it varies from 10 to 20 feet.

The Pupukea-Paumalu basal lens is in an aquifer of highly permeable Koolau basalt. The aquifer is open at the coast and consequently the lens discharges into the sea in a narrow band parallel to the coast line. The head and thickness of the lens is small because no effective caprock wedge exists to impede groundwater discharge.

A well (3902-01) and a test boring (3902-02) were drilled in the property in 1946 and 1956, respectively, and the Board of Water Supply maintains a small pumping station (wells 4002-04 and 05) in lower Paumalu valley just outside the property boundary. Well 3902-01 lies 6500 feet inland where the head was measured as 2.8 feet. At 3902-02, which is a 1 inch diameter boring, reliable measurements of head evidently were not possible. Head at the Board of Water Supply wells, 1500 feet in from the shore, is given as 2.7 feet.

Employing the head and distance data with an assumed value for aquifer hydraulic conductivity provides an estimate of groundwater flow in the distance between Waimea and Waialee. The common range of values for hydraulic conductivity of the Koolau formation is 1000 to 2500 ft/day. The equation for groundwater flux in a basal lens at steady flow is:

$$q = 41kh^2/2x$$

in which q (ft^2/day) is flow per unit width of aquifer over the full depth of flow, k (ft/day) is hydraulic conductivity, h (ft) is head, and x (ft) is distance from the discharge line at the coast. For the head value attributed to well 3902-01 and hydraulic conductivity of 1500 ft/day, flux through the area is calculated as 3.4 mgd; if hydraulic conductivity is 2500 ft/day, flux is 5.6 mgd. However, if head at the Board of Water Supply station is employed instead, flux is at least three times as great. The data base

is too meager to produce accurate values for groundwater flux, yet nevertheless a low estimate of 5 mgd is justified. This flow is more than sufficient to allow a sustainable yield in excess of the combined Board of Water Supply and proposed golf course demand.

Groundwater Development

A number of shallow wells have been drilled on the coastal plain between Waimea and Sunset Beach, but most, if not all, are not used. They produce brackish water suitable only for salt tolerant crops. In addition, a few injection wells for disposing of local drainage and treated sewage are located in the Sunset Beach area. Only four deep borings have been drilled, two private (originally by Finance Factors and Capital Investment) and two municipal. The data from these wells indicate that although the groundwater occurs as a thin basal lens, it can be exploited to yield potable water at modest rates of draft, and irrigation water at higher rates.

Essential information for these wells is as follows (for locations, see attached map):

Item	Well 3902-01	3902-02	4002-04	4002-05
Original owner	Finance Factors	Capital Inv.	County	County
Date drilling	1946	1956	1948	1949
Diameter (in.)	12	1	7	10
Elevation (ft.)	499	511	66	70
Depth BSL (ft.)	-55	-49	-59	-70
Head (ft.)	2.8		2.7	2.5
Chloride (mg/l)	143-378	43-110	42-122	42-122
Pump rate (gpm)	600		140	55
Distance coast(ft.)	6500	7200	1500	1500
Status	Unused, abandoned	Abandoned	BWS	BWS

The Board of Water Supply wells successfully yield potable water because they are pumped at low rates. The Finance Factor deep well, on the other hand, was pumped at too high a rate, and its output consequently exceeded the recommended potable limit on salinity of 250 mg/l chloride. Even at 600 gpm, however, this well produced good quality irrigation water.

Several million gallons per day can be safely extracted from the Pupukea-Paumalu portion of the Kawailoa basal aquifer. Currently only the Board of Water Supply pumps water, and only a small amount. Average withdrawal is about 60,000 gallons per day (.06 mgd). The municipal supply for Sunset Beach comes mainly from the Board of Water Supply

Waialee wells. On the Waimea side of the sector, water from Waialua is used.

Proposed Golf Course Irrigation

There will be no insurmountable difficulties in developing sufficient groundwater of acceptable quality to satisfy irrigation demands of the proposed golf course. A single well may be adequate for average demand, but augmentation with a second well would assure a supply to meet all contingencies, including periods of mechanical problems.

The recommended location of the first well is in Pakulena valley at an elevation of 430 feet (see map). General specifications for the well are as follows:

Elevation - 430 ft.

Casing diameter - 12 in.

Depth - 465 ft. (35 ft.BSL)

Pump rate - Approx. 350 gpm.

Expected Head - 3 ft.

Expected salinity - 200 to 300 mg/l chloride.

A second well, if needed, will be located and drilled later, following completion of the first well.

Effect of Golf Course Irrigation on Groundwater

Irrigation takes place over several important basal aquifers in Oahu without compromising their utility except in cases of egregious misuse of chemical biocides. For example. the Pearl Harbor aquifer of southern Oahu, which is vital to the water supply of the most populated portion of the State, is overlain by about 10,000 acres of sugar cane and pineapple, both of which are fertilized and irrigated. Similarly the Waialua basal aquifer is underlain by these crops. The quality and quantity of infiltration from excess irrigation on the proposed golf course should not be expected to degrade the basal aquifer to the level of unpotability, just as other aquifers are not degraded. Reasonable care in applications of fertilizers and water will control the passage of nitrate, the chief fertilizer component, to a few mg/l. Prohibition of the use of undesireable biocides will eliminate the danger of contamination by volatile organics, heavy metals and other refractory constituents that are unacceptable virtually at any concentration.

Wastewater Disposal

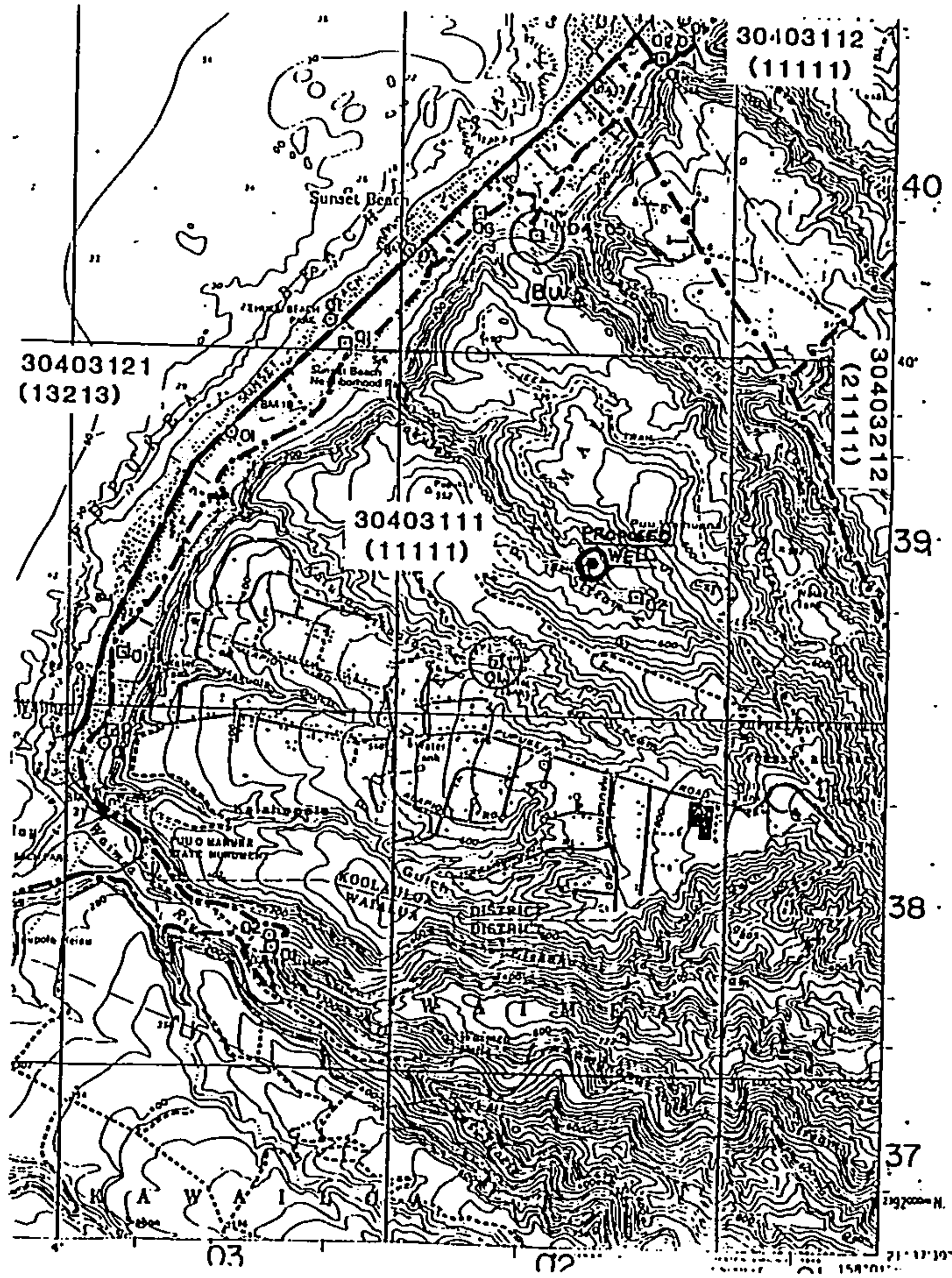
The proposed development is expected to generate less than 100,000 gallons per day of sewage, all of it classified as domestic. The sewage will be treated at the secondary level, then disposed of on the land.

Local disposal of the secondary effluent is technically possible by means of injection wells, land spreading, infiltration ponds, and golf course irrigation. All of the property lies inland of the Department of Health "no pass" line beyond which injection wells and infiltration ponds are not permitted except by variance. In view of these restrictions, the reasonable way to dispose of the effluent

is in golf course or other irrigation. This is a proven technique of effluent disposal in Hawaii, and its practicality has been demonstrated by field investigations conducted by the Water Resources Research Center of the University of Hawaii. Tests showed that percolate from excess irrigation consisting of secondary effluent does not carry bacteria or viruses. Judicious irrigation applications would minimize infiltration of nitrates and other nutrients.

The volume of effluent will amount to about 10 percent of golf course irrigation needs. To minimize the effect of return irrigation on groundwater near the Board of Water Supply station, effluent irrigation should be restricted to the area most distant from the wells. The normal flow path of groundwater beneath the golf course is directly toward the coast. Flow toward the Board of Water Supply wells could take place if heterogeneities in the aquifer divert flow lines from their normal paths and if pumping induces a drawdown gradient over a considerable distance. The pumps in the Board of Water Supply wells are quite small and are not likely to generate a drawdown cone that would pirate much of the flow beneath the golf course.

Disposal of effluent by land spreading and infiltration ponds is feasible if permission is granted by the Department of Health. Land spreading is a form of excessive irrigation while ponding depends on infiltration alone. Combining infiltration ponds with golf course irrigation is the most practical way to handle the effluent.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30403121
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PROPOSED WELL
Sunset Beach
40
39
38
37
03
02
KOOLAULOA DISTRICT
WAIALUA DISTRICT
K A W A I L O A

ASSESSMENT OF POTENTIAL IMPACTS
IRRIGATION OF LIHI LANI GOLF COURSE
PUPUKEA-PAUMALU, OAHU

John F. Mink

December 23, 1990

Introduction

The Lihi Lani golf course and proposed residential and other activities associated with it will be irrigated with groundwater developed within the area to which will be added treated waste water effluent. Fertilizers and pesticides will be used on the golf course and in landscaping, and the waste water effluent, although treated to the secondary level, will contain nutrients, in particular nitrogen (N) and phosphorus (P), as well as biological material. Surplus irrigation will carry nitrogen to the groundwater from both fertilizer applications and waste water effluent. The other significant plant nutrient, phosphorus, will become fixed in soil and will not penetrate deeper. Biological components in the waste water effluent will be consumed in the soil mantle. Only nitrogen from fertilizers and waste water effluent might affect quality of the groundwater. However, as will be explained later, the quantity of nitrogen percolating below the root zone will raise the concentration of N in the groundwater at the coast line to only about half the upper limit

set by the EPA for drinking water.

Salinity also will be added to the groundwater because the pumped irrigation water will have a higher salinity than the ambient groundwater. In the region between Paumalu Valley and Waimea Valley groundwater exists as a thin basal lens having a head (elevation of the water table above sea level) of less than 4 feet one mile inland. Potable water within the property starting about a mile inland of the coast may be extracted by means of small pumps of less than about 150 gpm capacity. For most purposes this small a pump is uneconomical because of the cost of well construction. Even so the Board of Water Supply at one time relied on a pumping station at Sunset Beach to provide water for local needs (wells 4002-04 and 4002-05). These wells are not presently used but are considered as operable by the Board.

The salinity of the water to be applied as irrigation will be about 350 mg/l chloride. The ambient groundwater which surplus irrigation will impact has a salinity of approximately 100 mg/l chloride for pumping rates less than about 150 gpm. The probable maximum concentration added to the natural groundwater will be about 44 mg/l chloride, bringing the total concentration to 144 mg/l at the coast. The recommended upper limit for potability is 250 mg/l. Average salinity in the area will be raised to 116 mg/l chloride. These values, as well as the nitrogen values, were derived from a mixing cell model that employs expected parameters of rainfall recharge, irrigation recharge, contaminant concentrations in applied irrigation, and concentrations in the ambient groundwater. The model is explained at the end of this report.

Herbicides and pesticides also will be used on the golf course and a fear exists that improper useage will provoke contamination of the groundwater. In a separate assessment by Murdoch and Green this issue is discussed, and the authors conclude that proper management and control of applications will eliminate the threat of significant groundwater contamination.

Hydrogeology and Groundwater occurrence

Pupukea-Paumalu is part of the Kawailoa Aquifer System. In the vicinity of Lihi Lani the aquifer is unconfined and carries a thin basal lens of fresh to brackish water floating on sea water. At the coast a weak caprock of sediments lying below an elevation of about 40 feet partially restrains the discharge of the lens but is not effective enough to cause a significant head build-up inland. At the recently drilled irrigation wells, which lie 6000 feet from the coast, head is 3.8 feet.

The aquifer consists of highly permeable Koolau basalt in which groundwater moves at a velocity of nearly 10 feet per day. This value is derived from Darcy's law employing a typical value of hydraulic conductivity for Koolau basalt of 1500 ft/day, an average gradient of 0.633 ft/1000 ft as determined from the measured head at the irrigation wells, and an assumed effective porosity of 10 percent.

At the irrigation wells the mid point of the transition zone, which is the half sea water isochlor (approx. 10,000 mg/l chloride), is computed as 152 feet below sea level using the Ghyben Herzberg ratio of 40 feet of fresh water below sea level for every foot above. The thickness of the fresh water core is unknown, but by analogy with similar groundwater systems is likely to be 75 to 100 feet. To withdraw potable water, defined as containing less than 250 mg/l chloride, pump capacity must be less than 300 gpm. At higher capacities, at least 500 gpm and perhaps as much as 700 gpm, irrigation quality water with less than 500 mg/l chloride can be pumped. Each of the irrigation wells will be outfitted with 350 gpm (0.5 mgd) pumps and will yield water having less than 350 mg/l chloride.

The property to be developed lies between Paumalu Stream and Kalunawaikaala Stream over a distance of 1.36 miles as measured along the cliff line above the coastal plain. Employing the carefully surveyed head of 3.8 feet at the irrigation well and hydraulic conductivity of 1500 ft/day yields a discharge value of 3 mgd/mile, or 4 mgd along the seaward margin of the property. This value is consistent with the rate of 3.4 to 5.6 mgd estimated in the preliminary groundwater report (Groundwater Conditions Pupukea-Paumalu, John F. Mink 6/6/88, submitted to Engineering Concepts, Inc.). A rate of 3 mgd over the outflow face is used later in the mixing model.

The top of the saturated aquifer is just above sea level and thus lies a minimum of 400 feet and as much as 650 feet below the ground surface where the golf course will be located. Several feet of soil and subsoil constitute the surface, below which 25 to 100 feet of saprolite transitions into unaltered fresh Koolau basalt. The soil mantle is an effective medium for depleting biological constituents of waste water effluent and for promoting the consumption of nitrogen accompanying both fertilizer enriched surplus irrigation and waste water and also for fixing phosphorus so it is removed from the infiltrate. The saprolite, which is thoroughly altered basalt in which most minerals have been hydrated and permeability elements destroyed by expansion of the rock mass, is a very effective filter that removes any particulate matter which may have escaped below the root zone. The percolate reaching the saturated aquifer in fresh basalt is clear of biological matter but includes added solutes, especially nitrogen and chloride.

Waste water effluent normally does not contain concentrations of heavy metals and other EPA designated contaminants in excess of EPA limits. Irrigation return water may carry residues of pesticides if these chemicals are improperly used, but by limiting pesticide types to those that break down during soil and saprolite passage and controlling their application, the quantities reaching groundwater should be non-detectable.

Groundwater Development

The Pupukea-Paumalu portion of the Kawailoa Aquifer System

has not been exploitcd for domestic water supply except at a BWS station consisting of two wells (4002-04 and 4002-05) located on the west bank of Paumalu Gulch nearly adjacent to the proposed land development. Neither of the wells are currently used but at least one is on standby status.

Domestic water for the northern part of the region is supplied by wells in Waialee from an aquifer that is not connected to the basal lens south of Paumalu. Pupukea is supplied with water from near Waialua several miles away. On the coastal plain numerous shallow wells have been dug or drilled but none yield potable water. Injection wells for disposal of drainage and waste water effluent also are located in the coastal plain. Dwellings rely on cesspools or septic tanks to dispose of household waste water.

Two borimgs, one a pumpable well (3902-01) and the other a test hole (3902-02), were drilled in Kalunawaikaala and Pakulena Valleys, respectively, more than twenty five years ago. The test hole could not be located during field work, but the well may still be useable. The wells are plotted on an accompanying map.

As part of the Lihi Lani development plan two irrigation wells were drilled (see the Appendix, "Pupukea Golf Course Wells" for a full description). The aquifer was proven to be highly permeable and to have a head of 3.8 feet at a distance 6000 feet from the shore line. At pumpimg rates required for irrigation, salinity exceeds the potable limit of 250 mg/l chloride. Smaller wells might yield potable water if rates were restricted to less than 300 gpm. For a reliable potable water station, however, wells would have to be located at least as far inland as the irrigation wells and preferably inland of the property boundary. Such wells would not be affected by percolation of water used in irrigation of the golf course.

The sustainable yield of the basal aquifer between Waimea and Paumalu is about 3.5 mgd. This figure is derived from the estimated flux of 3 mgd/mile, of which about 45 percent is developable as potable water (for an explanation of how the estimate is made, refer to the State Groundwater Protection Plan, Commission on Water Resources Management, Department of Land and Natural Resources). Within the limits of the property the proportional allocation of sustainable yield is 1.5 mgd. Total average draft for the project is not expected to exceed 0.5 mgd. The Board of Water Supply Sunset Beach wells averaged only 0.06 mgd when they were operational.

Groundwater Flow and Groundwater Mixing Model

Hydraulics of Groundwater Flow Toward the BWS Wells

The only wells that have had use as a domestic source of water are at the BWS Sunset Beach station located north of the edge of the property. Assuming groundwater flow is perpendicular to the coast line, the station lies about 400 feet away from the limiting flow line beneath the area to be irrigated. At the maximum rate the BWS wells have been pumped, 155 gpm, the envelope of influence of the pumping well would not include

groundwater flow lines from the golf course area. Neither would dispersion be effective in driving a significant amount of solute to the pumping well because of the high ratio of longitudinal to transverse dispersivity, on the order of 100:1, attributed to basalt aquifers in Hawaii. Low transverse dispersivity supresses the width of the dispersion halo surrounding a plume of solute.

The maximum half width of the hydraulic envelope of influence up gradient of the pumping well is computed as follows:

$$y = Q/2kbi$$

in which y is the maximum half width, Q is pumpage (155 gpm), k is hydraulic conductivity (1500 ft/day), b is depth of flow (70 ft) and i is the ambient gradient (0.633 ft/1000 ft). The veracity of the calculation is constrained by the assumptions, but nevertheless the computed value of y suggests that flow to the BWS well from beneath the golf course would be very small, if it took place at all.

Groundwater Mixing Model

The two solutes of interest are nitrogen (N) and chloride (Cl). Will the quantity that percolates below the root zone as a result of surplus irrigation degrade the ambient groundwater beyond the limit of potability?

The simplest mixing model is to consider the entire area of irrigation as a single cell and do a mass balance combining the volume and concentration of infiltrating water with ambient groundwater. For the nitrogen mixing model the assumptions employed are as follows:

1. The width of the cell is 0.5 mile, extending from Kalunawaikaala Valley to Paumalu Valley. Depth is 70 feet and ambient groundwater flow is 1.5 mgd. These values were discussed earlier.

2. The rate of application of fertilizer on the golf course is 346 lbs nitrogen per year (taken from "Environmental Assessment of Fertilizer, Herbicide and Pesticide Use on the Proposed Lihi Lani Golf Course", by Murdoch and Green).

3. Wastewater effluent contains 6 mg/l N.

4. 5 percent of the applied nitrogen escapes below the root zone (Murdoch and Green).

5. The average irrigation application is 4,500 gallons per acre per day (gpad), for a total of 540,000 gpd on 100 acres.

6. Irrigation efficiency is 90 percent (Murdoch and Green).

7. N concentration of the ambient water is 0.5 mg/l.

The mass balance yields an average concentration for the cell of 0.9 mg/l N, an increase of 0.4 mg/l over the background concentration. The EPA upper limit for drinking water is 10 mg/l.

The single cell model gives an average for the entire mass of water beneath the 100 acres irrigated. The concentration, however, varies from the start of the area to the discharge front along the coast because nitrogen build up occurs in the down gradient direction. To approximate the maximum value of N at the

seaward front of the property caused by surplus irrigation, a multi cell model was created in which concentration at any point along the gradient can be calculated. The model incorporates the same data as listed above but solves for each cell in a line of cells along the 10,000 feet distance from the inland to the seaward boundary of the property.

At the seaward boundary, groundwater contains 3.5 mg/l N, which is considerably less than the EPA potable limit of 10 mg/l. In the middle of the property N would be approximately 2.4 mg/l. These values are similar to those experienced in the most down gradient portion of the aquifers in southern Oahu, up gradient of which N is applied at a rate of 300 lbs/acre/year over 10,000 acres of sugar cane.

The chloride concentration model is similar to that explained above. In the single cell model the following is assumed:

1. The two irrigation wells yield water with 350 mg/l chloride at average rate of 200,000 gpd. The other increment of irrigation, waste water effluent, is assumed to contain 100 mg/l chloride, the same as assumed for ambient groundwater.

2. Ambient groundwater has 100 mg/l chloride and flow is 3 mgd. The mass balance calculation gives an average concentration of 116 mg/l chloride as a result of mixing, or 16 percent above ambient.

For the multi cell model the computed salinity at the discharge front of the lens is 144 mg/l, which is 106 mg/l less than the recommended upper potability limit of 250 mg/l.

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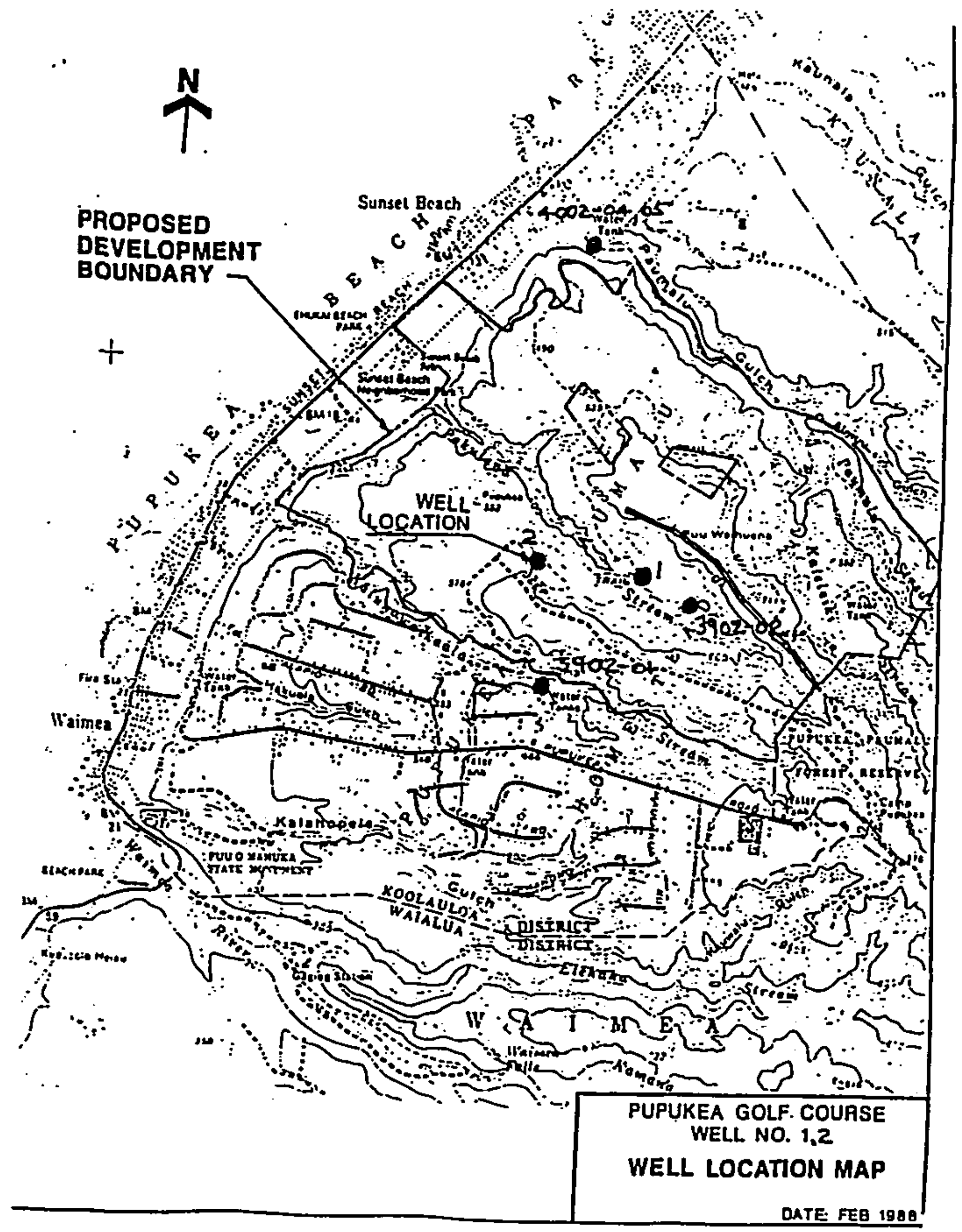


APPENDIX

PUPUKEA GOLF COURSE WELLS

Summary of Pump Test Results
Recommendations Pump Size and Setting

John F. Mink
December 11, 1989

Two wells were drilled in Pakulena Valley in the Pupukea region of northern Oahu during the past year as potential water supply sources for irrigating two golf courses (see attached map). Both wells were successful and were tested at 500 gpm for several days. At this high rate the pumped water is not potable but is excellent for irrigation. Salinity at 500 gpm is about 300 mg/l chloride (note: the recommended upper limit for potable water is 250 mg/l chloride, but the Board of Water Supply prefers to serve water having less than about 180 mg/l chloride).

The wells have been completed with blank casing, perforated casing, grout and a rock pack. They are ready to be equipped with permanent pumps.

Aquifer Properties

The aquifer penetrated by the wells contains a low-head basal lens which is partially confined at the coast by weak caprock. This coastal plain caprock is not very effective,

however, in impeding the free discharge of the lens. Where the wells were drilled approximately 6000 feet inland of the shore the head is 3.8 feet, which is characteristic of an open basal groundwater system.

The aquifer is composed of highly permeable Koolau basalt. So little drawdown was generated during testing that it was not possible to calculate aquifer properties, but by analogy with better known Koolau basalt aquifers the hydraulic conductivity is likely to be at least 1500 ft/day and the storativity .05 to .10. Aquifers with these favorable properties easily yield water to pumping wells at minimum drawdown. However, in a thin lens like the one in Pupukea high rates induce flow to wells from the brackish transition zone, often raising the chloride level to above the potability limit.

At a rate of 500 gpm the aquifer at the well sites yields water containing about 300 mg/l chloride. At lower rates the output would be less saline. If rates were reduced to about 250 gpm, chloride content would likely fall below the recommended upper limit of potability. The pumpage might not, however, conform to the Board of water Supply standard of less than 180 mg/l chloride.

Well Construction and Behavior

Design and construction of the wells were quite simple. Each reaches to about 35 feet below sea level and is fitted with blank 12 inch diameter casing to sea level and 12 inch diameter louvered casing to the bottom of the well. Following is a summary of construction details.

Item	Well 1	Well 2
Elev. Top Casing (ft)	419.8	468
Ground Elev. (ft)		465.8
Total Depth (ft)	455	500
Casing Dia. (in)	12	12
Blank Casing Length (ft)	420	462
Louver Casing Length (ft)	35	38
Depth to Static Water (ft)	416.0	464.3
Head (ft)	3.8	3.7
Test Rate (gpm)	500	500
Pump Set Depth (ft)	430	491
Airline Set Depth (ft)	420	480
Stable Drawdown (ft)	2.3	0.46
Maximum Test Chloride (mg/l)	254	336
Test Date	11/7-9/88	8/21-24/89
Test Time (hrs)	52	76
Recovery	Inst.	Inst.

Step drawdown and continuous rate tests were conducted on each well. The efficiency of each is excellent; drawdown was so minor that neither the efficiency of the wells nor the aquifer parameters could be calculated. A summary of the test results follows.

Test Results

Pupukea Well 1 Test 13:00 11/7/88 to 17:00 11/9/88
Pupukea Well 2 Test 08:00 8/21/89 to 12:00 8/24/89

Well 1			Well 2		
Time(hr)	Rate(gpm)	DrDn(ft)	Time(hr)	Rate(gpm)	DrDn(ft)
0 - 1	100	1.2	0 - 1	100	0
1 - 2	200	1.2	1 - 2	200	0
2 - 3	300	1.7	2 - 3	300	0
3 - 4	400	2.3	3 - 4	400	0
4 - 5	500	2.3	4 - 5	500	0.35
5 - 52	500	2.3	5 - 76	500	0.46

Recovery virtually instantaneous in both cases.

Groundwater Quality

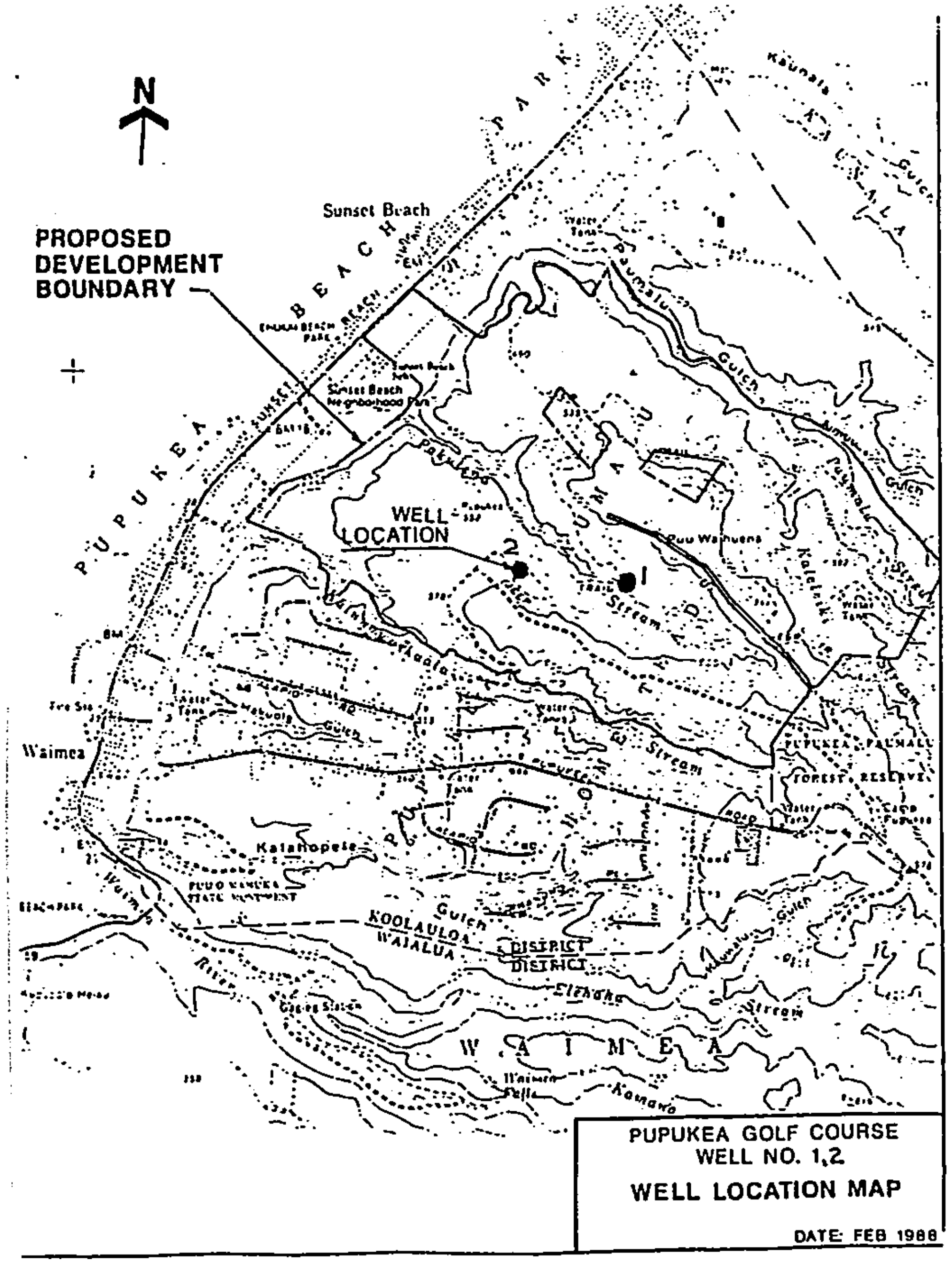
The concentrations of dissolved constituents in the pumped water are characteristic of slightly brackish Koolau basalt groundwater. Chemical analyses of samples from each well are attached.

The chloride content ranged from 255 mg/l in Well 1 to 336 mg/l in Well 2 while pumping at 500 gpm. Lower pumping rates would result in lower salinity. The iron concentration in Well 1 at 1.04 mg/l is somewhat high, but more than one analysis would be needed to verify this result.

Recommendations for Pump Size and Setting

The wells are capable of pumping up to 500 gpm irrigation grade water, but at the upper end of the range salinity becomes a serious constraint. At rates between 300 and 400 gpm the chloride content is manageable; at 250 gpm and less the pumped water might meet potability standards.

The recommended pump size is 350 gpm per well, which allows for a total output of 1 mgd when the wells are pumped continuously. Each well is very efficient and therefore drawdown is small. Pumps can be set at 10 feet below sea level in the louvered portion of the casing.



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DATE 11/30/88
PAGE 1 of 1

RECEIVED
DEC 5 1988
ENGINEERING CONCEPTS

LABORATORY ANALYSIS REPORT

TO: Engineering Concepts
ATTN: Ken Ishizaki

SAMPLES OF: Well water
RECEIPT DATE: 11/8/88
SAMPLED: 11/8/88
LOG NO.: 3294-3297

..MPLES:	Pupukea Well #1					Analysis Date / Initials
..renent ..s):						
	7.61					11/8 js
..uctivity ..s/cm)	1030					11/10 kt
..rate (mgN/L)	0.556					11/16 js
..ophosphate ..P/L)	0.077					11/16 js
..oride (mg/L)	255					11/10 kt
..fate (mg/L)	7.6					11/10 kt
..cium (mg/L)	19.61					11/29 BAL
..n (mg/L)	1.04					11/29 BAL
..on (mg/L)	0.101					11/29 BAL
..nesium (mg/L)	19.20					11/29 BAL
..assium (mg/L)	6.84					11/29 BAL
..ica (mg/L)	53					11/29 BAL

* REMARKS:

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JOB NO. 555
DATE 9/21/89
PAGE 1 of 1

RECEIVED
SEP 2 5 1989
ENGINEERING CONCEPTS

LABORATORY ANALYSIS REPORT

TO: Engineering Concepts
ATTN: Ken Ishizaki

SAMPLES OF: Well water
RECEIPT DATE: 8/22/89
SAMPLED: 8/22/89
LOG NO.: 3734

SAMPLES:	Pupukea Golf Course Well #2					Analysis Date
surement its):						Initials
pH	6.83					8/23 kt
nductivity nhos/cm)	1229					8/23 er
thophosphate (mg/L)	0.114					9/8 er
trate (mg/L)	0.75					8/23 er
loride (mg/L)	315					9/20 er
lfate (mg/L)	42.8					8/30 er
lcium (mg/L)	9.7					8/30 BAL
on (mg/L)	0.42					8/30 BAL
ron (mg/L)	0.122					8/30 BAL
nesium (mg/L)	28.4					8/30 BAL
assium (mg/L)	15.2					8/30 BAL
lica (mg/L)	60.3					8/30 BAL

* REMARKS:

AECOS
970 N. Kalaheo Ave., Suite A300
Kailua, Hawaii 96734

JOB NO. 1089-3733
DATE 9/22/89
PAGE 1 of 1

LABORATORY ANALYSIS REPORT

TO: Roscoe Moss Company
ATTN: Tracey El Runnels

SAMPLES OF: Well water (Pupukea)
RECEIPT DATE: 8/22/89, 8/28/89
SAMPLED: 8/21-22, 8/23-24/89
LOG NO.: 3733,3743

ANALYSIS DATE	9/12 mm					
MEASUREMENT	Chloride					
UNITS:	mg/L					
SAMPLE(S)						
Well #2:						
Sample #1 8/21/89	274					
Sample #2 8/21/89 12 noon	271					
Sample #3 8/22/89	279					
Sample #4 8/23/89 12:00 midnight	308					
Sample #5 8/23/89 6 pm	283					
Sample #6 8/24/89 12 noon	336					

* REMARKS:

John F. Mink
CONSULTING HYDROLOGIST

P.O. Box 4452
Honolulu, Hawaii 96812

(808) 737-6136 (Res.)
(808) 536-0081 (Off.)
Fax: (808) 536-0082 (Off.)

December 23, 1990

Mr. Norman Quon
Suite 2000 Pauahi Tower
1001 Bishop St.
Honolulu, HI 96813

Dear Norman:

Enclosed is a copy of the study I made on the impact of fertilization and irrigation on the golf course at Pupukea. A copy already has been sent to Group 70 and another to Engineering Concepts.

I am willing to argue the validity of the conclusions should the need arise.

Sincerely,

APPENDIX H

ENVIRONMENTAL ASPECTS OF STORM WATER RUNOFF

Lihi Lani Recreational Community
Pupukea, Oahu, Hawaii

December, 1990

by

Gordon L. Dugan, Ph.D. ,
Environmental Consultant

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INTRODUCTION

The proposed Lihi Lani Recreational Community Project, located at Pupukea in the Koolauloa District on the north shore of Oahu, as shown in Figure 1, consists of a gross area of 1130 acres, with approximately 492 acres being planned to be developed. The outline of the 1130 acre project, which contains two private land parcels and an access roadway, is presented in Figure 2. As can be noted in Figure 2, an approximately 1100 ft wide portion of the property extends to Kamehameha Highway. This area will provide the location of the main access road to the proposed development. With the exception of the 1100 ft wide access portion the remainder of the property commences on the bluff above the Sunset Beach area and cannot be seen from Kamehameha Highway. The majority of the bluff is within the 200-400 ft elevation range, while the upper portion of the property ranges up to almost 850 ft elevation.

The 492 acres of proposed developed areas, which are interwoven within the total 1130 acre property, includes a variety of separate land uses, most notable of which are an 18 hole golf course, a 120 lot subdivision, and 28 acres of affordable housing. The proposed separate land uses for the project and their accompanying acreages are presented in Table 1.

The proposed golf course is being planned to minimize the amount of land being altered. It is estimated that only 90 acres out of the 196 acres designed as golf course will actually be developed and maintained. The two private land parcels, which total about 34 acres are essentially encompassed by the proposed development. Undeveloped sections of the property separate many portions of the proposed developed areas.

The City and County of Honolulu Board of Water Supply's "Pass-No Pass" line, as does the Special Management Area (SMA) line, extends along the base of the bluff and is

2

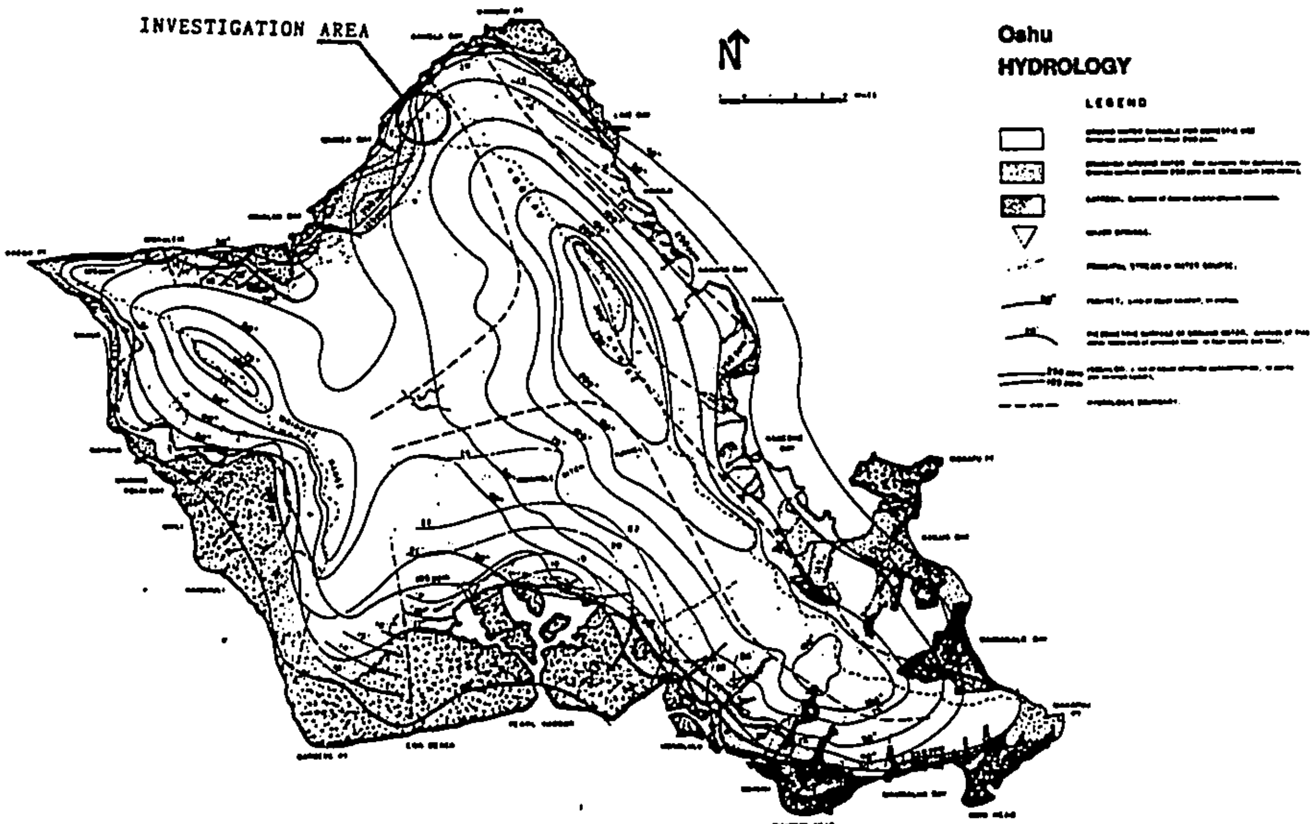

Figure 1. Hydrologic and Geologic Characteristics of Oahu, Hawaii
(Source: "2020 Plan," Board of Water Supply, City and County of Honolulu, 1971, page 13)

3

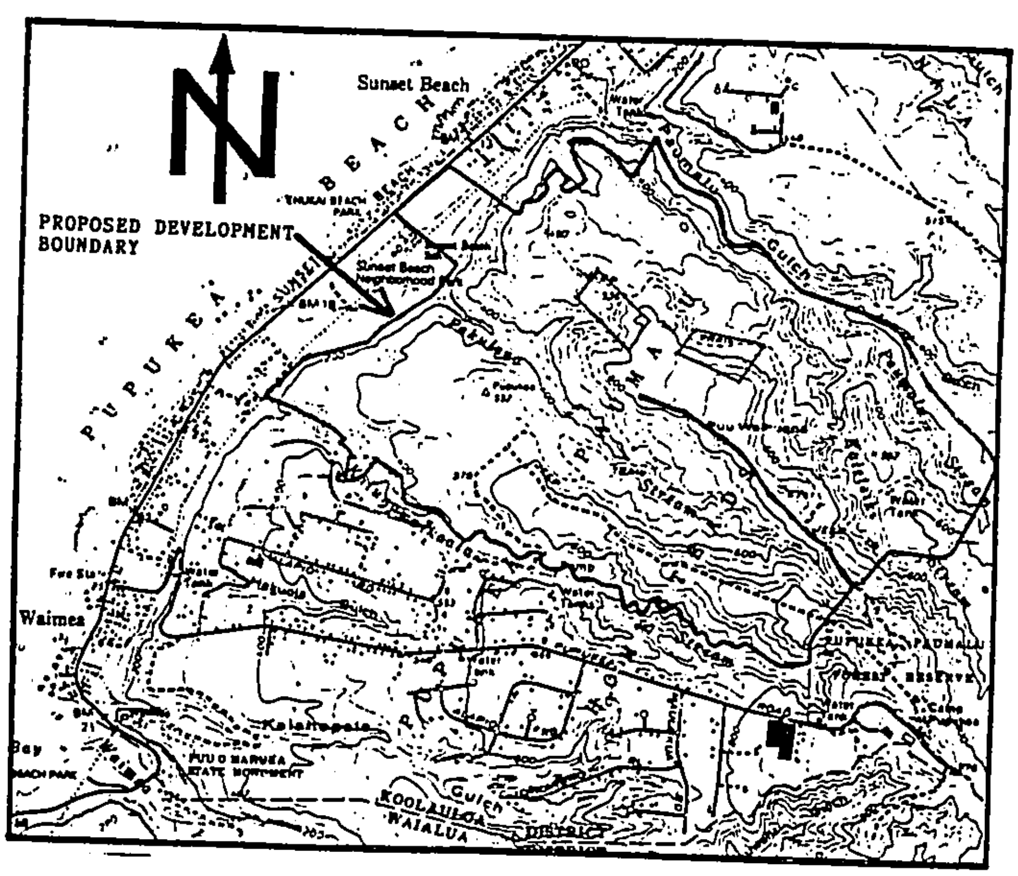

Figure 2. Lihi Lani Recreational Community Site Area, Pupukea, Oahu, Hawaii

TABLE 1

Proposed Land Uses,
Lihi Lani Recreational Community,
Pupukea, Oahu, Hawaii

Land Use[a] Type	acres
Golf course[b]	90
Golf Course Maintenance Area	5
Clubhouse	6
Driving Range	10
Tennis Center	12
Equestrian Ranch	19
Horse Pasture	78
Campground	15
Community Facilities	10
Subdivision(120 lots)	161
Affordable Housing	28
Roadways[c]	44
Sewage Treatment Plant	14
Total	492

a) Based on the December 10, 1990 Master Plan Map by Group 70, for Obayashi Hawaii Corporation, Pupukea, Koolauloa District, Oahu, Hawaii
b) Assume that 90 acres out of 196 acres designated within the golf course boundaries will actually be developed
c) Based on 50 ft Roadway

roughly coterminous with the makai property line, except for where it transverses the upper portion of the aforementioned approximately 1100 ft wide access area that extends to Kamehameha Highway. The State of Hawaii Department of Health's Underground Injection Control (UIC) line follows Kamehameha Highway in the area fronting the project.

A total of nine soil series, as well as approximately 40 acres of land designated as "rock land," are included within the 492 acres being proposed to be developed. The relationship of these soils to storm water runoff will be discussed in a later section of the report. The majority of the project is covered by Australian Iron Wood trees, which, under high density conditions, significantly limit undercover vegetative growth. Grasses, particularly California grass, along with attendant weeds and low brush typify the few open areas and sparsely tree covered portions of the property. The annual median rainfall at the project site area ranges from approximately 35 to 65 in., with a weighted overall median being about 50 in. (Giambelluca, et al., 1984).

A development project such as the one being herein proposed generally produce alterations in surface water runoff as a result of modifying existing ground conditions. Interest in these runoff changes is generally a result of concern over two factors: one, public safety, and two, environmental impact. The first factor requires the identification of changes in peak discharge rates, the magnitudes of which are necessary for designing adequate drainage structures to prevent flooding, while the second concern requires identification of changes in total runoff volume, as well as sediment, nutrient, and other constituent loads, and the effects these will have on the ecosystem of the natural resource serving as the "sink." It is this second concern, environmental impact resulting from increased runoff volume and sediment and nutrient loads, and its probable effect on subsequent receiving waters (nearshore ocean waters) that is under study in the present investigation as herein reported.

PURPOSE AND SCOPE

The purpose of this study is to evaluate the environmental impact of the proposed Lihi Lani Recreational Community as it relates to surface water runoff. From an assemblage of baseline hydrologic and water quality data, an estimate of the existing and projected volume and quality characteristics of surface water runoff will be made, along with an assessment of the environmental impact resulting from this runoff, in the form of written comments.

METHODOLOGY

The methodology used in this study consisted of assembling, analyzing, and interpreting existing data from federal, state, and county agencies, as well as from on-site surveys of field conditions.

Inasmuch as the scope of work consisted of estimating the alterations in volume and quality of surface water runoff resulting from the proposed project, it was necessary to identify those factors that affect runoff generation and runoff quality for both present and full development conditions.

Methods currently available to estimate the surface water runoff volume from a specific storm event requires the determination of reasonable rainfall-runoff coefficients for varying magnitude and duration storms, and for different land management, vegetation, soil, and soil moisture conditions, to name but a few hydrologic factors. In most practical situations, it is not considered feasible, due to the numerous influencing factors, to determine varying rainfall-runoff coefficients; rather, it is more practical for design and evaluation purposes to use a single coefficient for a particular land use over a given rainfall intensity range. However, in order to circumvent a major portion of the unavoidable error created by using a constant rainfall-runoff coefficient, methods developed by the Hawaii Environmental Simulation Laboratory (HESL) of the University of Hawaii at Manoa (Lopez, 1974; Lopez and Dugan, 1978), and the U.S. Soil Conservation Service (SCS)(1986), were utilized to determine representative storm water volumes under varying conditions.

The HESL/SCS methods are based on the use of soil maps (Foote et al., 1972) and the incorporation of curve numbers from the U.S. SCS which were obtained from empirical data, including precipitation, soil and changing soil moisture conditions, and vegetative cover information from the

classification of thousands of soils throughout the nation. These soils were classified into four groups, labeled A, B, C, and D, with Class A having the highest water intake rates and Class D soils the lowest (U.S. Soil Conservation Service, 1986).

One of the proposed project's nine soil series, Kapaa, is Class A; five are Class B, Kemoo, Paaloa, Paumalu, Wahiawa, and Waialua; two are Class C, Helemano and Manana; and one, Kaena, is Class D. The area designated as rock land (40 acres) was included with Class C soils. Overall Class B and C soils cover approximately 63 and nearly 35%, respectively, while Class A (1 acre) and D (7 acres) soils make up the remaining approximately 2% of the proposed developed area, as shown in Table 1. Because of the small areas of Class A and D soils the former was integrated with Class B soils, while the latter was included with Class C soils. The storm water runoff was calculated separately for Class B and C soils for each of the individual developed land use categories and then added together. The SCS method promotes a weighted average of the soil/land use values (curve numbers); however, for areas over 100 acres this method generally leads to notable differences in runoff, which are significantly lower as the acreage increases.

The developed land was separated into five general categories which had similar storm water runoff characteristics according to their land use. The five categories, which include all the separate land uses shown in Table 1, are: Golf Course, Subdivision, Affordable Housing, Roadways, and open waters for the wastewater treatment pond/marsh system. The Golf Course Category includes the golf course, horse pasture, driving range, campground, and one-half of the area allotted to the wastewater treatment system. The remaining one-half (7 acres) is assumed to be open waters/marsh that will be bermed to the extent that no storm water runoff would result from this area as a result of direct rainfall. The campground was included with golf courses because it was not known to what extent the land would be developed, thus, a conservative approach was taken. The Subdivision Category includes the subdivision, clubhouse, equestrian ranch, community facilities, and tennis center. The Affordable Housing Category was assigned the affordable housing acreage and the golf course maintenance area, while the Roadway Category only included roadways. The open waters of the wastewater treatment pond/marsh system only involved the aforementioned 7 acres which are assumed to produce no runoff from direct rainfall.

The rainfall recurrence interval storms chosen for evaluation purposes, 2, 10, 50, and 100 yr, with 1 and 24 hr durations, were obtained from a rainfall-frequency atlas for Oahu (Giambelluca et al., 1984).

Once the increase in surface water runoff volume has been established, it is necessary to determine the runoff quality for present and full development conditions.

The quality parameters of storm water runoff considered the most representative to identify potential changes under different land management practices (i.e. present and full development conditions) are: total nitrogen; total phosphorus; and suspended solids (sediments). Unfortunately, there are no water quality data from the intermittent streams that pass through the project, nor are there sufficient data from the nearby streams, including Waimea River, over one mile southwest of the proposed project.

To circumvent the problem of determining representative nitrogen and phosphorus values in surface water runoff, for comparative purposes, nitrogen and phosphorus values of 3.0 and 0.3 lb/acre-yr, respectively, were selected to represent the present (1990) development conditions. These values were derived from a compilation of data relating to nutrient outputs from rural and agricultural lands throughout the nation that were reported by Loehr (1972). To convert the

output loads to concentration values, nitrogen and phosphorus values of 3.0 and 0.3 lb/acre-yr, respectively, were calculated with the median annual rainfall of 50 in., and a rainfall-runoff coefficient of 0.30, which results in average (rounded-off) concentration values of 0.90 and 0.09 mg/L, respectively, for the present development conditions.

Representative suspended solids values in storm water runoff from the presently developed (1990) project site area are again difficult to determine, inasmuch as it is commonly presumed, by mainly indirect methods, that the majority of the annual suspended solids load is carried by heavy storm water runoff events which tend to occur on an infrequent basis. For the present study the concentration of suspended solids was based on composite measured and estimated suspended solids load per unit area from various Oahu streams, including those out of the entire Kaneohe Bay Drainage Basin, as reported by Jones et al. (1971). Following this reasoning the suspended solids concentration value for the present development conditions for comparative purposes was set at 800 mg/L.

Quality data for storm water runoff from developed areas are sparse, both locally and nationally. Loehr (1974) compiled urban storm water runoff quality data collected from throughout the United States, as well as from a few international locations. As expected, the data are diverse. Locally, Fujiwara (1973) reported urban water quality data collected from storm drains in different land use drainage areas of Honolulu (residential, commercial, and industrial), as shown in Table 2. These values compare favorably with similar situations from the continental U.S.

When evaluating projected storm water quality constituent concentrations it must be borne in mind that the values of concern are for surface water runoff, in comparison to values contained in percolated water. For example while certain forms of nitrogen (organic and

TABLE 2

Representative Storm Water Quality Data for Honolulu, Hawaii[a] (Fujiwara, 1973)

	Residential[b]	Commercial[c]	Industrial[d]
Total Solids	511	278	246
Suspended Solids	252	142	12
COD	142	209	40
BOD	10	19	7
Dissolved Oxygen	7.1	5.7	6.7
NO3-N	0.211	0.045	1.1
TKN	0.381	0.272	2.70
Total P	0.57	0.53	2.17
Ortho P	0.27	0.19	1.27
Grease	2.8	1919	2.2
Lead	0.407	0.987	1.657
Chromium	0.013	0.021	0.013
Zinc	0.512	0.792	0.729
Copper	0.036	0.036	0.021
Iron	0.377	0.295	0.049
Total Coliform	83,300	33,500	11,500
Fecal Coliform	1,965	463	580
Fecal Strep	6,393	7,900	7,350

[a]All units in mg/l except total coliform, fecal coliform, and fecal strep which are listed as No./100 ml.

[b]Storm water samples collected on Aupuni Street near Nuhelewai Stream.

[c]Storm water samples collected at Beretania Street between Maunakea and River Streets.

[d]Storm water samples collected near Iwilei and Pacific Streets.

ammonia) and nearly all the phosphorus are effectively removed from waters percolating through most Hawaiian soils those contained in surface water are not necessarily subjected to this sorption process. Thus, for this situation, constituents leached and/or introduced to surface water runoff (principally storm water) from vegetative sources, human and animal activity, and even fertilizers (if significant rainfall occurs shortly after application) can be carried and solubilized in the storm water runoff without being subjected to the sorption process in the soil column.

For the present study, the quality results of storm waters from the Honolulu residential area of Table 2 for nitrogen, phosphorus, and suspended solids of 0.60, 0.57, and 250 mg/L, respectively, were used for the proposed project's full development conditions, except for roadways, which utilized values from a State of Hawaii Department of Health (DOH)(1980) study. The nitrogen, phosphorus, and suspended solids values from the DOH study were, respectively, 1.41, 0.11, and 75 mg/L. The residential quality storm water runoff values were used for the golf course inasmuch as fertilization is applied under professional supervision with attention given to the application rate as well as abstaining from fertilization during periods of probable heavy rainfall, for economic as well as environmental reasons. Attention is likewise drawn to the heavy metal content of residential storm water runoff.

The aforementioned storm water runoff constituent concentrations for nitrogen, phosphorus, and suspended solids for present development (1990) and full development conditions can then be applied to the present and full development runoff volumes to determine the projected sediment and nutrient loads from the project site.

SURFACE WATER RUNOFF ALTERATIONS

Quantity

The estimated storm water runoff and constituent changes due to the proposed 492 acre Lihi Lani Recreational Community are shown in Table 3. The values presented, it must be emphasized, are only for comparative purposes, and are not intended to be representative of the accuracy implied by the practice of reporting results to one/two decimal places. This was done primarily for convenience of calculations and balancing. No attempt was made to compare these changes with contributions from its surrounding or parent watershed area, which would tend to negate apparent changes caused by the land use alterations within the project site.

As can be readily observed in Table 3, the storm water runoff volume under full development conditions for the 2 yr, 1 hr duration storm, is nearly four times greater than for the present (1990) conditions, but, the incremental difference is only 5.1 acre-ft. However, as the storm duration and recurrence interval increases, the difference reduces down to only approximately 11% greater for the 100 yr, 24 hr storm, which was the greatest calculated storm water runoff volume evaluated. At higher rainfall intensities and durations, soil saturation increases, thus, more runoff occurs.

The calculated increased runoff from the project area correspondingly indicates less potential groundwater recharge within the site of the project. However, in this situation the calculated reduction in potential recharge will be abated somewhat by the planning geometry of the proposed project, in that developed areas are interwoven with undeveloped areas. This should tend to increase the recharge potential (less overall storm water runoff) in the undeveloped areas to a greater degree than presented in Table 3. This is because a conservative approach was

TABLE 3
Estimated Storm Water Runoff and Constituent Changes due to the proposed Lihi Lani Recreational Community, Pupukea, Oahu, Hawaii

Storm			Storm Water Runoff											
Duration	Recurrence Interval	Quantity	Hydraulic			Nitrogen			Phosphorus			Suspended Solids		
			Development			Development			Development			Development		
			1990	Full		1990	Full		1990	Full		1990	Full	
hr	yr	in.	AF event	AF event	AF event	lb event	lb event	lb event	lb event	lb event	lb event	ton event	ton event	ton event
1	2	1.5	2.1	7.2	5.1	5.1	17.3	12.2	0.5	8.1	7.6	2.25	1.87	-0.38
1	10	2.1	7.6	16.4	8.8	18.6	36.2	17.6	1.9	20.0	18.1	8.26	4.55	-3.71
1	50	3.0	21.6	35.2	13.6	52.9	73.4	20.5	5.3	45.6	40.3	23.52	10.26	-13.26
1	100	3.5	31.6	47.6	16.0	77.4	97.3	19.9	7.7	62.6	54.9	34.40	14.05	-20.35
24	2	5.0	68.2	89.9	21.7	167.0	177.9	10.9	16.7	121.7	105.0	74.20	27.19	-47.01
24	10	8.5	175.6	205.7	30.1	429.9	394.5	-35.4	43.0	285.5	242.5	191.08	63.59	-127.49
24	50	10.4	240.9	274.8	33.9	589.8	522.4	-67.4	59.0	284.0	225.0	262.13	85.43	-176.70
24	100	13.0	334.6	370.0	35.4	819.2	698.6	-120.6	81.9	519.9	438.0	364.10	115.57	-248.53

a) From "Rainfall Frequency for Oahu," (Giambelluca, et al., 1984)

b) Based on a nitrogen value of 0.90 mg/l for 1990 conditions; and 1.41 and 0.60 mg/l, respectively, for roadways and the remainder of the project's "full" development.

c) Based on a phosphorus value of 0.09 mg/l for 1990 conditions; and 0.11 and 0.57 mg/l, respectively, for roadways and the remainder of the project's "full" development.

d) Based on a suspended solids value of 800 mg/l for 1990 conditions; and 75 and 250 mg/l, respectively, for roadways and the remainder of the project's "full" development.

Note: Constituent load results are based on hydraulic loads prior to rounding-off on one/two decimal points.
Table values based on Group 70's December 10, 1990 Master Plan map.

assumed for storm water runoff that didn't account for potential percolation from storm water runoff generated from developed areas and flowing over undeveloped areas before reaching a defined drainage course.

These runoff values (acre-ft/event) represent a volume of water and should not be confused with peak discharge rates which represent the maximum volume of storm water runoff discharge per unit of time (e.g., cfs or mgd). Peak discharge rates are required for engineering design of proposed drainage facilities and ascertaining the capacity of existing facilities, while total runoff volume provides a more realistic estimate of impact on water quality. Calculated peak discharge rates on Oahu for streams and/or drainage courses are usually determined from the City and County of Honolulu's Drainage Standards procedure (City and County of Honolulu, 1986).

Quality

Besides the changes in volume of storm water runoff, the quality of the various constituents being transported is of equal, if not of more importance. However, estimates of water quality constituents resulting from significant storm water runoff that occurs at the most only a few times a year is very perplexing, especially since information on this subject essentially only become available at both the local and national levels in the 1970's.

The summation of nitrogen, phosphorus, and suspended solids loads from both the present (1990) and projected (full) development for storms of 1 and 24 hr duration at recurrence intervals of 2, 10, 50, and 100 yr are shown in Table 3, along with the correspondingly previously discussed expected volumes for specific storms. For these determinations the roadways were calculated separately, with different constituent values, from the remainder of the projected developed area's storm water runoff quality.

The calculated incremental storm water runoff changes per storm event for the present and projected development conditions for the various duration and recurrence interval storms indicate that from the least to the greatest amount of rainfall: the nitrogen load increases slightly for the first five storm events and then decreases for the remaining three; phosphorus increases for all storms; and the suspended solids (sediment) load shows a decrease for all storm events. As was indicated in the discussion concerning storm water runoff volume, the interspersion of developed areas among undeveloped areas should tend to notably decrease the actual calculated runoff and consequently the constituent loads flowing from the property. This is particularly true for phosphorus which is readily adsorbed by contact with most Hawaiian soils. Removal includes adsorption with settled suspended solids during periods of low velocity conditions, such as in the proposed on-site detention/retention basins, as well as contact with bare soil and/or nutrient (nitrogen and phosphorus) uptake by vegetation in the drainage path.

The hydrologic and water quality aspects of the surface water runoff were only considered for the present and projected full development conditions. However, increases in constituent loads could result from construction activities, especially if a significant storm occurs during the interim period between earth moving operations or exposed soil conditions and soil stabilization completion. The impact of construction activities can be minimized by adhering to strict erosion control measures, such as those outlined in the City and County of Honolulu (1981) ordinance relating to grading, soil erosion and sediment control.

Other water quality constituents of general concern include biocides and heavy metals. Typically, the biocides in general use tend to break down more readily in comparison to the more long lasting types in previous years. This aspect will be presented in another report concerning the proposed project.

Heavy metals, on the other hand, do apparently increase somewhat as a result of urbanization, however, for a comparison basis, although it is not directly applicable for storm water runoff, only lead and iron (by a slight margin), according to the values in Table 2, actually exceed the primary (Department of Health, 1981) and secondary (U.S. Environmental Protection Agency, 1979) drinking water standards, respectively. Inasmuch as essentially all new automobiles have switched over to unleaded gasolines since the mid-1970's, it would be expected that the concentration of lead in residential storm water runoff would be steadily decreasing. The concern with iron concentrations in drinking water is due to its potential for staining fixtures and producing tastes.

For most development projects being considered the major water quality concern is the potential impairment of receiving waters, such as freshwater streams, lakes, reservoirs, estuaries, bays, or the oceans, and/or underlying potable groundwater supplies. For the development being herein considered there are no perennial fresh water streams within the property boundaries; a portion of the area along the makai portion of the property is underlain by brackish water (> 250 mg/L chloride), as shown in Figure 1; and there is no significant confining coastal water condition fronting the project property. The impact of the altered storm water runoff quantity and quality aspects on the fronting coastal waters will be considered in a separate report for the proposed project.

SUMMARY AND CONCLUSIONS

The proposed Lihi Lani Recreational Community, located at Pupukea on the north shore of Oahu, consists of a gross area of 1130 acres, with approximately 492 acres being proposed to be developed into an 18 hole golf course, 120 residential lots, 28 acres of affordable housing, and other ancillary facilities. The developed areas are somewhat interwoven within undeveloped areas.

A total of nine soil series, as well as approximately 40 acres of land designated as "rock land," are included within the 492 acres being proposed to be developed. The relationship of these soils to storm water runoff is discussed in the text of the report. The majority of the project is covered by Australian Iron Wood trees while grasses, particularly California grass, along with attendant weeds and low bush, typify the vegetation in the few open spaces and sparsely tree covered areas of the property.

The purpose of this study is to evaluate the environmental impact of the proposed 492 acre project as it relates to surface water runoff. To this end the study identified changes in total runoff volume, as well as sediment, nutrient, and other constituent loads. The study does not directly relate itself to peak discharge rates resulting from storms, which are required for designing adequate drainage structures to prevent flooding and other excess storm water runoff related aspects.

The methodology utilized in the evaluation of the environmental impact of storm water runoff from the project site consisted of the incorporation of methods reported by the Hawaii Environmental Simulation Laboratory of the University of Hawaii at Manoa and the U.S. Soil Conservation Service, soil maps, a rainfall frequency atlas, and derived storm water quality constituent values. The rainfall recurrence interval storms chosen for evaluation purposes were 2, 10, 50, and 100 yr, with 1 and 24 hr durations.

The results of the storm water runoff volume calculations indicated that under full development conditions the 2 yr, 1 hr duration storm is nearly four times greater than for the present (1990) conditions, although the incremental difference is only 5.1 acre-ft. However, as the storm recurrence interval and duration increases, the difference reduces down to only approximately 11% greater for the 100 yr, 24 hr storm, which was the greatest calculated incremental storm water runoff volume considered. At higher rainfall intensities and durations soil saturation increases, thus, more runoff occurs.

Besides the changes in the volume of storm water runoff, the quality of the various constituents being transported is of equal, if not of more importance. The incremental load changes per storm event for the present (1990) and full development project conditions for the various duration and recurrence interval storms indicate that from the least to the greatest amount of rainfall: the nitrogen load increases slightly for the first five storm events and then decreases for the remaining three; phosphorus increases for all storms; and suspended solids (sediment) shows a decrease for all storm events. The interspersion of developed areas among undeveloped areas should tend to notably decrease the actual calculated runoff and consequently constituent loads flowing from the property. This is particularly true for phosphorus which is readily adsorbed by contact with most Hawaiian soils. Removal includes adsorption with settled suspended solids during periods of low velocity conditions, such as in the proposed on-site detention/retention basins, as well as contact with bare soil and/or nutrient uptake by vegetation in the drainage path.

The foregoing hydrologic and water quality aspects were only considered for the present and projected full developed conditions. However, increases in constituent loads could result from construction activities, especially if a

significant storm occurs during the interim period between exposed and stabilized soil conditions. Thus, to limit these potential increases it is imperative that strict erosion control measures be adhered to.

Other water quality constituents of general concern include biocides and heavy metals. Typically, the biocides in general use tend to breakdown more readily in comparison to the more long lasting types in past years. This aspect will be presented in another report concerning the proposed project.

Heavy metals, on the other hand, do apparently increase somewhat as a result of urbanization, however, for a comparison basis only lead and iron (by a slight margin) are actually reported to exceed the primary and secondary drinking water standards, respectively. With essentially all new automobiles switching over to unleaded gasolines since the mid-1970's the concentration of lead would be expected to decrease with time. The concern with iron concentrations in drinking water is due to its potential for staining fixtures and producing tastes.

For the development being herein considered there are no perennial fresh water streams within the project boundaries and there is no significant confining coastal water condition fronting the project property. The impact of the altered storm water runoff quantity and quality aspects on the coastal waters will be considered in a separate report for the proposed project.

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January 15, 1991

MEMORANDUM

TO: Jeffrey H. Overton
Group 70
924 Bethel Street
Honolulu, Hawaii 96813

FROM: Gordon L. Dugan, Ph.D.
Environmental Consultant
704 Ainapo Street
Honolulu, Hawaii 96825

SUBJECT; Mitigation effects on storm water runoff quality and quantity for Lihi Lani Recreational Community

The hydraulic, nitrogen, phosphorus, and suspended solids loads that I determined for the Lili Lani Recreational Community, Pupukea, Oahu, entitled "Environmental Aspects of Storm Water Runoff, December, 1990," were based on unrestricted storm water runoff conditions. The numerous mitigation measures that are being proposed for the project should significantly reduce the calculated constituent loads as well as maintaining the individual storm water runoff volumes at or below pre-project conditions (1990).

Notably the use and timely application of slow release fertilizers will decrease their potential discharge into storm water runoff, which is particularly significant if a major storm occurs shortly after application. The utilization of on-site detention and retention basins, waste bunkers and grass swales, artificial marshes, and diversion of storm water runoff to golf course areas will not only retain the volume of runoff and promote percolation, but will also increase the deposition of suspended solids (sediment), of which phosphorus and the unoxidized forms of nitrogen (ammonia and organic) may be adsorbed upon. In addition these conditions will enhance the chance of storm water contact with bare soil, which is particularly effective in unoxidized nitrogen and phosphorus removal, and/or nutrient (nitrogen and phosphorus) uptake by vegetation in the drainage path. The proposed injection wells on the makai side of the property, fronting Kamehameha Highway, will also decrease storm water runoff volume and associated constituent loads.

Although the reduction of the overall constituent loads resulting from the mitigation facilities and measures being proposed for the project can not be easily quantified they will undoubtably significantly decrease the output of the constituent load that I originally determined for the project under unrestricted (no mitigative measures) storm water runoff conditions.

APPENDIX I

ENVIRONMENTAL ASSESSMENT

OF

FERTILIZER, HERBICIDE AND PESTICIDE USE

ON THE PROPOSED

LIHI LANI GOLF COURSE

A REPORT TO

Group 70, Inc.

December 17, 1990

PREPARED BY

Charles L. Murdoch, Ph. D

Richard E. Green, Ph. D.

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SUMMARY AND CONCLUSIONS

The proposed Lihi Lani Golf Course consists of 18 holes and attendant facilities mauka of Sunset Beach. The elevation of the area varies from about 400 feet to 650 feet. Most of the area consists of ridges and gulches, with some reasonably level land on the central ridge where the clubhouse will be located. Considerable earth moving will be required in construction of the golf course; graded areas will require stockpiling or importation of good soil for turf establishment and protection from pesticide leaching.

The upland soils on which the golf course would be located are well developed Ultisols and Alfisols with reasonably deep profiles and substantial organic matter (up to 3% in the surface horizon). They are moderately permeable and thus are expected to contribute recharge to the underlying aquifer when rainfall exceeds evapotranspiration during the months November through March. Areas planted to turf and treated with fertilizers and pesticides must have a sufficient depth of good soil (perhaps a minimum of 1 foot depth) to provide good water retention and retard the movement of pesticides. Imported soil should have an organic carbon content of at least 1.5% and adequate hydraulic conductivity to sustain an infiltration rate of 0.5 in./hr. for several hours.

The groundwater aquifer which receives recharge from the development area is likely to be important for domestic water supply in the Sunset Beach area in the future. Thus it must be protected from contamination by fertilizers and pesticides applied to a golf course. Of the pesticides typically used on golf courses in Hawaii in sufficient quantities to be considered, only metribuzin would be expected to move below the root zone. The typical amount of metribuzin used is small, only about 87 pounds annually on the entire golf course. This is not enough to cause concern in view of its fairly rapid degradation and low toxicity (EPA Health Advisory Level of 200 µg/L). Of the fertilizer elements typically used in golf course management, nitrogen is the only constituent of concern which is sufficiently mobile and persistent and is applied in sufficient quantity to leach to groundwater in measurable amounts. Nitrogen leaching will be mitigated by the reasonable management practices called for in this report, including carefully controlled water and nitrogen application, and reduced nitrogen application and/or use of controlled-release nitrogen sources during periods of high rainfall. Natural recharge is sufficiently high during the winter months to warrant special caution in the application of both water and chemicals during this period.

Movement of chemicals in surface runoff could result if soils are too shallow, lack sufficient permeability, or have insufficient organic matter. Most runoff from the site will enter Punamalu Stream where it will mix with

a substantial amount of flow from higher elevations outside the development area. Mixing with turbulent shoreline waters will effect further dilution, resulting in negligible impact on the quality of coastal waters.

Our analysis suggests no adverse impact on air quality or on birds which may frequent the area.

Other mitigating practices which will contribute favorably to the safe use of fertilizers and pesticides on the golf course are suggested in the recommendations which follow.

RECOMMENDATIONS

- Areas to be planted to turf and therefore treated with fertilizers and pesticides will require considerable earth moving. Graded areas should be covered with 12 inches or more of soil having good water permeability and an organic carbon content of 1.5% or higher.

- Irrigation management is critical, especially in view of the relatively high natural recharge during winter months. If excessive irrigation water is applied, the likelihood of nitrate movement to groundwater or runoff to streams in the area is increased. For this reason we recommend that either computerized environmental monitoring instruments or a U. S. Weather Bureau class A evaporation pan be used to estimate evapotranspiration and schedule irrigation application in the management of the proposed golf course. Excellent discussion of irrigation scheduling can be found in the book Golf Course and Grounds Irrigation and Drainage (Jarret, 1985).

- Judicious use of pesticides and fertilizers is essential, especially in the early establishment of turf since pesticides and nitrogen will be more likely to move before an extensive root system and thatch layer are developed. Reduced applications during the winter months is advisable. An Integrated Pest Management Program (IPM) should be used in which all possible means of controlling pests are employed in an integrated program. IPM is designed to reduce, although not eliminate, the use of chemical pesticides.

- As nitrogen has the greatest potential for movement to groundwater, special attention should be paid to this element. Either fertigation, whereby a small amount of soluble nitrogen is applied through the irrigation system and turf is watered only when needed, or slow-release N sources, such as IBDU, ureaformaldehyde, sulfur coated soluble fertilizers, etc, should be used to reduce the potential for leaching of fertilizer N to groundwater.

- A groundwater monitoring program should be implemented to assess nitrate levels before, during, and after golf course construction . Board of water supply wells 4002-04 and 4002-05 pump from the Kawailoa basal aquifer that may receive recharge from the proposed golf course.

- Adequate buffer space, with tall vegetation, should separate the golf course from housing areas, the clubhouse, and other public areas.

- As our conclusions are based on the assumption that sound management practices will be followed with regard to fertilizer and pesticide application and irrigation, we recommend that a well qualified Golf Course Superintendent (preferably a Certified Golf Course Superintendent) be given the responsibility of managing the golf course.

I. INTRODUCTION

The proposed Lihi Lani Golf Course will require application of fertilizers to supply essential nutrients to turfgrasses and ornamental plants, and limited amounts of pesticides to control their associated weed, disease, and insect pests. The term pesticide, used in its generic sense in this report, includes herbicides, fungicides and insecticides. The assessment provided in the report focuses principally on the potential for applied chemicals to move in surface runoff and to groundwater. Additionally, the potential for pesticide transport in the air and potential for negative impact on birds in the area are addressed briefly in the appendices. The toxicity and environmental behavior of pesticides which are likely to be used are considered in the analysis, as are soil, topographic and climatic factors which may impact on fertilizer and pesticide movement.

II. APPROACH

Key elements of the analysis are (1) calculation of quantities of applied chemicals (pesticides and fertilizer nutrients) which are likely to be used throughout the year, assuming the use of an IPM program, (2) compilation of soil, geologic and climatic information which will aid in the assessment of chemical movement, (3) estimation of water balance from rainfall, irrigation and evapotranspiration, (4) compilation of pesticide properties which may be of environmental significance, and (5) computation of the Attenuation Factor for pesticides used on golf courses, using properties of the chemicals and soil properties, in order to estimate the likelihood of chemical movement to groundwater.

Information on the layout of the golf course was provided by Group 70. Soil maps and associated soil survey publications provided information required for an assessment of infiltration and runoff potentials, as well as soil organic carbon contents. Published rainfall and evaporation data in the area provided an estimate of groundwater recharge with turf cover. Anticipated use of chemicals in golf course management is based on our own recommendations, and pesticide properties were obtained from published reports.

II. ANALYSIS OF RELEVANT FACTORS WHICH MAY IMPACT ON CHEMICAL MOVEMENT

A. Site Factors

1. Physical Setting and Soils

The Lihi Lani project area is located on the north-west slopes of the Koolau mountains on Oahu, just mauka of Sunset Beach. It is bounded on

the southwest by Kalunawaikaala Stream and on the northeast by Paumalu Stream, approximately. The northeast and south portions of the property are divided by Pakulena Stream. The proposed golf course is located on the upland area between Pakulena and Paumalu Streems (see Appendix Figure 1). The mauka end of the golf course is dissected by Kaleleiki Stream, which is a tributary to Paumalu Stream. None of theses streams is perennial. The golf course would likely provide runoff to Kaleleiki, Paumalu, and Pakulena Streams during periods of high rainfall, and runoff would reach the ocean through Paumalu and Pakulena Streams.

The elevation of the golf course varies from about 400 to 650 feet above sea level. The area is highly dissected, with some relatively level areas mixed with areas having slopes exceeding 25%. The soils are formed from basic igneous rock and are generally quite permeable. The principal soil series are the Manana silty clay, Paumalu silty clay (both Orthoxic Tropohumults) and Kemoo silty clay (Oxic Rhodustalfs). The soil distributions are shown in Appendix Figure 1, and their slopes and percentages of the total area in the golf course are given in Table 1. Dominant features of these soils include oxidic mineralogy, well structured and highly permeable surface horizons, and moderately high organic matter. Organic carbon data for the Manana soil (Soil Conservation Service, 1976) indicate organic carbon contents of about 3% in the top 20 cm, then decreasing with depth to about 1% at 60 cm and 0.4% at 150 cm. All the soils should have similar organic matter percentages in the profile, except where natural erosion has removed top soil. Very little of the area shows current severe erosion, probably because of adequate vegetative cover. No single soil type dominates the entire golf course area, as indicated by the approximate percentages occupied by each soil in Table 1.

Table 1. Soil types and approximate areas of each in the proposed golf course in Lihi Lani Recreational Community

Map symbol	Series & slope	Classification	Approximate % of total area
MpB	Manana silty clay 3-8%	Orthoxic Tropohumult	10
MpC	Manana silty clay 8-15%	Orthoxic Tropohumult	17
MpD	Manana silty clay 15-25%	Orthoxic Tropohumult	5
MpE	Manana silty clay 25-40%	Orthoxic Tropohumult	5
KpB	Kemoo silty clay 2-6%	Oxic Rhodustalfs	5
KpC	Kemoo silty clay 6-12%	Oxic Rhodustalfs	5
KpD	Kemoo silty clay 12-20%	Oxic Rhodustalfs	5
PeB	Paumalu silty clay 3-8%	Orthoxic Tropohumult	8
PeC	Paumalu silty clay 8-15%	Orthoxic Tropohumult	8
PeD	Paumalu silty clay 15-25%	Orthoxic Tropohumult	12
PZ	Paumalu-Badland complex 10-70%		20

2. Climate and Hydrology

Mean annual rainfall for the Lihi Lani area is approximately 50 to 60 inches (Giambelluca, et al., 1986). Mean pan evaporation for the area is approximately 70 to 80 inches per year. Mean monthly rainfall varies from about, 6 inches in November, December and January to about 3 inches in June. Mean monthly pan evaporation from the nearest weather station with evaporation data (State Key No. 892, Waimea 3, 420 feet elevation) varies from approximately 8 inches in August to about 4.4 inches in December and January (Figures 1 and 2). With careful irrigation there should be no net recharge of water. There are seasons of the year and occasionally weeks within all seasons, however, when rainfall is insufficient to meet water requirements of the turfgrass and irrigation will be required. Very careful irrigation scheduling (timing of application and amount applied) will be necessary in order to minimize recharge of groundwater. We recommend scheduling irrigation based on a water budget calculated from pan evaporation data (discusses in greater detail in section B-3).

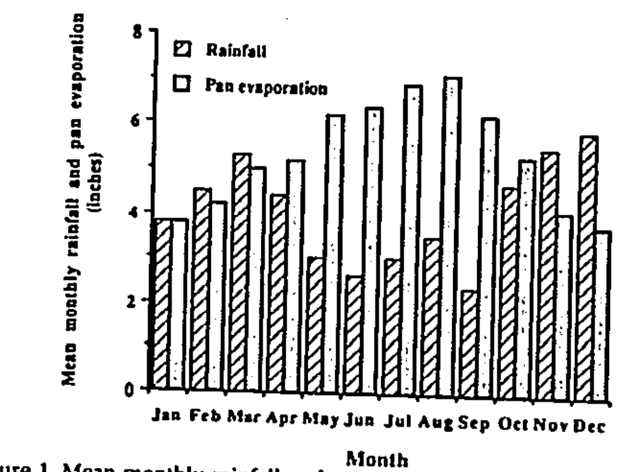

Figure 1. Mean monthly rainfall and mean monthly pan evaporation for the Lihi Lani area (Ekern and Chang, 1985; Giambelluca et al., 1986).

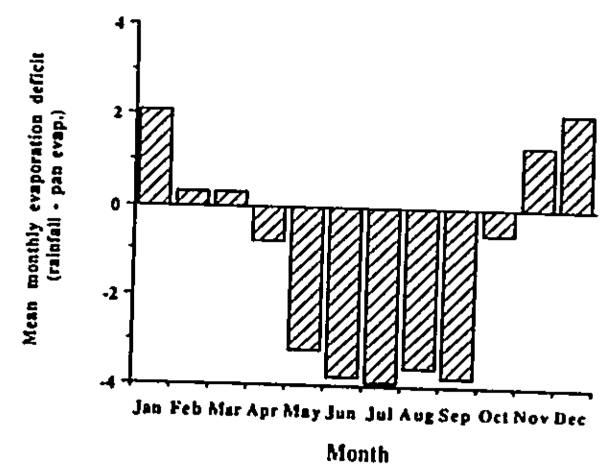

Figure 2. Rainfall minus pan evaporation for the Lihi Lani area (Ekern and Chang, 1985; Giambelluca et al., 1986).

The groundwater aquifer which could be impacted by the proposed development is identified and classified by Mink and Lau (1987). The aquifer code, 30403111, indicated that the aquifer is in the Kawailoa System of the North Sector of Oahu. The status code indicated that the aquifer is currently used for drinking water, is irreplaceable and is highly vulnerable to contamination.

B. Management Factors

1. Fertilizers

Fertilizers are applied to golf courses to supply those essential nutrients which are used in large amounts and which are deficient in most soils. In typical soils, the elements which are normally applied in a turfgrass fertilization program are nitrogen (N), phosphorus (P), and potassium (K). Fertilizers are normally applied to only the greens, tees, fairways, and part of the roughs of a golf course. Typical areas in these types of turfgrasses are estimated in the discussion below.

Turfgrasses use much more N than other elements. Based on turfgrass clipping composition, it has been shown that the turfgrasses grown in Hawaii use about twice as much N as K and about four times as much N as P.

The primary fertilizer elements of concern for contamination of ground and surface waters are nitrogen and phosphorus. Phosphorus is attached very tightly to iron and aluminum hydroxides which are plentiful in the soil of this location and moves little if any from the site of application. Phosphorus, therefore will not cause any problem with contamination of drainage water. Ammonium nitrogen (NH_4) likewise moves little in soils. Nitrogen applied in the ammonium form, however, is rapidly converted to the nitrate form (NO_3) which is not bound to the soil and moves readily with water. Because of high N uptake by turfgrasses, however, nitrogen will be used rapidly after application. Only under conditions where rainfall occurs soon after application of a soluble nitrogen source would there be loss by surface runoff or by leaching below the root zone. Thus nitrogen movement could be avoided by applying a slow-release nitrogen fertilizer. These include isobutyldienediurea (IBDU), ureaformaldehyde (UF), and sulfur-coated soluble fertilizers. A study by Brown et al. (1982) on highly porous sand golf greens in Texas compared the amount of nitrogen lost by leaching from various nitrogen sources. Irrigation was applied at relatively high rates to provide leaching opportunity. Results of their study showed that over a five-month period, approximately 23% of the nitrogen applied as a soluble N source (ammonium nitrate) was leached. Only 1.4% of the N applied as IBDU and 1.5% as UF leached.

Fertilizer use rates for the different golf course areas are shown in Table

2. Complete fertilizers (ones containing N, P, and K) are usually applied. Because nitrogen is applied in larger quantities and also because it is the only fertilizer element likely to cause contamination of ground or surface waters, only nitrogen application rates are given.

Table 2. Approximate fertilizer use rates for different areas of the Lihi Lani golf course (areas are estimates supplied by Group 70, Inc.)

Type of turf	Area (acres)	Fertilizer amount (lb. N/1000 sq. ft.)	Application frequency	Total annual application (tons N)
Greens	4	0.5	2 weeks	1.13
Tees	4	1.0	3 weeks	1.51
Fairways	46	1.5	8 weeks	9.77
Roughs	36	1.0	3 months	3.14
Total	90			15.55

2. Pesticides

There are a number of weed, insect and disease pests of turfgrasses in Hawaii, making it impossible to maintain high-quality turf without using pesticides. They are normally applied only in response to outbreaks of pests.

A typical pesticide program for golf courses in Hawaii is given in Table 3 below. This table gives our estimation of typical pesticide use on golf courses in Hawaii, not using an IPM approach to pest management. The Lihi Lani golf course will use an IPM program. Because it is an IPM program does not eliminate the use of pesticides, it is not possible to predict exactly how often pesticides will need to be applied. Pesticide use in an IPM program is normally 25 to 50% less than if IPM is not used. The amounts of pesticides in Table 3 are for reference only. The actual amount applied will likely be less.

There are several chemicals which may be substituted for certain ones in this suggested program. Properties of the chemicals listed in Table 3 (Hartley and Kidd, 1983), as well as those of other chemicals used in turf in Hawaii, are given in Appendix Table B-1. These tables do not include a complete list of all chemicals labeled for use on turf in Hawaii. In practice, however, any given golf course will use no more than one-half dozen or so of these chemicals over a period of a few years. All pesticides used in golf course management must be approved by the U. S. Environmental Protection Agency (EPA) and the Hawaii State Department of Agriculture. The safety of golfers, as well as possible environmental effects, are considered by EPA in granting registration of pesticides for use on golf courses.

Table 3. A typical pesticide program for an 18-hole golf course in Hawaii with areas equal to estimates for the Lihi Lani golf course.

Turfgrass area	Area (acres)	Chemical	No. appli. per year	Rate (ai./appli.)	Annual total
I. Herbicides					
A. Greens	4	MSMA	6 times/year	2 lb.. ai/acre	48 lb. ai
		bensulide	2 times/year	12 lb ai/acre	96 lb. ai
B. Tees	4	MSMA	6 times/year	2 lb. ai./acre	48 lb. ai
		Trimec®	3 times/year	1 pint/acre	12 pints
		bensulide	2 times/year	12 lb. ai./acre	96 lb. ai
C. Fairways	46	MSMA	6 times/year	2 lb. ai./acre	552 lb. ai
		Trimec®	3 times/year	1 pint/acre	17 gal.
		metribuzin	2 times/year	0.75 lb. ai./acre	69 lb. ai.
D. Roughs	36	MSMA	2 times/year	2 lb. ai./acre	144 lb. ai
		metribuzin	1 time/year	0.5 lb. ai./acre	18 lb. ai.
II. Insecticides					
A. Greens	4	chlorpyrifos	As needed	1 lb. ai./acre	24 lb. ai.
B. Tees	4	chlorpyrifos	As needed	1 lb. ai. acre	24 lb. ai.
C. Fairways	Spot treatments	chlorpyrifos	As needed	1 lb. ai./acre	50 lb. ai.
III. Fungicides					
A. Greens	4	metalaxyl	As needed	1.3 lb. ai./acre	33 lb. ai.
		chlorothalonil	As needed	8 lb. ai./acre	96 lb. ai.
B. Tees	4	metalaxyl	As needed	1.3 lb. ai./acre	33 lb. ai.
		chlorothalonil	As needed	8 lb. ai./acre	96 lb. ai.
C. Fairways	Spot treatments	chlorothalonil	As needed	8 lb. ai./acre	250 lb.ai.

3. Irrigation

Because rainfall is not uniformly distributed throughout the year, all golf courses are irrigated to supplement rainfall. Golf courses usually have permanent sprinkler irrigation systems with sophisticated control systems. Many are computer controlled, so that each sprinkler head on the golf course can be adjusted to apply a selected amount of water on each cycle.

Irrigation requirements of plants can be calculated from pan evaporation (PE) and rainfall (R) data if the water use requirement (transpiration plus evaporation) of the crop being grown is known. The water use requirement of warm-season turfgrasses is approximately 50% of pan evaporation (Handreck and Black, 1984). Irrigation systems are never completely efficient. If one assumes a 90% efficiency of water application, then

irrigation requirement can be calculated as (0.6 PE) - R. Water use requirement for warm-season turfgrasses was calculated for the Lihi Lani site from pan evaporation (Ekern and Chang, 1985) and rainfall (Giambelluca et al., 1986) data, assuming 90 acres of the golf course will be irrigated. Based on these data, average monthly irrigation requirements range from zero in November, December, January, February and March to over 9 million gallons in June, July, and September (Figure 3). The total annual irrigation requirement for the Lihi Lani area, calculated on the water budget method, averages approximately 48 million gallons. This is considerably less than the commonly cited one million gallons per day required for golf courses in Hawaii. Murabayashi (1989) reported that irrigation amounts for 11 golf courses in the State varied from 0.0023 million gallons per day per acre (mgd/acre) to 0.011 mgd/acre, a 478% difference. Average water use for the 11 golf courses was 0.006 mgd/acre. Based on Murabayashi's data, the average 90 acre golf course would require approximately 0.54 million gallons of water per day or 197 million gallons per year. The water budget method appears to be a more logical method of determining irrigation requirements, as it is apparent that there are differences in irrigation requirements between areas with different rainfall and evaporation amounts. Since the figures used here are long term averages, day to day (or year to year) irrigation needs may be much different, however, long term averages should predict the average irrigation needs. Daily irrigation scheduling will have to be done using current data.

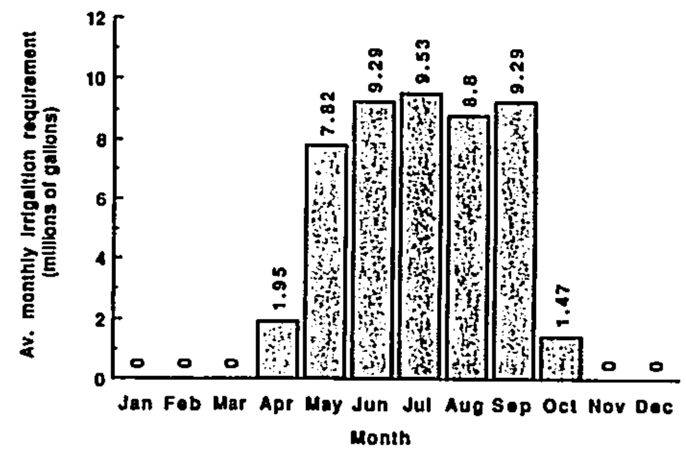

Figure 3. Mean monthly irrigation requirements for warm-season turfgrasses in the Lihi Lani area (based on 90 acres of irrigated area).

Irrigation practices may have a large influence on the movement of soluble nitrogen fertilizers in soils. If excessive irrigation water is applied soon after application of soluble nitrogen sources, the likelihood of runoff or leaching of nitrogen below the root zone is increased. From the above it is apparent that basing irrigation amounts on calculated water use is a much more efficient method of water utilization than is currently being practiced. The data reported by Murabayashi (1989) was from golf courses in areas ranging from very arid (the Kona Coast, Keihi) to relatively wet (Princeville). Basing irrigation scheduling on water use rates will not only result in large savings of water compared to present practices, but will also reduce the likelihood of chemicals being leached from the rootzone.

IV. POTENTIAL FOR CHEMICAL MOVEMENT TO GROUNDWATER AND SURFACE WATERS

A. Issues of Concern and the Scope of this Assessment

The principal issue addressed in this report is the potential for movement of fertilizers and pesticides to groundwater and surface waters.

The presence of agricultural chemicals in groundwaters at many locations in the State (Honolulu Star Bulletin, Aug. 13, 1989) is reason for caution in the use of chemicals in recreational areas such as parks and golf courses as well as in agriculture. It is important to recognize, however, that detection of a chemical in water bodies, even in potable water, does not necessarily constitute a health hazard as defined by the U. S. Environmental Protection Agency (EPA). In an effort to assist federal, state and local officials in responding to drinking water contamination, the EPA has set "Lifetime Health Advisory" levels (concentrations in drinking water) for many chemicals. EPA estimates these levels after reviewing available human data and experimental animal studies to evaluate potential human health effects. The Health Advisories are considered tentative and are updated as new information becomes available. Some agricultural chemicals which have reached groundwater in Hawaii, for example nitrate from fertilizers and the herbicide atrazine, have been detected at many locations in the State, but seldom are at a concentration considered a threat to human health. Also, Health Advisory Levels (HAL) vary widely for different chemicals: for nitrate the level is 10 milligrams per liter of water while for atrazine it is 3 micrograms per liter. Thus for these two chemicals, the HAL's differ by a factor of 3,333. The relative oral toxicity of a number of pesticides registered for use in golf courses, given in Appendix Table 1, reflect the wide range of toxicities obtained in animal feeding studies.

In the assessment which follows, we attempt to evaluate the potential for groundwater and surface water contamination by chemicals which might be applied to the proposed Lihi Lani Golf Course. Our assessment does not

include an estimate of the chemical concentration in waters (if a chemical is likely to move) or of human exposure or risk. Useful estimates of health risk are not possible when concentrations of chemicals in water are not known. However, when the evidence indicates the likelihood of no contamination or of concentrations well below the Health Advisory Level, further analysis of health risk is neither possible nor appropriate.

B. Potential impact on groundwater

Because the area treated with pesticides on a golf course is small, the total amount of pesticide applied is relatively small also. The pesticides used in golf course management are mostly of low toxicity (Appendix Table B-1). Most are either rapidly degraded in soil and/or are sorbed tightly to organic matter or soil colloids and move little from the site of application. The pesticides in Appendix Table 1 which are most likely to move below the root zone are metribuzin, mecoprop, dicamba, simazine, and trichlorfon. The relative mobility of these chemicals can be quantified by computation of the Attenuation Factor (AF) of each chemical for an appropriate set of conditions. Attenuation of chemical movement by the soil includes both retardation of movement due to sorption on soil organic matter and degradation in the soil by both biological and chemical pathways. The AF numerical index (Rao et al., 1985) is presently being evaluated (Khan and Liang, 1989; Loague et al., 1989) for use in an assessment methodology which the State of Hawaii will use in pesticide regulation. The AF index can have numerical values from AF = 0 (total attenuation) to AF = 1 (no attenuation). By definition, AF is the fraction of chemical remaining in the soil after a single application when the recharge is sufficient to carry the chemical to the bottom of a soil layer of a given depth (for example, 50 cm). For soil and water recharge conditions of practical interest in Hawaii, AF values for the five chemicals which are most likely to move beyond a depth of 50 cm are shown in Table 4. AF values range from 2.1×10^{-6} for simazine (lowest contamination potential) to 7.1×10^{-3} for trichlorofon (highest contamination potential). For comparison, DBCP which was used for 25 years in pineapple and has contaminated groundwater at many locations, has AF = 4.6×10^{-1}, indicating a much higher likelihood for DBCP movement to groundwater than any of the chemicals listed in Table 4. Also, the total amounts of chemicals in Table 4 which are used on golf courses are relatively small. Trichlorfon is not used in Hawaii to our knowledge, although it is labeled. Mecoprop and dicamba are components of the herbicide Trimec®. Total annual mecoprop and dicamba application for the golf course will be approximately 10 and 2.5 pounds, respectively. The total amount of metribuzin applied will be approximately 87 lb. annually. Simazine is used on few golf courses in Hawaii. If used, simazine application would not exceed 100 lb. annually for the entire golf course.

Table 4. Attenuation factors (AF) for the most mobile pesticides used on golf courses.†

Pesticide	AF
Metribuzin	3.5×10^{-6}
Mecoprop	1.3×10^{-3}
Dicamba	7.1×10^{-5}
Simazine	2.1×10^{-6}
Trichlorfon	7.1×10^{-3}

†Based on the following conditions: soil organic carbon content = 1.5%; soil bulk density = 1.2 g/cm³; soil water content = 35% by volume; water recharge = 0.1 cm/day; depth of penetration = 50 cm.

The soils in the Lihi Lani golf course area are fairly similar in their capacity to retard chemical movement. All are relatively rich in organic matter and thus would retard pesticide movement quite well. If earth moving is done to utilize steeper areas for the golf course, then soil having about 1.5% organic carbon would have to be imported to cover the leveled areas for adequate turf establishment and groundwater protection.

Chemical leaching is usually of greatest concern in areas of high water recharge. Rainfall and evaporation data in Figures 1 and 2 suggest that excess rainfall over evaportranspiration will be available for groundwater recharge or runoff about 5 months each year. Gentle rains over longer periods would be most effective for recharge, while high-intensity, short-duration storms would contribute most to runoff. Thus it is difficult to estimate the partitioning of rainfall into recharge and runoff. Even so, this area likely contributes to the recharge of the Kawailoa aquifer system, and potential leaching of chemicals is a legitimate concern. Land grading will likely be required on presently steep areas; such areas would be highly susceptible to chemical leaching unless a topsoil which is rich in organic matter is stockpiled and peplaced after grading to cover low-organic matter subsoils.

The importance of the Kawailoa groundwater aquifer as a drinking water source is a major consideration in this assessment. It is doubtful that any of the chemicals used on the golf course would reach the aquifer in sufficient concentration to adversely affect human health. Nitrate and metribuzin are the two chemicals most likely to move. It is doubtful that the small amount of metribuzin used on golf courses would contribute a measurable amount to the groundwater and the contribution of nitrate from fertilizer may be small relative to background nitrate present in the aquifer. Use of slow-release N sources will substantially reduce the likelihood of nitrate leaching. If small quantities of fertilizer nitrate did reach the aquifer, it

would not likely increase the level sufficiently to be of concern to human health; the nitrate Health Advisory Level (HAL) is 10 mg/L. The metribuzin HAL is 200 µg /L; detection at even 1 µg/L in aquifer water is unlikely.

C. Potential impact on surface water quality

The relatively steep topography of the area (Appendix Figure A-1 and Table 1) is conducive to rapid runoff during medium to high intensity rainfall. Runoff from the golf course will flow principally to Paumalu Stream to the north east, and will contribute less to Pakulena Stream to the south west. Both of these streams discharge into coastal waters off Sunset Beach. Paumalu Stream is a major drainage way to which thousands of acres of watershed in the Koolau Mountains contribute runoff. This suggests that chemicals in runoff from a golf course would be highly diluted in Paumalu Stream. With the present topography, some transport of chemicals in runoff and subsequently into the streams is very likely, despite management efforts to contain runoff. Use of slow-release nitrogen fertilizers should reduce nitrogen transport to acceptable levels. Pesticide transport in runoff would probably occur on occasions when medium to high intensity rainfall occurs soon after pesticide application. Data in Figures 1 and 2 suggest that the most likely months for runoff would be November through March. Management of chemicals during this period would be particularly critical. Considering dilution effects and the dynamic mixing of the coastal receiving waters, it is doubtful that chemicals in runoff from the Lihi Lani Golf Course would significantly alter the quality of shoreline waters. Erosion control during golf course development is a much more significant problem.

C. Impact on Migratory Birds and Endangered Hawaiian Waterbirds.

See Appendix C.

D. Impact on Air Quality.

See Appendix D.

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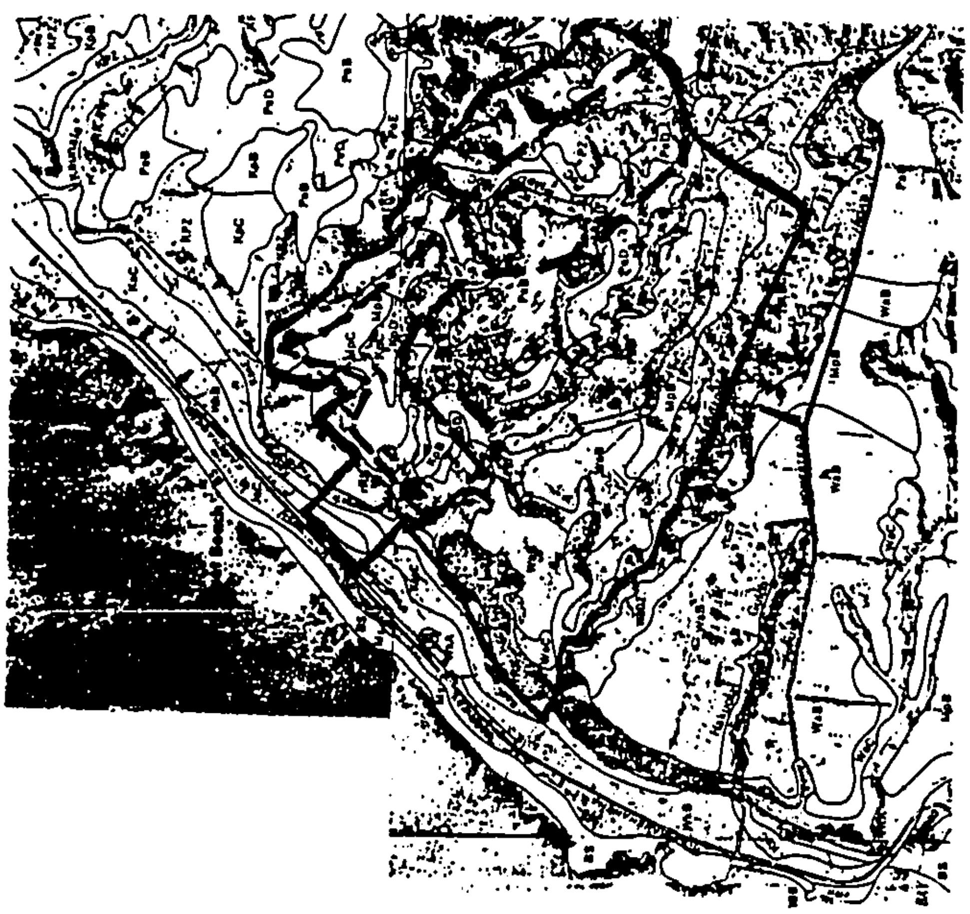
APPENDICES

Appendix Table 8-1. Properties of pesticides used on turf in Hawaii.

Pesticide common name	Trade name (s)	Oral LD-50 (mg/kg body wt)*	Toxicity to fish and wildlife*	Soil sorption index (Koc)**	Water solubility (mg/l)**	Half-life in soil (days)**	Leaching potential**
I. Herbicides							
MSMA	WeedHoe etc.	1800	Low	10000	1000000	100	Small
glyphosate	Roundup, Kleenup	150	Mod. to birds, none to fish	10000	1000000	30	Small
metribuzin	Sencor	2200	Moderate	41	1220	30	Large
2,4-D	part of mixtures	370-700	High to fish	109	300000	10	Medium
mecoprop	ditto	700-1500	Low	3	660000	21	Large
dicamba	ditto	1000-2000	Non toxic to fish	2	800000	14	Large
oryzalin	Surflan	10000	Mod. to birds, toxic to fish	2700	2.5	60	Small
oxadiazon	Ronstar	8000	Toxic to fish		0.7		
propyzamide	Kerb	5620-8350	Low	990	15	30	Small
simazine	Princep	>5000	Low	138	3.5	75	Large
chlorthal-dimethyl	Dacthal	>3000	Low	5000	0.5	30	Small
bensulide	Betasan, Betamec	770	Mod. to fish	10000	25	60	Small
paraquat dichloride	Ortho Paraquat CL	150	Mod. to birds, none to fish	100000	1000000	3600	Small
benfluralin	Balan	10000	Low to birds, high to fish	11000	0.1	30	Small
II. Insecticides							
chloropyrifos	Dursban	135-163	High	6070	2	30	Small
bendiocarb	Ficam	40-156	High				
carbaryl	Sevin	400-850	Moderate	229	40	7	Small
trichlorfon	Dylox	450-630	Moderate	2	154000	27	Large
III. Fungicides							
anilazine	Dyrene	<5000	Low	3000	10	1	Small
benomyl	Benlate	9590	Low	2100	2	100	Small
chlorothalonil	Daconil 2787	>10000	Low to birds, mod. to fish	1380	0.6	20	Small
iprodione	Chipco 26019 RP	3500	Low	500	13	20	Small
mancozeb	Dithane M-45	>8000	Low	1000	0.5	35	Small
quintozene	PCNB, Terrachlor	12000	Non-toxic	1000	0.44	21	Small
thiram	Tersan	7500	Low	383	30	20	Medium
triadimefon	Bayleton	568	Low	273	260	21	Medium
metalaxyl	Subdue	669	Non-toxic	16	7100	7	Medium
thiophanate-methyl	Cleary 3336	7500	Low	1000	3.5	0	Small

*From: Hartley, Douglas and Hamish Kidd (Eds.) 1983. The Agrochemicals Handbook. Unwin Bros., Ltd. Old Working., Surrey, England.

**From: Wauchope, R. D. 1988. U. S. D. A.-ARS Interim Pesticide Properties Database, Version 1.0. Unpublished



Appendix Figure 1. Approximate boundaries of Lihi Lani Recreational Community (exterior solid line) and golf course (interior dashed line) on soils map (from Foote, et al., 1972). Approximate areas of each soil and the soil classification are given in Table 1.

Appendix Table B-2. Toxicity classes of pesticides.

Class	Description	Warning Statement	Oral LD50
1	Highly Toxic	Poison, Skull & Crossbones	1-50
2	Moderately Toxic	Danger	51-500
3	Low Toxicity	Warning	501-5,000
4	Very Low Toxicity	Caution	>5,000

APPENDIX C

IMPACT ON MIGRATORY BIRDS AND ENDANGERED HAWAIIAN WATERBIRDS.

The fertilizers, herbicides, and fungicides used in golf course maintenance pose little or no hazard to birds frequenting the grassed areas or ponds associated with golf courses. Fertilizers are relatively non-toxic unless ingested in large amounts. All herbicides and fungicides used in golf course maintenance in Hawaii are of low to moderate toxicity (Appendix Table 1). The only chemicals used in golf course maintenance in Hawaii which are highly toxic to birds are the organic phosphate insecticides, especially chlorpyrifos.

Although chlorpyrifos is toxic to birds, it is strongly adsorbed on the thatch layer of turf and moves little from the site of application. One reason for its weakness in controlling soil infesting insects is the inability to get the insecticide through the thatch layer to the depth needed to contact these insects. Recent studies (Sears and Chapman, 1980; Tashiro, 1980) have shown that chlorpyrifos applied to turfgrasses does not penetrate more than 2 to 3 centimeters in the soil. In addition to resistance to movement in the soil, it has been shown that it is rapidly degraded in the soil, both by hydrolysis and microbial action (Miles et al. 1979).

Because of the adsorption of organic phosphate insecticides on organic layers in turf and their rapid break down, there is little chance of their movement from grassed areas into the ponds associated with the proposed golf course. Label instructions for application of these pesticides (which turfgrass managers are required by law to follow) specifically prohibit their direct application to streams and ponds.

The likelihood of bird injury by pesticides used in maintenance of the proposed golf course can be reduced by proper application of pesticides with reduced toxicity to birds. Appendix Table 1 shows that carbaryl and trichlorfon are less toxic to birds than chlorpyrifos. In most cases these insecticides may be substituted for chlorpyrifos with little loss of effectiveness.

Golf courses are frequently visited by birds. As far as we are aware, there have been no reported incidents of bird kill in Hawaii from chemicals applied in golf course management. Waterfowl and fish appear to thrive in ponds and water hazards on golf courses in Hawaii. Many golf courses cultivate white amur fish in the ponds to control algae. Mosquito fish are generally stocked to prevent mosquito problems. We are aware of no incidents of fish or waterfowl injury from chemicals applied to golf courses.

The labeling of herbicides and pesticides by EPA for particular uses, enforced by the Hawaii Department of Agriculture, is perhaps the best assurance of protection of humans and wildlife from their hazards. All pesticides must be applied in compliance with federal and state laws regulating their use. Hazards to both humans and wildlife are included in the decision to label a pesticide for specific uses, including use on golf courses, and in developing regulations on allowable application procedures of the pesticide for various uses.

APPENDIX D

IMPACT ON AIR QUALITY

Most herbicides and pesticides used on golf courses are of relatively low mammalian toxicity, with LD_{50} values ranging from hundreds to several thousand mg/kg body weight (Appendix Table 1). None of the chemicals listed in Table 2 above are highly volatile. A measure of volatility is the vapor pressure (VP). The compounds used in highest quantity, for which vapor pressure data is readily available, are chlorothalonil (VP=1.3×10^{-5} atm at 25° C) and chlorpyrifos (VP=2.4×10^{-8} atm at 25° C). In comparison, DBPC, which is known to be volatile, has a vapor pressure of 1.2×10^{-3} atm at 21° C, i.e. at least 100 times the vapor pressure of chlorothalonil and 100,000 times the vapor pressure of chlorpyrifos. In addition, pesticides are applied on golf courses in dilute sprays (50 to 100 gallons of spray solution per acre) to open areas. For these reasons there is little likelihood of volatility once the pesticides are applied.

If properly applied, there is also little potential for drift of spray particles from golf course spray equipment. The greatest danger of significant drift of pesticides is from aerial application. Golf course pesticides are applied with ground spray equipment. Boom height of spray equipment is less than one meter. Low spray pressures (20 to 40 psi) and coarse spray droplets further reduce the hazard of airborne fine droplets. Droplets larger than 100 micrometers diameter are not highly subject to drift.

Most of the spray volume from typical flat-fan nozzles used in agricultural spray equipment is from droplets larger than 100 micrometers. Table D-1 below shows a typical distribution of droplet sizes for a flat-fan nozzle (the type used in most golf course spray equipment). At the low concentrations used in pesticide application, this would not result in significant quantities of pesticides being carried downwind. High wind speed would increase the likelihood of drift of fine spray droplets, however, because high wind speed distorts spray patterns and results in poor coverage; spraying in periods of high wind is not common practice. Table D-2 below shows the percent of spray application volume deposited at 4 and 8 feet downwind and the distance downwind for the volume to drop to 1% or below for flat-fan nozzles under different conditions. Even under high wind conditions (almost 10 mph) and spraying at 40 psi, the distance downwind at which 1% or less of the total spray volume was deposited was only 17 feet.

Appendix Table D-1 Droplet size range for a typical flat-fan nozzle at 20 and 40 psi. (from Hofman et al., 1986)

Droplet size range (microns)	Percent of spray volume 20 psi	40 psi
0-21	0.1	0.4
21-63	3.0	10.4
63-105	10.7	20.1
105-147	16.2	25.4
147-210	36.7	35.3
210-294	27.5	7.7
>294	5.8	0.7

Appendix Table D-2. Percent of spray volume deposited at 4 and 8 feet downwind and the distance in feet for the volume of spray solution to drop to 1% of the total spray volume (from Hofman et al., 1986).

Nozzle ht. (in.)	Pressure (psi)	Wind speed (mph)	Percent deposited 4 ft.	8 ft.	Distance to drop to 1% of volume
14	40	3.5	3.1	0.6	7.0
27	40	3.5	5.9	1.5	13.0
18	30	5.3	9.3	2.2	14.0
18	25	9.9	10.3	3.1	15.5
18	40	9.9	9.1	3.6	17.0

To facilitate spray operations and to comply with label instructions of some pesticides, spray applications are only made in late afternoon or early morning hours when golfers are not on the golf course. This reduces the risk of exposure of people to airborne spray particles. Sufficient buffer space with tall vegetation between the golf course and housing sites and facilities (such as the clubhouse) which will be used by people will further reduce the chance of exposure to airborne pesticide particles.

The greatest danger of airborne pesticides is to the applicators of pesticides themselves. Mixing of wettable powder formulations and being in close proximity to airborne spray particles, particularly when operating spray equipment in a downwind position, places spray operators in particularly vulnerable positions. EPA and OSHA have strict standards which specify that spray operators wear appropriate protective clothing and breathing apparatuses.

834A 12th Ave.
Honolulu, HI 96816
January 18, 1991

Mr. Jeffrey H. Overton
Group 70, Ltd.
924 Bethel St.
Honolulu, HI 96813

Dear Mr. Overton:

Re: Proposed mitigation measures to protect the quality of surface and groundwater, Lihi Lani Recreational Community

Dr. Charles Murdoch and I have reviewed the proposed measures in the Draft EIS for Lihi Lani. Our comments on the practices related to fertilizers and pesticides are given below.

Management of Chemical Storage and Use: This is a very appropriate practice to avoid a point source of pesticide and nitrogen contamination of surface water and groundwater.

Land Application of Treated Wastewater Effluent: The effectiveness of turf in removing nitrogen and phosphorus, as well as microbial contaminants, from treated sewage effluent has been well demonstrated by researchers at the University of Hawaii Water Resources Research Center (see for example, Handley. L.L., and P.C. Ekern. 1981. Irrigation of California grass with domestic sewage effluent: Water and nitrogen budgets and crop productivity. WRRC Tech. Rept. No. 141). As stated in the EIS, caution must be exercised to prevent over-application of both fertilizer nitrogen and water when effluent containing nitrogen is used on a regular basis.

Lining of Golf Course Tees and Greens, and Marsh Treatment: This practice will likely have greater benefit than is indicated by the percentages of total fertilizer and pesticide applied to the golf course which will be applied to the lined areas, since the areas which are lined are those that are most susceptible to chemical leaching. Limited monitoring of the leachate from these areas, especially during periods of high rainfall, would provide useful information on chemical leaching with the practices used at that location.

Sincerely,

Richard E. Green, PhD

cc: Charles L. Murdoch

APPENDIX J

INTEGRATED PEST MANAGEMENT (IPM) PROGRAM FOR LIHI LANI GOLF COURSE

Prepared by:

Oliver V. Holtzmann, Ph. D.
Roy K. Nishimoto, Ph. D.
C. L. Murdoch, Ph. D.
W. C. Mitchell, Ph. D

January 15, 1991

INTEGRATED PEST MANAGEMENT (IPM) PROGRAM
FOR LIHI LANI GOLF COURSE

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EXECUTIVE SUMMARY

DEFINITION

Integrated Pest Management is the use of all known pest control tactics in design of a program to manage, not eradicate, pest populations, so that aesthetic or economic damage to turfgrass and harmful side effects to the environment are avoided.

GOAL OF IPM

To manage pest populations in such a manner that high quality turfgrass can be produced economically, and in an acceptable and ecologically sound manner.

BENEFICIAL EFFECTS OF TURFGRASSES ON THE ENVIRONMENT

Turfgrasses have several beneficial effects on the environment. It has been estimated that in a well established turfgrass area, there are approximately 850 plants per square foot. A single grass plant may have almost 400 miles of roots. With such an extensive and intertwined plant system it is not surprising that grass is estimated to trap some 12 million tons of dust and dirt from the air annually. As rain falls or we water our lawns, the trapped pollutants are not washed into our drinking water aquifers, but rather moved into the thatch and surface soil areas where they are immediately acted upon by billions of soil microorganisms that are present in these areas. Healthy turfgrass areas absorb rainfall six times more effectively than a wheat field and four time more effectively than a hay field. Studies at Penn State University concerning the effects of fertilizers and pesticides on water quality found that the runoff and leachate water collected just 2 days after chemical application were usually cleaner than Environmental Protection Agency (EPA) requirements for drinking water.

Much has been published recently about the deforestation of tropical rain forests and the effect this has on elevated carbon dioxide (CO_2) levels in the earth's atmosphere. The planting of trees has been suggested as a method of counteracting the increased CO_2 level. While the intentions of planting more trees is good, the practical aspects are not certain. Unfortunately, trees are slow to reach maturity, often taking 10 to 20 or more years and do not confer maximum environmental benefits until nearly mature. Wind, fire, vandals and age can all cause damage to trees that may kill them and result in having to start the process over. Turfgrasses, on the other hand, have an immediate and long-lasting positive effect on the environment. Grass is an excellent CO_2 and oxygen converter, a turfgrass area only 50 by 50 feet generates enough oxygen to meet the needs of a family of four. The same size turfgrass area would absorb large quantities of CO_2. In addition, turfgrasses also absorb and render harmless other air-polluting gases poisonous to humans, such as ozone, hydrogen fluoride and peroxyacetyl nitrate. Grasses are quickly renewed and their beneficial effects on the environment are immediate. In addition to their absorption of CO_2 and other gasses and production of oxygen, grasses are very efficient in cooling the surroundings. It has been estimated that the front lawn of the average sized home has a cooling capacity equal to approximately 8 tons of air conditioning (the average home-sized central air conditioner is only 3 to 4 ton capacity). This cooling is due almost entirely to the process of transpiration of moisture through microscopic openings (stomata) in the leaves of the grass plant. It has been shown that the surface temperature of green, irrigated turfgrass at noon on a summer day is approximately 40° F cooler than bare soil. The surface temperature of unirrigated, brown, dormant turf was approximately 25° warmer than bare soil, illustrating the tremendous cooling capacity of transpiration of moisture from the soil to the atmosphere (Anon., 1990).

Turfgrass is rarely confronted with a single pest problem, but rather a complex of pests; different kinds of mites, insects, weeds, disease causal agents and other pests. As a result, no single pest control tactic will give adequate control.

INTEGRATED PEST MANAGEMENT

Integrated Pest Management (IPM) is not new, for entomologists have been using it since 1923 and to date its development has progressed rapidly. Following World War II, the widespread use of the new synthetic organic pesticides took much of the uncertainty out of pest control and brought incalculable benefits to mankind. The effectiveness of the new pesticides and the economic benefits derived from their use has resulted in almost complete reliance on preventative application of chemical pesticides to control agricultural pests. Today it is apparent that the "calendar spray schedule" is no longer acceptable. The tendency has been to apply pesticides irrespective of the real need. Most everyone is aware of the undesirable side effects from the wanton uses of pesticides in our ecosystem. IPM is an effective program that DOES NOT ELIMINATE PESTICIDES but will reduce the sole reliance on chemicals and/or the amount of pesticide needed to manage pests.

Today IPM utilizes the broad interdisciplinary approach that employs a unified systematic effort using various management practices and pest control technologies to solve the problem. An IPM program requires the collaborative efforts of plant pathologists, weed scientists, entomologists, ecologists, economists, agronomists, horticulturists, turfgrass management specialists, and other specialists. To secure the needed basic information for an IPM program requires cooperation among a variety of disciplines.

IPM is not itself a tactic for controlling pests but rather a system for understanding various strategies and methods for managing pests. It is a concept of pest management that utilizes all known pest control technologies in a unified, compatible, systematic manner in order to maintain pest populations below levels that cause economic damage or unacceptable aesthetic or functional injury to turfgrass with minimal adverse effects on non-target organisms, environment, and hazard to man. IPM is a DECISION MAKING PROCESS to determine if, when, where, and what strategy and mix of pest management tactics should be used.

The system must be flexible and offer a variety of options because pest problems, control techniques, economics, and human values are continually changing. The IPM system is organized and integrated into a single unit after the basic information on the biology and ecology of the pests, economic costs and environmental acceptability of control methods are known. The development of base line data is time consuming and expensive. In Hawaii, most of our pests are from foreign areas (Australian and Oriental regions) where basic biological and ecological information is lacking.

Although an on-going formal unified Turfgrass IPM Program in Hawaii has not been developed, we have sufficient basic research information experience and expertise for developing such a program. Golf course superintendents utilizing IPM concepts need a thorough understanding of pest identification, life cycles, techniques for monitoring pest populations, action (economic threshold) levels, and environmentally acceptable control measures for the pests on their particular site. Turfgrass IPM programs do not eliminate use of pesticides but are designed to reduce dependency on them and thus reduce overall pesticide use.

BASIC PHILOSOPHIES OF AN IPM SYSTEM

There are several basic tenets that must be accepted by the Golf Course Superintendent and other personnel who are responsible for turfgrass management utilizing an IPM program. The following are among those tenets:

1. IPM IS A CONTAINMENT STRATEGY, NOT AN ERADICATION PROGRAM.
   The continual presence of a harmful species in the ecosystem is natural. Low levels of a pest population not only do no observable plant damage, but in most cases have a beneficial effect as hosts for the beneficial organisms (parasites and predators) which attack them.
2. IPM maximizes the natural control factors (physical and biological) by reducing the indiscriminate use of pesticides and environmental manipulations.
3. Turfgrass managers must accept a certain level of loss or damage since pests are managed in an economic threshold range.
4. IPM DOES NOT ELIMINATE THE USE OF PESTICIDES AS A PEST MANAGEMENT TECHNIQUE. The objective of IPM is to use chemicals more wisely, which can mean less often and/or in lower quantities.
5. IPM does not work for all pest control problems. IPM is not the panacea or alternative that will solve all pest problems.

COMPONENTS OF AN IPM SYSTEM

There are 10 components in an IPM program that must be developed and organized into a unified system. Implementation of some of these components will depend upon the turfgrass manager in making the decision to accept, reject or modify to meet the needs of the particular golf course, the desires of management and the level of turfgrass quality desired. A success of an IPM program for golf courses will depend largely upon having a qualified Golf Course Superintendent who is capable of understanding and supervising an IPM program.

1. DEFINE THE MANAGEMENT UNIT:

   Limits of the management unit are characterized by patterns and movements of key pests and the local cropping system. The management unit may be a tee, green, rough, fairway, the whole golf course, island or state.

2. IDENTIFICATION OF THE PEST SPECIES AND BENEFICIAL ORGANISMS:

   Positive, accurate identification of the organisms in the management unit is necessary to secure biological, ecological, distribution, biological control, pesticide resistance, etc. information. Some of the organisms may be beneficial (parasites and predators) while others may be pests or migrants through the area. An organism should not be called a pest until it is proven to be a pest. An organism may be a pest under certain conditions in a particular area and not in other situations. Pests interact with one another in the environment and this interaction may offset or compound their effects on turfgrass. One should not assume their effects to be additive.

   The pests (weeds, insects, nematodes, rodents, birds, diseases, etc.) may be separated into categories of importance. Identification of pest status must be coupled with the action (economic threshold) level.

Key Pests are the perennially persistent species that require some pest management action every season. Key pests are the focal point around which pest management systems are built. Usually there are only a few key pests; for insects, less than 1% are pests.

Occasional pests are relatively minor pests whose populations may increase enough to cause significant damage to turfgrass at certain times or in specific areas. Their flare-ups are often due to disruptions in natural control, climatic irregularities, or mismanagement by man. IPM is aimed at preventing these occasional outbreaks.

Potential pests include the vast majority of the insects and mites in the area. These organisms do not cause any significant damage or loss to turfgrass under the prevailing management practices.

Migrant pests are highly mobile, non-residents, that may migrate in and infest the turfgrass for short periods of time, often causing severe economical damage. Migrant pests are rarely seen in Hawaii.

Non-pests comprise approximately 99% of the insects and mites in turfgrass. They have no potential for becoming injurious to turfgrass.

3. DEVELOP A RELIABLE MONITORING SYSTEM:

A sampling method that is simple, accurate, not time consuming, has freedom from bias, etc. must be developed. The sample should be randomly selected and representative of the population. Sampling methods should not interfere with regular turfgrass management practices. The sample is the basis for the development of the economic threshold or ACTION LEVEL. **Point sampling** is a method of measuring pest population density related to the number of insects or their damage per unit of turfgrass area. **Sequential sampling**, not widely used in IPM, requires continued sampling until a predetermined upper or lower infestation level is found. **Random sampling**, most commonly used in IPM, requires good field coverage. It measures the number of insects or damage per sample unit without consideration of the total number of pests per acre. Action levels for many of the pests of turfgrass in Hawaii have to be developed. As techniques for sampling and monitoring pest populations become more accurate, reliable and usable, an understanding of the effect of climatic conditions and the interrelationships between the turfgrass, insects, weeds and diseases can be established.Sampling techniques and procedures vary with the pest and the turfgrass situation. Time requirements and economic factors make it necessary to develop practical sampling techniques for each pest and cropping situation involved. An understanding of turfgrass growth and management and the related pest interactions is an essential aspect of monitoring. The high value of turfgrass requires monitoring the areas once every ten days, weekly, or more frequently if pest populations are increasing rapidly and approaching the action level. Predictive models can be developed using population real time information and historical records to simulate future population trends.

4. ACTION LEVELS (ECONOMIC THRESHOLD):

Most IPM specialists consider the terms **Action Level** and **Economic Threshold** to be synonymous. Action level is the density or population of a pest at which an artificial control measure must be applied to prevent an increasing pest population and economic loss or loss of aesthetic value of the turfgrass. The population level determines whether a pest species has attained "real" pest status. Action Levels may change throughout the year at different stages of turfgrass development and type of pest. Thresholds are revised to account for new pests, new varieties, new management practices, etc. Most pests cause economic losses to turfgrass during limited periods of time each season. Action levels should be higher in the rough than fairways and lowest for greens and tees. Action levels have not been determined for many of the turfgrass pests in Hawaii.

5. UTILIZING NATURAL CONTROL AGENTS:

Within a turfgrass cropping system there are natural control factors that are either physical (temperature, humidity, air movement, exposure, soil pH, etc.) or biological (host suitability, specificity, food quality, parasites, predators, pathogens, etc.). These natural factors keep more than 99% of the pests under control 100% of the time. When turfgrass pest populations rapidly increase to near-damaging levels, there is a rapid response to natural enemies and other elements of natural control that exert pressure on the increasing pest population. The rough areas may act as reservoirs for the beneficial parasites and predators of the turfgrass pests.

6. PESTICIDE MANAGEMENT:

Judicious use of pesticide chemicals is the hallmark of IPM. IPM DOES NOT ELIMINATE CHEMICALS. Pesticides will be applied only when necessary. Timing of applications is based upon data obtained through the monitoring system, action level, environmental factors and experience. IPM will prolong the use of chemicals by reducing the development of pesticide resistance. Pesticide use will be more precise and will complement other pest control tactics integrated into the IPM system. Any pest management tactic should only be applied when economically and environmentally justified.

7. INTEGRATION OF MANAGEMENT TECHNOLOGIES WITHIN AND BETWEEN MAJOR DISCIPLINES:

Complexity of the agroecosystem requires the specialists of all disciplines to work together as a team to understand the actions, interactions and reactions of the pests' life systems in order to maximize the natural control factors that suppress pest populations.

8. PREDICTION OF LOSS AND RISK:

Implementation of an IPM system is an educational process. Prediction of loss and risk is based upon data obtained in the monitoring process and experience.

9. MAKE A DECISION AND ACTION:

Data obtained in monitoring, plus conditions present and experience gained over the years will help in making the decision to apply or not to apply an artificial control measure. A valid decision may be to not spray but wait a few days to see if the parasites or predators can continue to suppress the pest species. The skills required to implement an effective IPM program must be learned and practiced.

10. EVALUATION AND FOLLOW UP:

A follow up is necessary to ascertain and evaluate the effectiveness of the decision. If a mistake is made, the conditions should be noted and will assist in making decisions when similar conditions arise again.

OUTCOMES OF IPM

1. IMPROVED CONTROL:

Understanding the relationships between the turfgrass, pests and environment insure the management technique will be applied only when needed.

2. PESTICIDE MANAGEMENT:

Timing of a management pest control technique is based upon the data obtained through observation and monitoring the management site. Pesticide management should prolong the usefulness of the chemical.

3. ECONOMICAL TURFGRASS PROTECTION:

Applications of pesticides will only be used when necessary. Utilizing the Action or Threshold Level concept to determine the timing of a pesticide application will decrease the number of pesticide applications per season.

4. REDUCTION OF ENVIRONMENTAL POLLUTION:

Applications of the pesticides will be based upon need and not the "calendar schedule" wanton use. Pesticides selected will have the least potential for leaching, surface water contamination, damage to fish and wildlife and will be applied in the safest manner to reduce drift and hazard to man.

ROADBLOCKS TO ACCEPTANCE OF AN IPM PROGRAM

1. Inadequate understanding of the IPM program by growers, administrative and maintenance personnel.
2. Lack of acceptance of the Action Level concept of IPM turfgrass management.
3. Lack of trained people with experience in IPM programs in Hawaii.

TURFGRASS MANAGERS CONCERNS

It will be the responsibility of the golf course superintendent to manage the IPM program. The superintendent will be well trained and experienced in IPM turfgrass management. The value of turfgrass is high and golf course superintendents realize that pesticides are expensive, simple to apply as "added insurance-peace of mind", and are generally effective in controlling the pest. However, with experience and knowledge of IPM, they realize the fallacy of relying soly on chemical controls. Timing of IPM management procedures, monitoring, etc. are important and require technical training for personnel. It will be the responsibility of the golf course superintendent to see that maintenance presonnel are aware of IPM proceedures.

A turfgrass IPM program will, over the long-term, save money, provide quality turfgrass, reduce pollution of the environment and provide effective pest and pesticide management.

TURFGRASS MANAGEMENT FOR PEST CONTROL

The most effective pest control is a dense, vigorous turf. Weed invasion is much less likely if the turf provides a dense cover. Many serious turfgrass diseases only attack turf which is in a weakened condition. Although some fungi and many insects are able to attack a healthy turf, recovery from such attacks is much more rapid and complete than if the turf is in a weakened condition when attacked. Any turfgrass IPM program must first consider all aspects of turfgrass selection, establishment and culture of turfgrasses in order to obtain the most effective pest management with least dependence on chemical pesticides. Adequate fertilizer and water must be applied to maintain turfgrasses in a vigorous condition. Turfgrass fertilization programs will be designed to supply the required essential nutrients at an optimum level. Turfgrass irrigation

scheduling will be based on need rather than calander schedule. These practices will be necessary in order to provide a healthy, vigorous turfgrass yet avoid over application of fertilizers and water.

Since the elevation at the site of the proposed Lihi Lani golf course is well below 1000 meters, only warm season grasses are adapted at this location. The bermudagrasses (Cynodon spp.) are the warm season grasses used on golf courses throughout the warm parts of the world. They are well adapted for use at the Lihi Lani site.

Cultural practices are given for establishing and maintaining vigorous turf on the different areas of the golf course (roughs, fairways, tees and greens). Included are choice of turfgrass cultivars, soil preparation and establishment, mowing, fertilization, irrigation, cultivation, and other practices to produce a vigorous, pest resistant turf.

MANAGEMENT OF INSECT AND MITE PESTS OF TURF

A brief description of the difference between mites and insects, their biology and ecology and the relevance of these to developing management strategies in the framework of an IPM program are discussed. Since they are cold blooded animals, their activity is regulated primarily by temperature. The mild temperatures in Hawaii allow insects and mites to be active throughout the year, although there may be seasonal variation in population size.

The insect and mite pests of turfgrasses are described and for each species information is presented on the type of damage, host range, stages of life cycle, monitoring methods for determining the size of their populations, action levels (economic threshold) for initiating management techniques (if known), biological control agents, cultural control techniques, and chemical control methods.

There are 10 invertebrate arthopod pests that may become a problem in turfgrass in the Lihi Lani area. Common and scientific names and classification of seriousness of the pests are given below.

Key Pest:

Grass webworm (GWW) (Moth): *Herpetogramma licarsisalis* (Walker)

Occasional Pests:

Bermudagrass mite (BGM) (Mite): *Eriophyes cynodoniensis* Sayed

Hunting billbug (HBB) (Snout beetle): *Sphenophorus venatus vestitus* Chittenden

Lawn armyworm (LAW) (Moth): *Spodoptera mauritia* (Boisd.)

Rhodesgrass mealybug (RGMB) (Mealybug): *Antonina graminis* (Maskell)

Southern chinch bug (SCB) (chinch bug): *Blissus insularis* Barber

Potential Pests:

Bagworm (BW) (Moth): *Brachycytarus grisseus* deJoannis

Black cutworm (BCW) (moth): *Agrotis ipsilon* (Hufnagel)

Bermudagrass scale (BGS) (scale): *Odonaspis ruthae* Kotinsky

Fiery Skipper (FS) (Moth): *Hylephila phyleus* (Drury)

MANAGEMENT OF DISEASES AND NEMATODES:

Environmental and cultural practices not only affect insect and mite pests, but are important in the development of disease and nematode pests of turfgrasses. For a disease to develop to epidemic levels, three factors must be present; a susceptible host, a causal agent (pathogen), and an environment conducive for optimum development of the disease. Any practice which will eliminate any of these will prevent disease occurrence.

In general the bermudagrasses are less susceptible to diseases than other turfgrasses, such as creeping bentgrass (*Agrostis stolonifera* L.). This is especially true for the Lili Lani golf course, since creeping bentgrass is not climatically adapted and would be under serious stress at this location. The general cultural factors predisposing bermudagrasses to disease are discussed.

Eleven diseases present in Hawaii and two that may someday appear are discussed. Information on classification, symptom recognition, and factors highly favorable or contributory to development of each are presented. Some turfgrass damage not due to pathogenic organisms is sometimes mis-identified as a disease. Some examples of these are; oil spills, fuel leaks, herbicide injury, insect injury, etc. Methods of recognition and differieniating these from turfgrass diseases are presented.

The major and potential diseases of bermudagrass which might be a problem in the Lihi Lani area are:

Plant Diseases and Nematodes:

Key Pests:

Brown Patch: *Rhizoctonia solani* **Grease spot:** *Pythium* spp.

Melting out: *Bipolaris* spp.

Occasional Pests:

Algae: Freshwater algae **Anthracnose:** *Colletotrichum* spp.

Fading out: *Curvularia* sp. **Fairy ring:** Basidomycetes

Fusarium blight: *Fusarium* spp. **Leaf rust:** *Puccinia* spp.

Potential Pests:

Bacterial stripe: *Xanthomonas* spp. **Dreschlera leaf spot:** *Dreschlera* spp.

Nematodes:

Criconemoides spp. *Helicotylenchus* spp.

Meloidogyne spp. *Pratylenchus* spp.

Trichodorus spp.

*Dreschlera leaf spot is not presently a problem at low elevations in Hawaii, but could possibly cause problems in the future.

IPM action levels, cultural controls and fungicides registered for use in Hawaii are discussed for each disease.

Five species of plant parasitic nematodes are commonly found infesting turf in Hawaii. Injury by nematodes has not been as great as on the mainland United States. Plant quarantine methods of preventing introduction of serious pest nematode species from the mainland will help to prevent nematodes from becoming a problem of turf.

MANAGEMENT OF WEEDS:

There are hundreds of weeds in Hawaii but only about thirty species are considered pests in turfgrass. The concepts of weed management differ from those of insect and disease management. Small populations of pest insects are beneficial by providing food for parasites and predators that attack them. Small infestations of weeds if, allowed to mature and produce seed are detrimental to turfgrass management. The concepts of weed management are discussed.

Three types of weeds ie, grasses, sedges and broadleaves are identified and discussed in relation to the management and location of the Lihi Lani golf course. The more important weeds expected to occur in this area are listed below.

Grasses:

Key Pests:

Goosegrass: *Eleusine indica*

Henry's crabgrass: *Digitaria adscendens*

Hilograss: *Paspalum conjugatum*

Smutgrass: *Sporobolus poiretii*

Occasional Pests:

Annual bluegrass: Poa *annua* **Dallisgrass:** *Paspalum dilatatum*

Lovegrass: *Eragrostis* spp. **Stargrass:** *Chloris divaricata*

Swollen fingergrass: *Chloris barbata* **Vaseygrass:** *Paspalum urvillei*

Potential Pests:

Sandbur *Cenchrus ecninatus*

Sedges:

Key Pests:

Green kyllinga: *Kyllinga monocephata* — **Purple nutsedge:** *Cyperus rotundus*

Occasional Pests:

White kyllinga: *Kyllinga brevifolius*

Broadleaves:

Occasional Pests:

Alternanthra: *Alternanthera repens* — **Asiatic pennywort:** *Centella asiatica*

Broad-leaved plantain: *Plantago major* — **Buttonweed:** *Borreria laevis*

Creeping indigo: *Indigofera endecaphylla* — **Dandelion:** *Taraxacum officinale*

Drymaria: *Drymaria cordata* — **Garden spurge:** *Euphorbia hirta*

Kaimi clover: *Desmodium canum* — **Marsh pennywort:** *Hydrocoytle sibthorpioides*

Prostrate spurge: *Euphorbia prostrata* — **Purslane:** *Portulaca oleracea*

Sensitive plant: Mimosa pudica — **Synedrella:** *Synedrella nodiflora*

Yellow wood sorrel: *Oxalis corniculata*

Potential Pest:

Pink wood sorrel: *Oxalis martiana*

The major pest management tactic for weeds in turf is a dense, vigorous turf which will preclude invasion of weeds. When weeds do invade, the pest management tactic is application of an herbicide. Information is presented on the herbicides registered in Hawaii and their most effective use for controlling specific weeds.

Monitoring methods used in weed science, action levels for specific weeds, and herbicides registered in Hawaii are discussed. Action levels for greens will be much lower than for tees and fairways.

Pesticide use:

The aim of an IPM program is to reduce the dependance upon chemical pesticides. It is unlikely that an IPM program for golf turf would ever completely eliminate their use. Proper use of chemicals implies that the proper equipment is used for specific applications. Pesticides are formulated in various forms. Information about the different formulations and proper equipment for their application is presented.

Laws and regulations regarding the use of pesticides are continuously changing. The mention of trade names in this report does not constitute an endorsement of the product by the authors. The pesticides discussed are suggestions for control of turfgrass pests. It is the responsibility of the pesticide user to make sure that label directions are followed precisely.

Choosing correct nozzle sizes and pressures, proper boom height, etc. are all necessary in order for pesticides to perform properly. Calibration of spray equipment is essential for the pesticide to be effective. Methods of calibrating pesticide application equipment and measuring amounts of pesticides to use are discussed.

INTEGRATED PEST MANAGEMENT PROGRAM FOR LIHI LANI GOLF COURSE

BENEFICIAL EFFECTS OF TURFGRASSES ON THE ENVIRONMENT

Turfgrasses have several beneficial effects on the environment. It has been estimated that in a well established turfgrass area, there are approximately 850 plants per square foot. A single grass plant may have almost 400 miles of roots. With such an extensive and intertwined plant system it is not surprising that grass is estimated to trap some 12 million tons of dust and dirt from the air annually. As rain falls or we water our lawns, the trapped pollutants are not washed into our drinking water aquifers, but rather moved into the thatch and surface soil areas where they are immediately acted upon by billions of soil microorganisms that are present in these areas. Healthy turfgrass areas absorb rainfall six times more effectively than a wheat field and four time more effectively than a hay field. Studies at Penn State University concerning the effects of fertilizers and pesticides on water quality found that the runoff and leachate water collected just 2 days after chemical application were usually cleaner than Environmental Protection Agency (EPA) requirements for drinking water.

Much has been published recently about deforestation of tropical rain forests and the effect this has on elevated carbon dioxide (CO_2) levels in the earth's atmosphere. Planting of trees has been suggested as a method of counteracting the increased CO_2 level. While intentions of planting more trees is good, the practical aspects aren't certain. Unfortunately, trees are slow to reach maturity, often taking 10 to 20 or more years and do not confer maximum environmental benefits until nearly mature. Wind, fire, vandals and age can all cause damage to trees that may kill them and result in having to start the process over. Turfgrasses, on the other hand, have an immediate and long-lasting positive effect on the environment. Grass is an excellent CO_2 and oxygen converter, a turfgrass area only 50 by 50 feet generates enough oxygen to meet the needs of a family of four. The same size turfgrass area would absorb large quantities of CO_2. In addition, turfgrasses also absorb and render harmless other air-polluting gases poisonous to humans, such as ozone, hydrogen fluoride and peroxyacetyl nitrate. Grasses are quickly renewed and their beneficial effects on the environment are immediate. In addition to their absorption of CO_2 and other gasses and production of oxygen, grasses are very efficient in cooling the surroundings. It has been estimated that the front lawn of the average sized home has a cooling capacity equal to approximately 8 tons of air conditioning (the average home-sized central air conditioner is only 3 to 4 ton capacity). This cooling is due almost entirely to the process of transpiration of moisture through microscopic openings (stomata) in the leaves of the grass plant. It has been shown that the surface temperature at noon on a summer day of green, irrigated turfgrass is approximately 40° F cooler than bare soil. Surface temperature of unirrigated, brown, dormant turf was approximately 25° warmer than bare soil, illustrating the tremendous cooling capacity of transpiration of moisture from soil to the atmosphere.

Thus turfgrasses can have several distinct beneficial effects on man's environment. Unfortunately, turfgrasses, as well as all other plants, have several pests which often reach damaging levels which make it necessary to institute control measures. Controlling turfgrass pests usually involves applying a chemical pesticide (in this report pesticide is used generically and refers to a material applied to control a pest; herbicides, insecticides, miticides, algicide, nematocide, and fungicides are all pesticides). All pesticides applied to turf, as do pesticides for any use, must be approved for use on turf by the United States Environmental Protection Agency (EPA). Pesticides used in the State of Hawaii must also be approved for sale by the Hawaii Department of Agriculture (DOA). EPA regulations, as

well as DOA regulations, are enforced by the DOA. If EPA determines at any time that a particular pesticide is causing a problem, its use on a given crop or at a specific site where it is causing problems can be repealed. Generally, problems with pesticide application on golf courses have been few. In a recent study of fertilizer and pesticide use on golf courses on Cape Cod, Massachusetts (Cohen, et al., 1990), an area with a shallow groundwater aquifer, very vulnerable to pollution, 19 monitoring wells were installed upgradient in greens, tees, and fairways on four golf courses. In addition, soil core samples from the same four golf courses were taken and analyzed. Ground water and soil samples were taken and analyzed for 17 pesticides over 4 to 6 cycles for a period of 1.5 years. Seven of the pesticides used on the golf courses were never detected in any of the samples. Only chlordane (which is no longer used on golf courses) was detected at levels exceeding the EPA's Health Advisory Level (HAL). The authors concluded that "results show no cause for concern about use of these currently registered pesticides".

Even though proper use of pesticides on golf courses appear to cause few problems, means of reducing the amount and/or frequency of pesticide applications will further assure that pests are prevented from destroying valuable turf with the least possible environmental hazard. One such method of reducing the use of chemical pesticides is through an Integrated Pest Management Program (IPM) in which all possible avenues of pest control are utilized in an integrated manner.

INTRODUCTION TO INTEGRATED PEST MANAGEMENT

Turfgrass is rarely confronted with a single pest problem, but rather a complex of pests; different kinds of mites, insects, weeds, disease causal agents and other pests. As a result, no single pest control tactic will give adequate control.

Integrated Pest Management (IPM) is not new, for entomologists have been using it since 1923 and to date its development has progressed rapidly. Following World War II, widespread use of the new synthetic organic pesticides took much of the uncertainty out of pest control and brought incalculable benefits to mankind. Effectiveness of new pesticides and the economic benefits derived from their use has resulted in almost complete reliance on preventative application of chemical pesticides to manage agricultural pests. Today it is apparent that the "calendar spray schedule" is no longer acceptable. The tendency has been to apply pesticides irrespective of real need. Most everyone is aware of undesirable side effects of wanton uses of pesticides in our ecosystem. IPM is an effective program that DOES NOT ELIMINATE PESTICIDES but will reduce sole reliance on chemicals and/or the amount of pesticide needed to manage pests.

Today IPM utilizes the broad interdisciplinary approach that employs a unified systematic effort using various management practices and pest control technologies to solve the problem. An IPM program requires collaborative efforts of plant pathologists, weed scientists, entomologists, ecologists, economists, agronomists, horticulturists, turfgrass management specialists, and other specialists. To secure needed basic information for an IPM program requires cooperation among a variety of disciplines.

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The system must be flexible and offer a variety of options because pest problems, control techniques, economics, and human values are continually changing. An IPM system is organized and integrated into a single unit after the basic information on the biology and ecology of the pests, economic costs and environmental acceptability of control methods are known. Development of base line data is time consuming and expensive. In Hawaii, most of our pests are from foreign areas (Australian and Oriental Regions) where basic biological and ecological information is lacking.

Although an on-going formal unified Turfgrass IPM Program in Hawaii has not been developed, we have sufficient basic research information experience and expertise for developing such a program. Golf course superintendents utilizing IPM concepts need a thorough understanding of pest identification, life cycles, techniques for monitoring pest populations, action (economic threshold) levels, and environmentally acceptable control measures for the pests on their particular site. Turfgrass IPM programs do not eliminate use of pesticides but are designed to reduce dependency on them and thus reduce overall pesticide use.

DEFINITION

Integrated Pest Management is the use of all known pest control tactics in design of a program to manage, not eradicate, pest populations, so that aesthetic or economic damage to turfgrass and harmful side effects to the environment are avoided.

GOAL OF IPM

To manage pest populations in such a manner that high quality turfgrass can be produced economically, and in an acceptable and ecologically sound manner.

BASIC PHILOSOPHIES OF AN IPM SYSTEM

There are several basic tenets that must be accepted by the Golf Course Superintendent and other personnel who are responsible for turfgrass management utilizing an IPM program. The following are among those tenets:

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COMPONENTS OF AN IPM SYSTEM

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Limits of the management unit are characterized by patterns and movements of key pests and the local cropping system. The management unit may be a tee, green, rough, fairway, the whole golf course, island or state.

2. IDENTIFICATION OF PEST SPECIES AND BENEFICIAL ORGANISMS:

Positive, accurate identification of organisms in the management unit is necessary to secure biological, ecological, distribution, biological control, pesticide resistance, etc. information. Some of the organisms may be beneficial (parasites and predators) while others may be pests or migrants through the area. An organism should not be called a pest until it is proven to be a pest. An organism may be a pest under certain conditions in a particular area and not in other situations. Pests interact with one another in the environment and this interaction may offset or compound their effects on turfgrass. One should not assume their effects to be additive.

Pests (weeds, insects, nematodes, rodents, birds, pathogens, etc.) may be separated into categories of importance. Identification of pest status must be coupled with the action (economic threshold) level.

Key Pests are the perennially persistent species that require some pest management action every season. In the absence of control, they frequently occur above the action level. Key pests are the focal point around which pest management systems are built. Usually there are only a few key pests; for insects, less than 1% of the insects in the area. The others have no pest potential because of their biology and feeding habits or are prevented from doing damage to turfgrasses, at least most of the time, by natural control factors.

Occasional pests are relatively minor pests whose populations may increase enough to cause significant damage to turfgrass at certain times or in specific areas. Their flare-ups are often due to disruptions in natural control, climatic irregularities, or mismanagement by man. IPM is aimed at preventing these occasional outbreaks.

Potential pests include the vast majority of insects and mites in the area. These organisms do not cause any significant damage or loss to turfgrass under prevailing management practices. Care must be taken in the management of key and occasional pests so as not to alter conditions that potential pest populatiom may erupt and become serious.

Migrant pests are highly mobile, non-residents, that may migrate in and infest turfgrass for short periods of time, often causing severe economical damage. Locusts, armyworms, and birds fall into this category. Migrant pests are rare in Hawaii.

Non-pests comprise approximately 99% of the insects and mites in turfgrass. They have no potential for becoming injurious to turfgrass. The effects of these organisms are often beneficial in the turfgrass ecosystem by controlling pests, recycling nutrients, pollination of crops, providing shelter and food for parasites and predators.

3. DEVELOP A RELIABLE MONITORING SYSTEM:

A sampling method that is simple, accurate, not time consuming, has freedom from bias, etc. must be developed. The sample should be randomly selected and representative of the population. Sampling methods should not interfere with regular turfgrass management practices. The sample is the basis for the development of the ECONOMIC THRESHOLD or ACTION LEVEL. Point sampling is a method of measuring pest population density related to the number of insects or their damage per unit of turfgrass area. Sequential sampling, not widely used in IPM, as it requires continued sampling until a predetermined upper or lower infestation level is found. Random sampling, most commonly used in IPM, requires good field coverage. It measures the number of insects or damage per sample unit without consideration of the total number of pests per acre. Action levels for many of the pests of turfgrass in Hawaii have to be developed. As techniques for sampling and monitoring pest populations become more accurate, reliable and usable, an understanding of the effect of climatic conditions and interrelationships between turfgrass, insects, weeds and diseases can be established. Sampling techniques and procedures vary with the pest and turfgrass situation. Time requirements and economic factors make it necessary to develop practical sampling techniques for each pest and cropping situation involved. An understanding of turfgrass growth and management and related pest interactions is an essential aspect of monitoring. The high value of turfgrass requires monitoring the areas once every ten days, weekly, or more frequently if pest populations are increasing rapidly and approaching the action level. Predictive models can be developed using population real time information and historical records to simulate future population trends.

4. ACTION LEVELS (ECONOMIC THRESHOLD):

Most IPM specialists consider the terms Action Level and Economic Threshold to be synonymous. Action level is the density or population of a pest at which an artificial control measure must be applied to prevent an increasing pest population and economic loss or loss of aesthetic value of the turfgrass. The population level determines whether a pest species has attained "real" pest status. Action Levels may change throughout the year at different stages of turfgrass development and type of pest. Thresholds are revised to account for new pests, new varieties, new management practices, etc. Most pests cause economic losses to turfgrass during limited periods of time each season. Action levels should be higher in the rough than fairways and lowest for greens and tees. Action levels have not been determined for many of the turfgrass pests in Hawaii.

5. UTILIZING NATURAL CONTROL AGENTS:

Within a turfgrass cropping system there are natural control factors that are either physical (temperature, humidity, air movement, exposure, soil pH, etc.) or biological (host suitability, specificity, food quality, parasites, predators, pathogens, etc.). These natural factors keep more than 99% of the pests under control 100% of the time. When turfgrass pest populations rapidly increase to near-damaging levels, there is a rapid response to natural enemies and other elements of natural control that exert pressure on the increasing pest population. The rough areas may act as reservoirs for the beneficial parasites and predators of the turfgrass pests.

6. PESTICIDE MANAGEMENT:

Judicious use of pesticide chemicals is the hallmark of IPM. IPM DOES NOT ELIMINATE CHEMICALS. Pesticides will be applied only when necessary. Timing of applications is based upon data obtained through the monitoring system, action level, environmental factors and experience. IPM will prolong the use of chemicals by reducing development of pesticide resistance. Pesticide use will be more precise and will complement other pest control tactics integrated into the IPM system. Any pest management

tactic should only be applied when economically and environmentally justified.

7. INTEGRATION OF MANAGEMENT TECHNOLOGIES WITHIN AND BETWEEN MAJOR DISCIPLINES:

Traditional disciplines were entomology, weed science and plant pathology but now it includes economists, sociologists, nematologists, etc. Complexity of the agroecosystem requires the specialists of all disciplines to work together as a team to understand actions, interactions and reactions of the pests' life systems in order to maximize the natural control factor that suppress pest populations.

8. PREDICTION OF LOSS AND RISK:

Implementation of an IPM system is an educational process. Prediction of loss and risk is based upon data obtained in the monitoring process and experience.

9. MAKE A DECISION AND ACTION:

Data obtained in monitoring, plus conditions present and experience gained over the years will help in making the decision to apply or not to apply an artificial control measure. A valid decision may be to not spray but wait a few days to see if the parasites or predators can continue to suppress the pest species. The skills required to implement an effective IPM program must be learned and practiced.

10. EVALUATION AND FOLLOW UP:

A follow up is necessary to ascertain and evaluate the effectiveness of the decision. If a mistake is made, the conditions should be noted and will assist in making decisions when similar conditions arise again. Records should always be made of conditions and the action taken in a pest management program. With experience, methods of monitoring turfgrasses can be more finely tuned and more reliable decisions made.

OUTCOMES OF IPM

1. IMPROVED CONTROL:

Understanding relationships between turfgrass, pests and environment insure the management technique will be applied only when needed.

2. PESTICIDE MANAGEMENT:

Timing of a management pest control technique is based upon the data obtained through observation and monitoring the management site. Pesticide management should prolong the usefulness of the chemical.

3. ECONOMICAL TURFGRASS PROTECTION:

Applications of pesticides will only be used when necessary. Utilizing the Action or Threshold Level concept to determine timing of a pesticide application will decrease the number of pesticide applications per season.

4. REDUCTION OF ENVIRONMENTAL POLLUTION:

Applications of pesticides will be based upon need and not the "calendar schedule" wanton use. Pesticides selected will have the least potential for leaching, surface water contamination, damage to fish and wildlife and will be applied in the safest manner to reduce drift and hazard to man.

ROADBLOCKS TO ACCEPTANCE OF AN IPM PROGRAM

1. Inadequate understanding of the IPM program by growers, administrative and maintenance personnel.
2. Lack of acceptance of the Action Level concept of IPM turfgrass management.
3. Lack of trained people with experience in IPM programs in Hawaii.

TURFGRASS MANAGERS CONCERNS

Without experience and an understanding of the systematic approach to IPM, it is often difficult for a turfgrass manager to accept IPM as an alternative to sole reliance on chemical pest control. The value of turfgrass is high and the risk involved with IPM is great. Managers realize that pesticides are expensive, simple to apply as "added insurance-peace of mind", and are generally effective in controlling the pest. Timing of IPM management procedures, monitoring, etc. are important and require technical training for personnel. Turfgrass managers are also concerned with the possibility of interference with other turfgrass maintenance practices. only through experience can the concerns of the turfgrass managers be alleviated.

A turfgrass IPM program will, over the long-term, save money, provide quality turfgrass, reduce pollution of the environment and provide effective pest and pesticide management.

GROWTH AND DEVELOPMENT OF TURFGRASSES IN HAWAII

Climatic Adaptation

The grass family (Poaceae or Gramineae) is relatively large, containing some 6 subfamilies, 600 or more genera and 6,000 or more individual species. The number of grasses suited for use as turf is much smaller. Only approximately 25 species are used to any extent as turfgrasses. All of the grasses used for turf are contained in three subfamilies; the Festucoideae, Panicoideae, and the Eragrostoideae. The members of the Festucoideae are adapted to cooler environments and have been refered to as cool season grasses. The members of the Panicoideae and Eragrostoideae are adapted to warmer regions of the world and are called warm season grasses. The optimum temperature range for growth and development of cool season grasses is approximately 60 to 75° F. Root and shoot growth is severely restricted at soil temperatures above 80° F. Warm season grasses, on the other hand, grow best at approximately 80-95° F. Shoot growth ceases, green color is lost, and the turf becomes dormant at soil temperatures below approximately 50° F.

Cool season grasses used on golf courses include the bluegrasses (*Poa* spp.), fescues (*Festuca* spp.), ryegrasses (*Lolium* spp.), and bentgrasses (*Agrostis* spp.). The bermudagrasses (*Cynodon* spp.) are the most important warm season grasses used on golf courses, although zoysiagrasses (*Zoysia* spp.) are sometimes used for fairways in northern areas of the warm humid region of the mainland U. S. and for summer putting

greens in Japan. Seashore paspalum (*Paspalum vaginatum* Sw.) has found limited use on golf courses where salt tolerance is of prime consideration.

Studies of the distribution of grasses in North America show that cool season grasses dominate in areas with mean July minimum temperatures below 15 to 18° C (59-64° F) (Teeri and Stowe, 1976; Ehleringer, 1978). In Hawaii, it was found that warm season grasses predominate at elevations below 1000 meters (3281 feet). The elevational transition area (the elevation at which the proportion of cool season and warm season grasses is approximately equal) of 1400 meters (4395 feet) corresponds to a low mean monthly minimum temperature of approximately 9° C (48° F) and a mean maximum temperature for the warmest month of approximately 21° C (70° F) (Rundel, 1980). A similar study along an altitudinal gradient in Kenya (Tieszen, et al., 1979) showed that the elevation at which cool season and warm season grasses were present in equal abundance was approximately 2300 meters (7546 feet). The mean maximum temperature for this elevation in Kenya was approximately 22° C (72° F) and the mean minimum temperature was 8° C (46° F), very close to the 48° F at the elevational transition in Hawaii. Thus cool season grasses in Hawaii and other tropical areas appear to be adapted to areas with lower temperatures than the mean minimum monthly temperature of 15° to 18° C (59°-64° F) reported from temperate regions (Terri and Stow, 1976; Ehleringer, 1978). Rundel (1980) suggested that perhaps the relatively even temperature throughout the year in tropical areas may be the reason for this disparity. The difference in mean summer and winter temperatures below 1650 meters (5413 feet) elevation in Hawaii is less than 5° C (approximately 9° F) (Price, 1966).

Since the elevation at the site of the proposed Lihi Lani golf course is well below 1000 meters, only warm season grasses are adapted at this location. Although creeping bentgrass (*Agrostis stolonifera* L.) is thought by many to make a putting surface superior to that of the hybrid bermudagrasses (*Cynodon dactylon* x *C. transvaalensis*) and therefore has been used in southern areas of the mainland U. S., its use on the Lihi Lani golf course would require very frequent applications of pesticides (particularly fungicides) because of its higher susceptibility to fungus diseases. Our discussions will therefore be restricted to various cultivars of bermudagrass only.

Plant Structure

Grass plants are composed of a complex arrangment of leaves, stems, and roots that arise from seed and various vegetative propagules. These parts are interrelated in that the roots function to absorb water and nutrients from the soil and to anchor the plant. The leaves are the site of manufacture of plant food which is essential for growth and development of all parts of the plant.
Because it has been demonstrated that mowing of turfgrasses greatly reduces root growth, one of the most critical aspects of turfgrass management is to maintain an acceptable balance between root and shoot growth at the mowing height and frequency required for acceptable playing conditions on various areas of golf courses. Turfgrasses are thought to have coevolved with grazing animals through the centuries. They are therefore uniquely adapted to withstand frequent defoliation by mowing and traffic. Tolerance to these factors is because of the position of the growing point located atop an unelongated stem called a crown near the surface of the soil.The capacity to sustain a dynamic and complex turfgrass community depends greatly on a through knowledge of how turfgrasses grow and develop.

Root Growth

Grasses have two types of root systems; the primary or seminal roots developed from germinating seed. Primary roots are only functional during the seedling stage and are active only for 6 to 8 weeks. Adventitious roots are the only roots of mature turfgrasses. They are formed from meristematic tissue near the base of crowns or at the nodes of lateral stems (stolons and/or rhizomes) which come in contact with the soil. The root system of grasses is fibrous and very extensive. Bermudagrass roots have been observed at depths of 10 to 12 feet under unmown conditions. The major portion of the root system of bermudagrasses mown at less than 2 inches is in the upper 18 inches of the soil. Under putting greens conditions the major portion of the root system is in the upper 12 inches.

Environmental influences on root growth

The primary requisites for a deep, extensive root system is a healthy, actively growing plant that is climatically adapted, adapted to environmental conditions of the site, and is growing under conditions of adequate soil moisture and nutrients availability.Numerous environmental and cultural factors greatly influence the degree of rooting. Some of the factors which influence rooting include:

1. Soil temperatures.
   For the bermudagrasses, soil temperatures of 80-85° F are optimum.

2. Soil pH.
   pH of 5.5 to 6.5 is optimum

3. Soil oxygen levels.
   Soil compaction and waterlogged conditions are the primary cause of reduced soil oxygen.

4. Presence of toxic chemicals or salts.
   Poor quality irrigation water and pesticide residues are the primary sources of chemical injury to root systems.

5. Mowing heights or excessively frequent mowing.
   Shoots of grasses are the site of food manufacture. Roots are supplied with plant food only when there is a surplus of food above that required for shoot growth.Since mowing drastically reduces the amount of leaf surface, the immediate effect is a reduction of root growth.

6. Fertilization.
   Nitrogen (N) fertilization greatly stimulates shoot growth. At high rates of N, the demand for available carbohydrates for increased shoot growth reduces the amount available for root growth and the root system may die. Potassium (K) has been shown to greatly influence development of a deep, extensive root system, probably because of its role in carbohydrate formation and utilization.Adequate levels of phosphorus (P) are also improtant in development of a deep, extensive root system.

7. Thatch .
   Thatch is a layer of undecomposed organic matter which accumulates between the soil surface and the green turfgrass surface. Thatch layers interfere with the movement of water and oxygen in the soil. The thatch layer may remain constantl wet and provide the only area where roots can obtain water and air. The turf then becomes very shallow rooted and vulnerable to soil moisture stress.

9. Irrigation amount and frequency.
   Turf roots are only able to grow in areas of the soil where adequate moisture and oxygen are present. Light, frequent irrigations wet only the upper layers of the soil. Turfgrasses should be watered to the depth of the root system (8 to 12 inches) and only frequently enough to prevent permanent wilting of the turf.

Shoot Growth.

The shoot system of turfgrasses consists of a complex system of stems and leaves. The stem is composed of nodes and internodes. Leaves or lateral branches are borne at the nodes. Rhizomes are specialized stems which grow below ground and form new plants at the nodes. Stolons are above ground stems which creep on the soil surface and produce new plants at nodes which come in contact with the soil. Bermudagrasses have both stolons and rhizomes. These structures are responsible for the ability of the bermudagrasses to spread rapidly and form a dense, uniform turf. Stolons and rhizomes are the only means of planting new turf of many cultivars of bermudagrass, as they do not produce seed. The leaves of grasses are composed of the flattened green portion, the blade, and the leaf sheath which surrounds the stem and anchors the leaf. Most people use the term leaf when reality they are referring to the leaf blade. The leaf blade is the site of the process of photosynthesis in which plant food is manufactured from carbon dioxide which is absorbed from the air, and water and mineral nutrients from the soil. Chlorophyll, the green pigment in the leaf blades, gives plants the unique ability to carry out this process. It also gives turfgrasses the dark green color which make them so attractive.

Environmental Influences on Shoot Growth.

Since the root and shoot are mutually dependent, factors which influence root growth also have a large influence on shoot growth. Factors which perhaps most directly influence shoot growth include:

1. Amount of solar radiation.
   Bermudagrasses are relatively intolerant of shade and may be severely affected by growing in reduced light levels.

2. Excessively high or low temperatures.
   The optimum temperature for shoot growth of turfgrasses is higher than that for root growth. For bermudagrasses, the optimum for shoot growth is approximately 85-95° F. Air temperatures below 70° F result in reduced growth and may result in a semi-dormant state if prolonged.

3. Nitrogen fertilization.
   Nitrogen fertilization greatly stimulates shoot growth. Excessive nitrogen may increase shoot growth at the expense of stored carbohydrates, thus negatively affecting root growth.

4. Iron and magnesium fertilization.
   Iron is intimately involved in the formation of the green pigment chlorophyll and magnesium is an integral part of the chlorophyll molecule itself. Therefore, adequate iron and magnesium availability are crucial in maintaining proper color and shoot growth under conditions where the leaves are removed frequently by mowing.

5. Mowing height and frequency.
The demands on golf turf, especially for tees and greens, are such that turf must be mown very frequently and at low mowing heights. Mowing greatly reduces the leaf surface available for food manufacturing. Bermudagrasses are maintained under putting greens conditions of daily mowing at a height of 3/16 inch or less. Grass maintained under these conditions is under great stress and requires more frequent fertilizer and water applications. It also requires more pesticide, since grasses under stress are more susceptible to pests than grasses growing under ideal conditions.

TURFGRASS MANAGEMENT

The most effective pest control is a dense, vigorous turf. Weed invasion is much less likely if the turf provides a dense cover. Many serious turfgrass diseases only attack turf which is in a weakened condition. Although some fungi and many insects are able to attack a healthy turf, recovery from such attacks is much more rapid and complete than if the turf is in a weakened condition when attacked. Any turfgrass IPM program must first consider all aspects of turfgrass selection and establishment and culture of turfgrasses in order to obtain the most effective pest management with least dependence on chemical pesticides.

CULTIVAR SELECTION

As mentioned previously, only the warm season grasses are adapted at elevations below 1,000 meters (3281 feet) in Hawaii. The bermudagrasses (*Cynodon* spp.) are the warm season grasses most frequently used on golf courses throughout the warm parts of the world. There are several bermudagrasses available for use in Hawaii. Each has characteristics which make them suited for use on different areas of golf courses.

Bermudagrasses as a group are adapted to a wide range of soil conditions although they prefer well drained soils with a pH of approximately 6.0 to 6.5. They are very drought and salt tolerant, highly disease resistant, wear resistant, recover well from traffic and form an extremely dense vigorous turf. Certain hybrid bermudagrass cultivars (*C. dactylon* x *C. transvaalensis* Burtt-Davey) are well adapted to very close frequent mowing required for golf putting greens. Bermudagrasses are intolerant of shade and require relatively frequent applications of fertilizer.

Roughs

The Lihi Lani golf course will be designed using the "target golf" concept in which only the teeing grounds, landing areas, greens and immediate surroundings are maintained. The roughs are largely ungraded and will consist mainly of the natural vegetation of the area. The primary roughs, or the roughs immediately surrounding the landing areas, tees, greens, etc. should be the same grass as the fairways. This will eliminate the encroachment of different grasses into these maintained areas and therefore the need for herbicide applications to control the invading cultivars.

Fairways

Common (*C. dactylon* (L.) Pers), Sahara (*C. dactylon* (L.) Pers), Tifway (Tifton 419) (*C. dactylon* x *C. transvaalensis* Burtt-Davey), Tifway II (*C. dactylon* x *C. transvaalensis* Burtt-Davey), and Tifgreen (Tifton 328) (*C. dactylon* x *C. transvaalensis* Burtt-Davey) are the bermudagrasses most commonly used for fairways. All have similar adaptations, although common is less dense, less wear resistant, and less resistant to

drought, soil salinity and certain insects than Sahara and the three hybrid bermudagrasses. Sahara bermudagrass is a selected strain of common bermudagrass. It is finer textured, denser and darker green than common bermudagrass. It is also said to be more drought tolerant than common. Sahara is a relatively new cultivar and has not been used to any extent in Hawaii. Tifway, Tifway II and Tifgreen are finer textured grasses which form a dense vigorous fairway turf. Tifway, because of its stiff, upright leaf growth, was specifically selected for use on fairways because it provides an excellent lie from which to hit fairway shots. Tifway is the most popular hybrid bermudagrass for fairway turf in regions where warm season grasses are adapted.

Tees

The same cultivars mentioned above for use on fairways are the most frequently used grasses for tees throughout the warmer parts of the world. Because of the more dense growth habit, tolerance to close mowing, and resistance to insects and diseases, Tifway bermudagrass is perhaps the most desirable cultivar for this use.

Greens

Tifgreen and Tifdwarf (*C. dactylon* X *C. transvaalensis* Burtt-Davey) bermudagrass are two cultivars most frequently used for putting greens throughout the warm parts of the world. Creeping bentgrass (*Agrostis stolonifera* L.) is perhaps the most desirable grass for greens in areas where it is adapted. As mentioned previously, however, creeping bentgrass is not well adapted in Hawaii and would require frequent pesticide (especially fungicide) if used for greens on the Lihi Lani golf course. Tifgreen has proven to be more wear tolerant and less susceptible to certain diseases. Tifgreen is perhaps the most desirable Cultivar for use at the Lihi Lani site.

ESTABLISHMENT

The establishment phase of turfgrasses is perhaps one of the most critical phases.Thin, open areas resulting from failure of the turfgrass to establish properly provide avenues for encroachment of weeds. Serious loss of soil may also occur in thin areas if heavy rainfall is experienced. Proper establishment minimizes the time required to achieve a satisfactory level of turfgrass cover and quality. Failure to follow good establishment practices may make it impossible to achieve adequate turfgrass quality later.

Soil preparation

The primary objective of soil preparation for planting is to provide a fine, granular soil for good seed-soil (or vegetative propagules-soil) contact and rapid establishment of a deep healthy root system. The soil should have adequate water percolation rate and drainage (both surface and internal) to prevent waterloging or ponding in low areas after wet periods.There should be no nutrient deficiencies or toxicities. All large rocks should be removed which might interfere with play or cause droughty areas once turfgrasses are established. All organic debris such as tree stumps, large roots, etc. should be removed, as they may decay and cause depressions in the surface. Organic debris also often leads to the invasion of fairy ring fungi which are discussed in the section on turfgrass diseases.

The soil should contain sufficient organic matter to provide nutrient and moisture retention properties and to retard the movement of pest control chemicals to groundwater. The existing topsoil in graded areas should be stockpiled and replaced on the surface once grading is complete. This will ensure a surface soil with higher organic matter than would be the case if the graded subsoil were used for the final grade.

The topsoil and subsoil should be tested prior to final grading for essential nutrients and pH. Any needed lime and fertilizer should be applied to the subsoil and cultivated in to a depth of 4 to 6 inches before replacing the topsoil. Nutrient deficiencies and pH should also be corrected when the topsoil is replaced.

Tees and greens should always be specially constructed to provide adequate drainage and compaction resistance. The United States Golf Association Specifications for constructing putting greens should be followed in constructing greens. The tees should also be constructed using a soil mixture dominated by sand. Methods similar to the U. S. Golf Association specifications for greens construction is suggested for tee construction.

Weed control

Weeds which are difficult to control or cannot be selectively controlled in desirable turfgrasses should be controlled prior to planting turf. Included in this category in the Lihi Lani area would be bermudagrass, smutgrass or rattail grass (*Sporoboulus* spp.), Haole Koa (*Leucena leucocephala* L.), Broom sedge (*Andropogon virginicus* L.), etc. Translocated non-selective herbicides can be applied prior to grading operations to kill existing perennial weeds. Sufficient time should be allowed between spraying and grading operations to allow the herbicide to translocate throughout the plant and kill perennial parts which might reinvade the graded areas. Roundup (glyphosate) will provide adequate control of most weeds in the area. It is also a relatively environmentally safe herbicide with little likelihood of leaching to groundwater or contaminating surface waters.

Greens and tees should be fumigated with methyl bromide plus chloropicrin to ensure the complete control of all weed seed and vegetative propagules. The use of methyl bromide is restricted to Licensed Pest Control Operators only. It's use also requires a permit from the State Health Department. It is applied as a gas under a gas-tight plastic sheet. Because of the relatively small areas treated (greens and tees combined constitute only approximately 5 to 6 acres), the special precautions followed in its use, and its rapid breakdown after treatment, however, if properly applied there should be no negative environmental impact from its use.

Planting turf

Turfgrasses are propagated by seed or by vegetative propagation. Common and Sahara bermudagrass are the only cultivars which can be planted by seed. The other bermudagrass cultivars are all interspecific hybrids and do not produce seed. Methods of vegetative propagation include sprigging (planting pieces of stolons and/or rhizomes) in rows, stolonizing (planting pieces of stolons and/or rhizomes broadcast over the entire area), sodding (planting pieces of sod solid over the entire area), or plugging (planting plugs of turf and soil at spaced intervals over the area). The recommended method of vegetative propagation for fairways is sprigging, as it requires less planting material than other methods and there are sprigging machines available which greatly facilitate the operation. For tees and greens the recommended method of vegetative propagation is stolonizing, as it provides rapid establishment of a more uniform surface than other methods.

If fairways and primary roughs are seeded, the highest quality seed obtainable should be used (seed quality refers to purity, and seed germination). The seed should be free of noxious weeds and off-type bermudagrasses. Common bermudagrass lots are often contaminated with an extremely coarse, undesirable type of giant bermudagrass. Beware of lots with even small percentages of weed seed as some weeds have extremely small seeds. A seed lot containing 0.2% of a weed seed which has 1 million seed per pound

would contain 2,000 weed seed per pound. At recommended seeding rates for bermudagrass, this would result in 3 to 5 potential weeds per square foot. Hulled bermudagrass seed (seed with the husks removed) should be used. Minimum seed purity for bermudagrass seed should be 98%; minimum germination should be 85%. Seeding rate for hulled seed is 40 to 65 lb/acre.

For sprigging bermudagrasses, only sod containing no foreign grasses should be used. Sod fields should be inspected prior to accepting sprigs to be sure there is no contamination. Approximately 200 to 300 bushels of sprigs/acre are required (a square yard of dense sod will produce approximately 1 bushel of stolons). Since there are few sod farms in Hawaii, and perhaps none which can supply the large amount of stolons needed for sprigging the fairways of a golf course, arrangements should be made in advance for growing the sod. The sod can either be contracted by arranging with a local grower to supply the needed sod at a specified time in the future or a sod nursery can be prepared on the golf course site well in advance of anticipated planting time.

A cultipacker seeder is the best method for planting seeded bermudagrasses. This equipment firms the soil around the seed at a shallow depth (0.1 to 0.4 inches) which is very important in promoting rapid seed germination and seedling establishment. Mechanical spriggers should be used for vegetative propagation of hybrid bermudagrasses. This equipment places sprigs (pieces of grass consisting of stolons, rhizomes, stems, leaves etc.) in 1 to 2 inch deep furrows spaced 10 to 18 inches apart. A roller mounted over each furrow then firms the soil around the sprigs in the rows. Tees, if planting the same cultivar used for fairways, can be planted at the same time and in the same manner as fairways.

Greens should always be planted after the fairways and areas surrounding the greens have been established. The rootzone soil should always be fumigated with methyl bromide plus chloropicrin. Fumigation should be done after fairway and surrounding plantings have germinated. This will kill any seedlings which have invaded the greens from seed carried by wind, water, birds, or other means. It is not unusual to find greens seriously invaded by common bermudagrass which was seeded in the fairways after greens are planted. This sometimes requires refumigation of greens and replanting the desired putting green grass. Tees should be planted at the same time as greens and in the same manner if a cultivar different from that used on fairways is to be used on the tees. Greens and tees (if tees are planted by vegetative propagation) should be stolonized. A hydromulcher with a mixture of sprigs, mulch and fertilizer can be used to plant greens and tees. Sprigs can also be broadcast by hand and covered using a topdressing machine. Higher rates of sprigs (12 to 16 bushels of sprigs/1000 sq. ft.) should be used on Greens and tees.

Mulching of new plantings, whether seeded or planted by vegetative means, is a good practice. Mulches provide soil erosion protection, stabilize soil temperatures, and conserve soil moisture. Wood cellulose fiber mulch can be spread from a hydroseeder which provides good coverage.

Post planting care is critical to achieving successful turf establishment. Newly sprigged areas should be irrigated immediately after planting to avoid loss from desiccation. It is not as critical that new seedings be irrigated immediately, however, the sooner new seedings are irrigated following planting, the more rapidly seed germination and turf establishment will occur. Frequent (2 to 3 times/day), light irrigations should be scheduled for a two to three week period after germination or until the seedlings have established sufficient root depth to draw water from deeper soil levels. The amount of irrigation at one application during this phase is small. Water should not puddle or runoff. It is also not necessary to soak the soil to a great depth.

Light, frequent applications of nitrogen fertilizer during the establishment (11 to 40 lb. N/acre/2 wks.) (0.25 to 0.5 lb. N/1000 sq. ft./2 wks.) will greatly speed the rate of establishment of a dense, vigorous turf. N application frequency should be reduced once the turf has become fully established.

Mowing of new fairway and rough plantings should start when the seedlings have reached approximately 2 inches height and have established sufficient cover to prevent rutting of the soil by mowing equipment. They should also have sufficient root system to prevent being pulled from the soil by mowers. The first cuttings (for about a 6 to 10 week period) should be at approximately 1 to 1.5 inches high. Afterward the cutting height can be gradually lowered until the desired height is reached.

Mowing of new greens and tees should be started as soon as the young shoots are firmly rooted (the new shoots will be approximately 0.3 to 0.6 inches high). The mowing should be done when the seedlings are dry, preferably near midday. The clippings should not be removed during the establishment phase. The initial mowing frequency is about 2 to 3 times/week. This will be reduced as the turf matures. Grass catchers should be used when the turf is producing large enough quantity of clippings to create shading and environmental conditions conducive to disease activity.

Frequent topdressing with light applications of the same material used in the rootzone of greens and tees is necessary for achieving a smooth, uniform surface.Topdressings should be light (0.1-0.25 cu. yd./1000 sq. ft.). Topdressing frequency should be about weekly. Topdressing material should be applied with a topdressing machine. The topdressing should be worked into the turf and smoothed by careful matting with a flexible steel drag. Tees and greens should be dry enough when topdressing is applied to prevent rutting by equipment.

MAINTENANCE OF ESTABLISHED TURF

Roughs

Mowing

The roughs of the Lihi Lani golf course will be mostly unmowed. The natural vegetation of the area will comprise all except for a small area of rough surrounding the landing areas of fairways (the primary rough). The primary rough will be the same cultivar used in the fairways. Bermudagrass primary roughs should be mowed at approximately 1.5 inches. Higher mowing heights may be desired for tournament play, or on other special occasions. Because of the thick, dense growth habit, bermudagrass roughs mowed at heights above 1.5 inches are excessively penal. The mowing frequency will depend on the growth rate of the grass. Typical mowing frequency for bermudagrass primary roughs is 1 to 2 week intervals.

Fertilization

Once a mature sod is formed, the primary rough fertilization level can be decreased to 2 to 3 applications/year of approximately 40 lb. N./acre. The amount and frequency of fertilization can be adjusted, depending upon the desired level of growth of the roughs.

Weed control

Weed control may be practiced in the primary rough because weeds here may provide a seed source for infestation of fairways. A mixture of 2,4-D, dicamba, and MCPP is generally used for broadleaf weed control. MSMA and metrubuzin are most commonly

used for grassy weed control (see the section on weed IPM). Of course, the aim of an IPM program is to reduce the dependance on chemical weed controls. Good establishment and maintenance practices will reduce the dependance upon herbicides to control weeds. The action level for weed control in roughs will be lowest of that of any area of the golf course.

Insect control

Insecticide applications may sometimes be necessary in the primary roughs to control severe insect outbreaks which may spread to adjacent fairways. Insecticide treatments should be restricted to spot treatment on a curative basis.

Other cultural practices

Cultivation (aerifying, slicing, etc.) is done less often on roughs than on fairways and is limited to areas of intense traffic such as where motorized cart traffic is intense.

Liming may be necessary to adjust soil reaction periodically (usually no more often than once/2 to 3 years). A soil test should be taken at 2 year intervals to determine the need for soil reaction adjustment.

Irrigation is seldom practiced on roughs except in arid and semiarid climates. Irrigation of roughs may not be necessary at the Lihi Lani site.

Fairways

Mowing

Bermudagrass fairways should be mown at approximately 0.5 to 0. 75 inch heights. Hybrid bermudagrasses (Tifway, Tifgreen, Tifway II) are usually mowed at lower heights than common bermudagrass. Mowing interval is normally ever 2 to 3 days depending upon rate of growth of the grass. A rule of thumb for mowing frequency which takes into account the growth rate of the grass is to never remove more than one-third the height of the grass at one mowing.

Seven to ten-bladed real mowers are used to maintain proper fairway surface quality. The lower the mowing height, the higher the clip frequency of the mower should be, therefore the greater the number of blades the mower reels should have. Fairway mowers may be self propelled units, pulled behind tractors, or mounted on tractors. Five, seven and nine gangs are common. Hydraulically driven reels give a better cut under close mowing conditions than ground driven reels, especially under wet soil conditions. Mower blades must be kept sharp and properly aligned at all times. Dull or improperly aligned mowers will tear the turf and provide ideal entry points for disease organisms. A reel grinder and back lapping equipment is a must for every golf course. Proper mowing speed is also essential for proper cutting quality and to avoid injury to the grass. Rippling and tearing of the leaf blades are the results of operating mowers at excessive speeds. Mower turns should be made at a reduced speed and should be wide enough to avoid bruising or tearing of the turf and compaction and rutting of the soil.

Mowing should be done in early morning to keep ahead of play. Clippings are returned to the turf. Mowing of wet turf should be avoided if at all possible. Alternating the direction of mowing on fairways encourages upright growth of the grass and provides a better lie for the golf ball.

Fertilization

The fertilizer requirement of fairways varies with the species and cultivar of grass being used, the soil type, soil cation exchange capacity, amount of rainfall and/or irrigation received, growing conditions, amount of play, desired quality of fairways desired by management, etc. Bermudagrass fairways usually receive nitrogen fertilization throughout the year in Hawaii, although the frequency and rate may be reduced in winter months (October through March) when the growth rate slows because of cool, cloudy weather. Usually a complete fertilizer (one containing the 3 major plant nutrients; N, P and K) with a 4-1-2 ratio is applied. The rate and frequency of application will depend largely on the desired level of appearance and the source of nitrogen in the fertilizer. Fertilizers in which the nitrogen is in a slow-release form (ureaformaldehyde, IBDU, or sulfur coated urea) may be applied at higher rates and less frequently. Slow release N forms are more desirable than soluble N forms from the standpoint of reducing the potential for leaching of nitrate to groundwater, as the N becomes available at approximately the same rate as N uptake by the turfgrass. Slow-release N forms are also desirable from the standpoint of maintaining a more steady rate of growth of turf because large amounts of available N are not present soon after fertilizer application. Lush, succulent growth of turfgrass resulting from excessive nitrogen stimulation is also more susceptible to drought stress, wear stress, and attack by disease organisms. Alternate ways of providing a steady rate of N fertilization is to apply a small amount of N with each irrigation through the irrigation system (fertigation), however irrigation application is never uniform, especially under the windy conditions which exist at the Lihi Lani site. Fertigation is not recommended at this location. Reduced leaching potential and increased uniformity of growth of turf could be obtained by light, frequent applications of soluble N sources, but this would increase the frequency of fertilizer applications and thus increase maintenance costs. This increased cost of more frequent fertilizer application with soluble N sources may be offset by the greater cost of slow-release N sources. Each Golf Course Superintendent will have to determine the most desirable material for their own situation.

Regardless of the N source and frequency of application, sufficient nitrogen must be applied to maintain turfgrass density, recruperative potential, and color. Commonly, 300 to 400 pounds of N/acre/year are applied to fairways in Hawaii.

The need for phosphorus (P) and potassium fertilizer is generally less than for N. If soil deficiencies of P and K are corrected at time of establishment of turf, and a complete fertilizer with a 4-1-2 ratio is used, then the P and K requirements of the turf should be met. Periodic soil testing (once/year or once/2 years) should be done to determine the need for additional P and K applications.

Liming may be required periodically to maintain the proper soil reaction (pH). The soil pH should be maintained in the 5.5 to 6.5 range for best growth of bermudagrasses.

Irrigation

Irrigation programming (amount of water to apply, when to apply it, how much to apply at one time) is one of the most critical aspects of golf course management. Proper water management has a very strong influence on all aspects of turf growth and quality. Over watering is one of the most common problems encountered on golf courses in Hawaii. Over watering has many detrimental influences on turfgrass growth. Excess water causes waterlogging of soils and reduces the soil oxygen necessary for root growth and metabolism, increases soil compaction, leaches mobile nutrients (especially N) from the soil, increases the potential for pesticide leaching, and results in soft succulent growth which is susceptible to diseases and environmental stresses. Under watering results in

reduced growth and vigor of turfgrasses and, if the grass is under moisture stress too long, death of the plants. It is therefore extremely important that good irrigation management be practiced.

Evapotranspiration of turf is the water transpired by the plants plus that evaporated from the soil, thus the name evapotranspiration. Water use by dense vigorous turfgrass stands which fully cover the soil is essentially all transpiration. Grasses transpire large amounts of water. Most of the water is used for regulating the temperature of the plant rather than for building plant material. Warm season grasses use approximately 25% to 50% less water than cool season grasses. Research has shown very little difference in water use between different genera of warm season grasses. The aim in irrigation programming should be to replace the water actually used by the plant. In some cases where brackish irrigation water is used, or when salts from fertilizers accumulate in the soil and there is insufficient rainfall to leach them from the rootzone, it may be necessary to apply additional water above the need of the turf in order to leach salts out of the rootzone. This is sometimes referred to as a "leaching fraction".

Several methods may be used to determine the amount of water and when to apply it. Perhaps the most simple and most reliable is the "water budgeting method" or simply determining the amount of water used by the turf in a given amount of time and replacing that amount before the turf suffers from extended moisture stress. This requires knowledge of the water holding capacity of soil and the rate at which water is being used by the turfgrass. For practical purposes, the depth of rooting of turfgrass under fairway conditions can be considered to be 1 foot. Thus the reservoir for holding moisture can be considered to be 1 foot deep.

The available water holding capacity of the soil can be determined by a soil laboratory. As a general rule of thumb, clay soils may hold as much as 3 inches of water per foot of depth. Sandy soils may hold as little as 0.5 inches of water per foot of depth. Clay loam soils may hold 1.5 to 2.0 inches per foot of depth. As the moisture content of the soil decreases, it becomes increasingly difficult for the plant to extract the water from the soil. It is therefore desirable to apply irrigation water before all the water is used. General it is recommended that irrigation be applied when one-half the available soil moisture has been depleted. Therefore if the turf is growing in a soil which stores 1.5 inches of available moisture per foot of depth, 0.75 inches of water should be applied when 0.75 inches have been used. Actually, since irrigation efficiency is never 100% additional water (10 to 15% in addition to that actually used) is usually applied to account for inefficient sprinkler coverage. Thus 0.83 inches would be applied when 0.75 inches were used. If a leaching fraction is needed, this amount would also be added.

Once the available water holding capacity of the soil has been determined, the next information needed is the water use rate (usually expressed in parts of an inch of water per day). There are several methods by which this can be determined. Perhaps the simplest, most reliable method is the utilization of a U. S. Weather Bureau Class A Evaporating Pan. This is a standardized pan (6 feet in diameter) which is set up according to certain specifications and the amount of water evaporating daily is measured. Rainfall falling into the pan will be automatically accounted for as negative evaporation. Pan evaporation is a unifying measure of weather elements and can be used to estimate the amount of water used by plants in response to those same weather elements. Research at several locations has shown that warm season turfgrasses, including bermudagrass cultivars, use only approximately 50% of pan evaporation. Thus in the example given above, if one were irrigating with 0.83 inches of water when 0.75 inches were used, the water would be applied when 1.5 inches of water had evaporated from the pan. This requires reeding the evaporation every day. Recorders are available which record the amount used but this still requires looking at the record. Modern Irrigation systems have electronic weather sensing elements which sense the weather conditions (usually amount of sunlight, temperature, relative humidity, and wind speed) and calculate water use rate. This is then fed into a computer program which programs the water application rate. Modern computer controlled irrigation systems are very complex. Often the water application rate of each sprinkler head on the golf course can be individually programmed (valve-in-head sprinklers).

Since water use rate will vary greatly from area to area on the golf course depending on the aspect of slope, the amount of sunlight, the available soil moisture holding capacity, the rooting depth of the turf, the amount of traffic, the amount of wind, relative humidity, temperature, etc., the amount of water applied in different areas of the golf course will vary from the overall estimation obtained by pan evaporation or from electronic weather sensors. These figures can serve as a basic guide. The amount of water applied to individual areas on the golf course will have to be adjusted to account for environmental differences. Only by close observation of all areas covered by the irrigation system by an experienced turfgrass manager can proper adjustments be made. This must be a continual practice, because sprinkler output often changes due to nozzle wear, changes in water pressure, etc.

Thatch control

Thatch is the undecomposed layer of organic material that accumulates between the soil surface and the green portion of the turf. Thatch interferes with water and air movement into and through the soil, and provides an ideal environment for certain insect and disease organisms. If thatch becomes dry, it may be very difficult to rewet and actually shed water like a thatched roof (thus the name). Since thatch is the result of plant material being produced at a rate exceeding its decay, cultural practices are the best method of thatch control. Moderate N fertilization, moderate irrigation rates, irrigating deeply and less frequently, soil cultivation, especially core aerification, avoiding excessive applications of pesticides which may reduce populations of earthworms and decomposing fungi, maintaining proper soil reaction (pH of 6.0 to 7.0) for optimum soil microorganism activity are all cultural practices which will reduce the thatching potential of turfgrasses.

Vertical mowing (using special mowers in which the blades operate in a vertical plane to thin the turf and remove some of the dead organic matter) in combination with core aerification is the most effective method of correcting a thatch problem once it is present. Thatch correction should be done when the turf is actively growing so that recovery is rapid.

Compaction correction

Soil compaction resulting from motorized golf carts and/or turfgrass maintenance equipment can become a problem on fine-textured soils with a high clay content. Compaction tendency increases on wet soils. Soil compaction results in decreased water infiltration and percolation rates, restricted root system due to oxygen deficiency in the rootzone, a shallow-rooted, unthrifty turf, a decline in turfgrass density and increased susceptibility to environmental stress and diseases.

Soil compaction can be reduced by proper cultural practices. Practices which are particularly helpful include: restricting use of motorized golf carts when the fairways are wet; restricting the use of motorized golf carts to cart paths only; using the "90 degree rule" in which motorized golf carts are operated on paved cart paths until even with the golf ball to be played then approaching the golf ball at a 90 degree angle, playing the shot and returning to the path at a 90 degree angle; keeping mowing equipment off the fairways when they are wet; maintaining adequate mowing height to provide adequate shoot growth

to cushion vehicular traffic; irrigating infrequently enough to allow the soil surface to dry between irrigations; installing adequate surface and/or subsurface drainage to remove excessive water.

Soil compaction is corrected by core aerification or slicing equipment. The frequency of these operations will depend upon turf use patterns, and environmental factors discussed previously. Core aerification of fairways should be done at least 2 times/year. Areas receiving intense traffic or where soil conditions are especially conducive to compaction may require more frequent aerification.

Greens

Mowing

The demand for high quality, uniform, smooth putting surfaces requires extremely close and frequent mowing. This places severe stress on the turfgrass. Rooting depth, carbohydrate reserves, wear resistance, ability to recover from injury, resistance to diseases, and resistance to environmental stress are all adversely affected by close mowing.

The use of 8 to 9 bladed reel mowers is necessary to maintain the high quality of cut demanded of putting greens. Clippings are always removed from putting greens, as they would interfere with putting if left on the greens. Two basic types of greens mowers are used, the walking greens mower which has a single reel and cuts a 18 to 22 inch mowing width and the riding triplex (three cutting units) which cuts a 58 to 62 inch mowing width. Walking greens mowers provide a higher quality cut, cause less injury to the turf, and cause less compaction to putting greens soils than the larger, heavier riding mowers. Riding mowers, of course, are faster. One to 2 riding greens mowers can cut the 18 greens of a golf course in 2.5 to 3 hours while it may take as many as 6 walking greens mowers to cut the same greens in the same amount of time.

Bermudagrass putting greens in Hawaii should be mown at 0.19 to 0.25 inches (3/16 to 1/4 inch). Although some golf courses in Hawaii mow greens as close as 0.125 inch (1/8 inch), this practice places great stress on the turf and is not recommended as a general practice. Generally, the higher cutting height is preferable in terms of vigor of the turfgrass. The lower height may be preferred by better golfers. The decision on mowing height must be carefully considered by the individual superintendent and depends largely on the desires of management. From the viewpoint of IPM, the higher mowing height will reduce the susceptibility of putting greens grass to turfgrass pests, especially diseases which attack weakened turf, and will reduce the number of pesticide applications required to maintain quality turf.

Daily mowing is the general rule to maintain high quality putting surfaces, especially during periods of active growth of the turfgrass. During the winter months, temperatures at Lihi Lani will often be low enough that growth rate is reduced and less frequent mowing can be practiced. It has been found that less frequent mowing (even skipping one day in seven) results in improved root depth and improved turfgrass vigor.

The mowing pattern should be altered daily in each of four directions to minimize the development of grain (the tendency for the grass to grow in one direction). This procedure is usually described as "around the clock" in directions designated 12 to 6, 3 to 9, 4:30 to 10:30 and finally 1:30 to 9:30. The cycle can be reversed once the four directions are completed (6 to 12, 9 to 3, 10:30 to 4:30, and 9:30 to 1:30). The exact directions may be limited by turning areas, especially where riding triplex greens mowers are used. Turfgrass wear and thinning is usually a problem around the perimeter of greens mowed with a riding triplex mower. This results from the standard practice of making a final mowing pass around the perimeter of the green to clean up missed areas from turning and to pick up any loose clippings left when the mowers were turned. The wear problem can be alleviated by skipping the perimeter cut periodically, by moving the perimeter cut in or out one tire width on alternate days, by reducing the speed of the mower during the final outer cut, or by doing the final perimeter cut with a hand greens mower.

Fertilization

Putting greens are constructed of sand or mixtures dominated by sand. They are usually very porous and have low cation exchange capacity (CEC). As a result, nutrient holding capacity is usually low. The frequent irrigation generally practiced on putting greens results in leaching of nutrients which move readily with water (particularly nitrogen). In Hawaii, the sand used for putting green construction is usually coral sand, as silica sand must be imported. Use of coral sand results in high pH of putting greens soils and creates conditions of reduced availability of certain minor elements (especially iron).

Fertilizer rates are generally higher for putting greens than for other areas of the golf course, primarily because of the increased demands from close mowing. Minor elements, especially iron, are applied more frequently on putting greens than on other areas of the golf course also. The nutrient requirements of putting greens, as for all other areas of the golf course, vary with the cultivar of grass used, the mowing height and frequency, the amount of water being applied, the soil mix utilized in the putting green, the environmental conditions, the type of fertilizer used, the desires of management, etc. While it is not possible to use one fertilizer program for all situations, characteristics of fertilizer carriers and criteria for selecting a fertilizer program (a combination of type of carrier, application rate and frequency, application time, etc.) are discussed in this section. Some generalities are also made.

The fertilizer program may utilize a complete fertilizer throughout the year or a complete fertilizer applied 2 to 3 times per year supplemented with straight nitrogen (N) carriers at other times. Since nitrogen is used in large quantities by turf and leaches readily from the soil, it must be applied more frequently and at higher rates than phosphorus (P) and potassium (K). Nitrogen fertilizer sources may be water soluble (ammonium sulfate, urea, calcium nitrate, etc.) in which the nitrogen is immediately available. Other nitrogen carriers are water insoluble (or very slowly soluble) and the nitrogen must be released from complex compounds before it is available to the plants (slow release or controlled release nitrogen). The latter includes N carriers such as ureaformaldehyde, IBDU, and sulfur coated urea). Soluble nitrogen sources have the advantage of providing a rapid initial turf response, however, the nitrogen is soon used by the turf or leached from the rootzone and the response is short-lived. Soluble N sources also a high salt index (an index of the tendency to raise the osmotic potential of the soil solution) and may cause burning of the turf if applied at excessive rates or to wet turf and not watered in well. Slow release N sources were developed in an attempt to eliminate the disadvantages of soluble N fertilizers. They may be applied at higher rates and less frequently than soluble N sources. One of the chief advantages of slow release N sources is the reduced tendency for leaching of N, since nitrogen is released at a rate similar to the N requirements of the turfgrass.

Phosphorus

Phosphorus is required in much smaller amounts than either N or K and also is not prone to leaching as are the latter. It is still important to maintain adequate levels of P in the rootzone, however, as P has been shown to be very important in root development. since P moves very slowly in soil, application of P after core aeration and before topdressing is

applied is the preferred way to achieve deep soil penetration of this nutrient.

Potassium

Potassium is less prone to leaching than nitrogen, although it may leach from greens high in sand content. Potassium may be applied as part of a complete fertilizer along with N or as a straight potassium carrier such as potassium sulfate or potassium chloride. Slow release potassium fertilizers have not been developed. Potassium has been shown to be very important in conferring stress resistance to turfgrasses. Adequate potassium fertilizer should be applied as part of an IPM program in order to maintain hardy, stress resistant turf.

Iron

Iron (Fe) is the micronutrient most commonly applied to golf putting greens. Because it is in the unavailable form at high pH (above about 6.0), it is especially critical in Hawaii, where golf greens are constructed with beach sand. Iron is very important in the formation of chlorophyll in the plant, therefore applications of Fe result in a rapid, dramatic greening response. As long as sufficient N is applied to maintain adequate recuperative growth, reducing the amount of N fertilization and increasing frequency of Fe applications enable maintenance of an attractive green turf color without producing a soft, succulent type of growth. Iron is commonly applied as iron sulfate or as chelated iron. Iron sulfate is a soluble form of iron. It is rendered unavailable in soils with high pH, therefore it is taken up primarily through the leaves of the turf. Iron sulfate applications at the rate of 2 to 3 ounces per 1000 sq. ft. at biweekly to monthly intervals are needed on coral sand greens. Iron chelate is an iron molecule attached to an organic molecule which prevents it from being tied up in the soil. It is somewhat more soil residual than iron sulfate and can be applied at higher rates and less frequently. The greening response to chelated iron is not as rapid or as dramatic as that to iron sulfate.

Soil reaction adjustments

Soil reaction (pH) may be lowered in soils by application of elemental sulfur (95%), or by use of acid forming fertilizers (ammonium sulfate, urea, sulfur coated urea, etc.). The pH may be raised by application of agricultural limestone. The amount and rate of application of each can only be determined by soil analysis by an experienced laboratory technician. Golf greens constructed with coral sand have a high pH (7.5 to 8.5) which is impossible to adjust. Materials, such as sulfur, applied to the green would react with the coral in the sand and the pH would remain the same. Use of acid forming fertilizers on coral sand is not desirable, as an insoluble precipitate, similar to cement, is formed when the coral reacts with acid. Water percolation through the green may be seriously impaired by dissolution of the coral.

If the greens are constructed of Mansand or silica sand, the standard soil reaction adjusting materials (sulfur and lime) may be used to adjust the pH to the desirable range.

Irrigation

Irrigation is one of the most critical maintenance practices on golf greens as well as other areas of the golf course. The principles of irrigation scheduling by water budget previously discussed also applies to irrigation of golf greens. It should be remembered, however, that each individual green will have specific irrigation requirements because of differences in amount of sunlight, exposure to wind, amount of traffic, etc. Pan evaporation data can serve as a good starting point from which to adjust needs of specific greens.

Deep, infrequent irrigation is preferred to frequent shallow irrigation. The extremely close mowing practiced on golf greens, however, results in shallow root systems and a smaller reservoir from which the turf may draw water. The fact that golf greens are constructed of mixes with a high sand content and have a low water holding capacity (less than 1 in./ft. of depth) further reduces the amount of water available after irrigation. It may be necessary to irrigate golf greens which are exposed to environmental conditions conducive to high evapotranspiration rates on a daily frequency.

The most desirable time to apply irrigation water from the standpoint of health of the turfgrass is in the early morning. Morning watering allows drying of the leaves soon after sunup and prevents leaf wetness over night. It may be necessary to start irrigation before dawn in order to complete irrigation of all stations before golfers or mowing equipment is on the course. Scheduling irrigations of different sections of the golf course on different days, will help to decrease the time required to complete the irrigation schedule each day.

The water application rate should be uniform over the entire green and slower than the water infiltration rate of the soil in order to prevent puddling or runoff. Sprinkler application rate can be adjusted by changing nozzle size. The pressure should be that recommended by the manufacturer for best performance of the nozzle being used. Changing pressure may alter the coverage of the sprinkler head.

Syringing (application of a small amount of water in fine droplets) may be necessary on exposed greens during midsummer when evapotranspiration rates exceed the rate at which water is taken up by the plant. Syringing functions primarily to increase the relative humidity of the immediate area surrounding the turf leaf and also reducing the temperature of the surface, thereby reducing the transpiration rate of the turf. Most modern golf irrigation systems have a syringe cycle built into the sprinklers around the greens. Alternately, syringing can be done manually, using a hand-held hose attached to a quick coupler valve near the green.

Cultivation

Correcting compaction

Soil compaction is especially severe on golf greens because of the amount of traffic and the lack of cushioning because of close mowing. Symptoms of soil compaction include restricted root growth, slow water infiltration rates, and turf thinning. Soil compaction can be prevented by proper construction using a desirable sand which will resist compaction.

Core cultivation followed by light topdressing with a suitable sand is the best way to relieve compaction once it occurs. Tines of 0.25 to 0.63 inch diameter are available. The larger tines remove a larger core and are more effective in relieving compaction. The smaller tines may be desirable when environmental conditions are not best for rapid recovery or to prevent interference with putting quality. Soil cores left by the coring machine can be left on the surface to dry, then broken up by running a vertical mower over them and using the cores for topdressing. This should only be practiced if the soil mix in the green is desirable. Cores should always be removed if the sand content of the green is low, or if there is a heavy thatch accumulation.

The holes left by coring should be filled with topdressing. Pure sand of proper particle size is the most desirable topdressing material. Proper topdressing sand should have more than 85% of the particles between 0.5 and 0.25 mm diameter. No more than

0.25 inch of topdressing is desirable. The sand should be worked into the holes by dragging with a flexible steel mat behind a utility vehicle.

Thatch control

Prevention of thatch accumulation through proper cultural practices is the most desirable method of thatch control. Critical cultural practices include; avoiding over stimulation of turf with N fertilization, avoiding over irrigation, utilizing vertical mower attachments on greens mowers frequently (light vertical mowing 1 to 2 times/week during vigorous growing periods), and light, frequent topdressing. Heavy applications of topdressing and topdressing material containing organic amendments are to be avoided, as they increase thatch accumulation.

Accumulated thatch layers are best removed by a combination of vertical mowing, core cultivation and topdressing. Vertical mowing to remove accumulated thatch is much more drastic than the light, frequent vertical mowing recommended to prevent thatch accumulation. In the case of thatch removal, the blades should penetrate to the soil level. This requires use of a self propelled vertical mower and results in disruption of putting quality for some time. Frequent core cultivation, followed by light topdressing in combination with the vertical mowing will speed removal of the thatch layer.

Tees

Mowing

The cutting height on tees must be low enough so that leaf growth does not interfere with striking the golf ball when it is teed at the desired height. A low mowing height also provides a firm, solid footing for the golfer's stance. Common bermudagrass tees should be mowed at 0.75 to 1.0 inch height. Hybrid bermudagrass tees can be mown at 0.3 to 0.5 inches. The mowing frequency will depend upon the growth rate of the grass. In practice tees are mowed 2 to 4 times per week. Clippings are usually removed but may be left on the grass if they are not excessively heavy. Tees are usually mowed with a triplex mower with six to eight blades per reel.The mower blades should be kept sharp and well adjusted. Before mowing tees, the area should be inspected and shoe spikes and wooden tees should be removed, as they may damage reel blades or bedknives of mowers.

Fertilization

Sufficient N fertilization must be maintained to provide rapid recovery from divot injury. Potassium fertilization is also important to impart wear resistance to the turf. Frequent fertilization with a 4-1-2 ration complete fertilizer (1.0 to 1.5 lb. N/1000 sq. ft./month) is perhaps the best method of maintaining good growth on tees.

Soil reaction adjustment

Tees are often constructed of sand. In the case of coral sand, the remarks about pH adjustments previously discussed for golf greens also apply for tees. Otherwise, lime and sulfur may be used to raise or lower the pH, respectively. Amount and frequency of application can best be determined by submitting a soil sample to a competent soils laboratory.

Irrigation

Tees are mown relatively closely and frequently and may be constructed similarly to putting greens, therefore irrigation of tees is similar to that discussed for greens. The water budget method, utilizing pan evaporation data should be used as a guide for scheduling irrigation. Amount and frequency of irrigation of individual greens will need to be adjusted for micro environment conditions.

Divot injury

Because of the nature of the type of play on golf tees, divots are taken which cause thinning of the green and may lead to weed invasion. Divot injury is best controlled by frequent moving of the tee markers. The teeing ground is defined as the area between the tee markers and two club lengths behind them. Divot injury can best be controlled by frequent moving of the tee markers. Tee markers should be changed every day. On small tees or in cases of heavy play, they should be changed 2 times per day. This will allow maximum recovery time for each area.

In addition to frequent marker changes, topdressing of divot marks with sand will speed the rate of recovery of divot marks. Optimum fertilizer and irrigation practices are required to keep the grass in a vigorous condition. Over watering which leads to increased soil compaction should be avoided.

Thatch control

Thatch control on tees is the same as previously discussed for greens.

Compaction correction

Tees may become compacted from vehicular or foot traffic. Coring and topdressing as described for greens are best cultural controls of compaction. Coring should be done at least 3 times/year on tees.

MANAGEMENT OF TURFGRASS PESTS IN HAWAII

Hawaii has fewer pests of turfgrasses than the mainland United States. Experience on various crops from the mainland U. S. has shown that the use of chemical pesticides has been reduced between 25-50% with an IPM program. Brief discussions of the insect, mite, nematode, plant pathogens, and weed pests of turfgrasses in Hawaii are presented.

Both federal and state laws and regulations concerning the sale and use of pesticides are continually changing. Pesticides mentioned in the various sections of this document were registered in Hawaii for application to turfgrass when this report was prepared. The mention of trade names does not constitute an endorsement. It is the responsibility of the user to make sure label directions are followed precisely.

MANAGEMENT OF TURFGRASS INSECT AND MITE PESTS

Insects and mites are soft-bodied, invertebrate organisms that have lived on earth for more than 300 million years. They are better adapted than humans to exist on earth. Insects vary in size from 0.01 inch to over 10 inches in length. they can be found from below sea level (Death Valley) to the top of the highest mountains and in the air to 6,000 feet or more. Most insects are not harmful to man and in fact are very beneficial. Less than one percent of the insects known to man are considered pests. Being cold blooded

organisms, activity of insects and mites is controlled by temperature and humidity. Cool temperatures slow down all activities, including feeding, reproduction, etc. Activities of mites and insects increase with increasing temperatures up to a certain point. Extremely high or low temperatures are lethal. Each insect and mite species has an optimum range of temperatures for their biological activities. Turfgrass insect and mite pests occupy a specific part of the turfgrass environment, namely leaves, stems, thatch and soil. The mild temperatures in Hawaii allow insects and mites to be active throughout the year although there may be some seasonal variation in population size.

A turfgrass manager should familiarize himself with the basic biological and ecological knowledge of the insect and mite pests. Good pest management depends upon correct identification of pests and the injury they produce. The manager should know about their behavior, growth and development, life stages causing damage, and food preference. In addition, he must understand environmental factors, such as humidity, temperature, soil type, location etc. that affect pest populations growth.

GENERAL BIOLOGY OF INSECTS AND MITES

Adult insects may be recognized by being segmented and having a body divided into three sections, the head, thorax and abdomen. The head contains structures to monitor the environment, antennae (1 pair that contains sensory hairs,cells, etc.), compound eyes, simple eyes, and mouthparts that are adapted for sucking plant juices or chewing plant tissue. The thorax contains appendages for locomotion, 3 pairs of legs, and may be wingless or have one or two pairs of wings. The abdomen is the terminal end of the insects body and the last segment contains structures for reproduction, ovipositor in the female and claspers in the male. Insects possess structures for the five senses common with man, sight, touch, smell, taste, and hearing. Adult moths and butterflies do not damage turfgrass while adult billbugs, chinch bugs and mealy bugs will feed on turfgrasses.

Mites are relatives of insects but differ greatly. They have only one body region that is sac-like. Antennae and wings are lacking. Adult forms usually have simple eyes and four pairs of legs. Mouthparts are called chelicerae, not mandibles, and are adapted for sucking plant juices.

All insects and mites develop from eggs that are deposited by the female on or in plant tissue or near a food source and conditions suitable for development. This stage of the life cycle is resistant to most pesticides. Size, color, ornamentation, and placement of eggs differs greatly and is characteristic for each species. Eggs do not damage turfgrasses.

Upon hatching from the egg, growth and development of insects and mites are accomplished in distinct steps or a series of molts, in which the exoskeleton (outer shell) is shed and renewed. They change in form and size as they grow. The amount of change varies from group to group. This change is called **metamorphosis**. Two basic types, simple and complete, are found in insects. Stages between molts are called **instars**. Growth ceases with the adult stage.

Immature forms that hatch from eggs of insects with simple metamorphosis are called nymphs. Nymphs resemble the adults except in size, body proportions, and the development of wings. Wings are developed externally during the early instars (stages) and compound eyes are present. There is no prolonged non-feeding stage prior to the last molt. Nymphs generally live in the same habitat and feed on the same food as adults. Chinch bugs, mealybugs, grasshoppers, cockroaches, stink bugs, termites, etc. all develop with simple metamorphosis.

Eggs of insects with complete metamorphosis hatch into a worm-like stage, the larva. Larvae of insects vary in form, some have legs or are legless, some lack a well developed head. Mouthparts of larvae may be different than the adult (caterpillars have chewing types while the adult butterflies and moths have sucking mouthparts). Food habits of the immature forms may be similar (bill bugs or snout beetles) or different than the adults. Larvae do not have compound eyes. Wing development is internal. Larvae molt and pass through several instars, increasing in size and often changing in color. The larva is the most damaging stage in the development of insects having complete metamorphosis and is the primary target of a pest management program. After the last larval instar, the insect changes into a pupa. Pupae do not move about, are inactive and do not feed. The pupa may be enclosed in a special cell or protective covering, which may be a hibernaculum, cocoon, or formed by the last larval skin, the puparium. The pupal stage is highly active, biologically for all larval tissues are broken down and reconstructed into adult tissues. Wings develop externally. The pupal stage is difficult to kill with pesticides for it does not feed or come in contact with pesticidal sprays. Moths, butterflies, beetles, flies, wasps, and bees develop through complete metamorphosis.

Turfgrass problems can result from causes other than insects. Careful observation should be made of areas exhibiting injury. Other causes of turf injury may be improper irrigation, improper fertilizer practices, excess accumulation of thatch, poor root system, detrimental weather conditions, improper mowing height, improper selection of turfgrass cultivar, oil or fuel spills, pesticide injury and acid or basic soil reaction. Many of these conditions are discussed in more detail in the section on turfgrass management.

When examining turfgrass, look for signs of insect or mite injury such as; thin grass stands, discolored, twisted or withered leaf blades, dying or dead patches, chewed or frayed leaf blades, and the presence of webbing or frass (fecal pellets) in the grass. The presence of large numbers of bufo toad or bird droppings indicate feeding on insects and a turfgrass problem may be developing. Small mounds or burrows also indicate the presence of turfgrass pests or predators in the damaged area. Inspect the zone between the healthy and damaged turfgrass.

In IPM we encourage the use of all pest control tactics in an integrated unified program. Pesticides are not eleminated as a tactic, but are used in a precise manner only when needed. There are many alternatives to chemical pesticides and all should be considered.

Damage to turfgrass is done by feeding of adult and/or immature forms. The type of injury is closely associated with the type of mouthparts. Insects with chewing mouthparts have laterally moving mandibles that tear off pieces of plant tissue and those with sucking mouthparts have the parts modified into a beak through which the plant sap is sucked. Mites also suck juices from the plant. Some pests feed only at night. Unless special effort is made to find the pest they may go undetected for some time.

Most turfgrass injury from mites or insects can be prevented by regular inspections of the areas and immediate remedial action. Insects and mites damage may be recognized by defoliation, yellowing, twisted growth, shortening of the internodes, stunting, browning and bleaching of leaves or dieback of the turfgrass. Early detection of such symptoms may prevent rapid buildup of insect pest populations when conditions are optimum.

In Hawaii there are ten arthropod invertebrate pests of turfgrasses. Five are larvae of moths or butterflies (Order: Lepidoptera). One is a snout beetle or bill bug (Order: Coleoptera). One is a mealybug (Order: Homoptera). Early workers have erroneously called the mealybugs scale insects (i.e. Rhodesgrass scale). One is a scale insect

(Homoptera). One new pest of St. Augustinegrass which has only recently (August 1990) been reported in the state is a chinch bug (Order:Hemiptera). One species of mite (Order:Acarina) is a pest of bermudagrass. Each of these will be covered separately.

MOTHS AND BUTTERFLIES
Order: Lepidoptera

KEY PESTS:

GRASS WEBWORM (GWW). *Herpetogramma licarsisalis* (Walker) (Family: Pyralidae) is the most serious pest of turfgrasses in Hawaii. It was first reported in 1967 feeding on Kikuyugrass, *Pennisetum clandestinum* Hchst ex Chiov., (Davis, 1969). It was infesting pasture grasses and then spread to turfgrasses.

Damage: Larvae damage turf by feeding on grass blades and crowns. Their presence is noticed by the feeding injury (ragged blades), green fecal pellets, and the conspicuous amounts of webbing on the surface leading to holes into the thatch. Feeding occurs at night. During the day larvae may be found near the base of the grass curled up. When disturbed, they become active and move rapidly away. Larvae are usually shiny green when feeding and brownish when unfed. The larvae live in silken tunnels near the soil line. The first indication of damage is usually the ragged appearance of turfgrass, although it is still green. After a period of time, with continued feeding, large brown patches appear. These patches may coalesce into larger areas.

Host Range: Larvae of the GWW will damage pasture grasses and are considered serious pests of Sunturf bermudagrass, *Cynodon magennisii* Hurcombe. Davis (1968) reported larvae feeding on 13 other grasses in Hawaii (Table 1), including all the important bermudagrasses. Host preference studies by Murdoch and Tashiro (1976) with Sunturf bermudagrass; common bermudagrass, *C. dactylon* (L.) Pers.; Tifdwarf bermudagrass, *C. dactylon* x *C. transvaalensis* Burtt-Davey; Tifway bermudagrass *C. dactylon* x *C. transvaalensis* Burtt-Davey; FB-137 bermudagrass, *C.* sp. showed the least feeding injury on common and Tifway bermudagrasses. Feeding injury spread more rapidly on the fine textured grasses than on coarse textured ones. Reinert and Busey (1983) reported on resistance of several bermudagrass selections to the tropical sod webworm, *Herpetogramma phaeopteralis* Guenee, not found in Hawaii, but closely related to the GWW. In their studies common bermudagrass and the FB-119 selection had less feeding injury.

DESCRIPTION OF THE LIFE STAGES: Reports on the biology of the GWW have been published by Champ (1955), Davis (1969), Tashiro (1976, 1977,1987) and Marsden, (1979a.)

Adult: Moths are gregarious and often found clustered on vegetation. They are attracted to lights and may be a nuisance around the home when populations are high. The moth is nearly a uniformly light brown in color with small dark dots scattered about the wings. Wing span is about 0.75 inches when at rest in the field. Fully expanded wings reach 0.94 inches and the body is about 0.5 inches long. When at rest, the insect is triangular in shape. Preovipositional period varied from 3 to 6 days. Egg production averaged 249 per female with a maximum of 557. Mating and oviposition occurs at night. Adult longevity averaged 13.1 and 13.5 days for male and female moths, respectively.

Egg: Females usually deposit their eggs on the upper surface of a leaf, along the midrib near the base of the blade. Eggs are flat, elliptical and laid singly or in masses overlapping each other like shingles. Newly deposited eggs are creamy white and as

Table 1. Host range of *Herpetogramma licarsisalis* in Hawaii.

Host common name	Host scientific name
Narrow-leaved carpetgrass	*Axonopus affinis* Chase
Californiagrass (paragrass)	*Brachiaria mutica* (Forsk)
Stargrass	*Chloris divaricata* R. Br.
Bermudagrasses	*Cynodon* spp. Rich
Henry's crabgrass	*Digitaria adscendens* H. B. K.
Pangolagrass	*Digitaria decumbens* Stent
Goosegrass (wiregrass)	*Eleusine indica* (L.) Gaertn.
Centipedegrass	*Eremochloa ophiuroides* (Munro) Hack.
Torpedograss (Wainakugrass)	*Panicum repens* L.
Hilograss	*Paspalum conjugatum* Berg.
Panama paspalum	*Paspalum fimbriatum* H. B. K.
Seashore paspalum	*Paspalum vaginatum* Sw.
Kikuyugrass	*Pennisetum clandestinum* Hochst ex Choiv.
Rattailgrass	*Sporobolus africanus* (Poir.)
St. Augustinegrass (buffalograss)	*Stenotaphrum secundatum* (Walt.) Kuntz

development of the embryo progresses, change in color from light yellow to orange. Just prior to hatching, the black head of the larva is visible through the chorion (egg shell). Egg development ranges from 4 to 6 days. Hatching of the egg takes place at night. Eggs have been collected on grasses up to 4000 feet elevation.

Larva: There are 5 larval instars in the development of the GWW. The first instar, with a black head capsule, does not eat the chorion. It is translucent and amber colored until feeding begins. It then changes to light green as a result of the ingested plant material. All other instars have brown head capsules. Larger larvae are various shades of color from brown to green, depending upon the quantity of fresh food ingested. The body of larger non-feeding larvae are mostly brown and may have a rose tint over most of the body. The prothoracic shield (above the first pair of legs) is lighter brown than the head capsule and each segment of the body has a ring of dark brown spots. Many of the brown spots bear 1 to 3 conspicious setae (hairs). First instar larvae are about 0.04 inch long and the mature larvae (5th instar) are nearly one inch. Larvae feed at night and hide in the thatch near the surface of the soil during daylight. First and second instar larvae feed on the upper surface of the blades leaving the lower surface intact. Third to fifth instars notch and eat entire leaves and spin large quantities of silk webbing. Larval development averages 14.3 days. Prior to pupation, the fifth instar larva becomes quiescent, slightly shorter in length, and constructs a silken sheath (hibernaculum), covered with insect excrement and plant debris. Pest management tactics are applied against the larval stage.

Pupa: GWW pupation takes place within the hibernaculum. Pupae at first are creamy white color, then change to light brown and finally dark brown. Sex of the pupae can be determined. The average length of the pupae is about 0.4 inch. Duration of the

pupal stage averages 7.3 days. Adults emerge from the pupal stage at night. Pesticides are ineffective against this stage of development. Natural control factors affect this stage of development.

At 24. 5° C (76.1° F) the total duration from egg hatching to adult emergence averaged 21.7 days. If the temperature was 30° C (86° F), the period was shortened to 16 days. Tashiro (1976) estimated that the optimum temperature for development of the GWW was slightly above 31° C (87.8° F).

MONITORING METHODS:

A simple, rapid, accurate method of measuring the population of GWW larvae in turfgrass is essential for a pest management program. Several techniques have been tried. One of the earliest was a sprinkling can application of one gallon of water containing either pyrethrins or a detergent over an area of one sq. yd. The number of larvae rising to the surface within a ten minute period were counted (Anon., 1981; Niemczyk, 1981). Plywood boards 0.5 x 12 x 24 inches were placed on the turfgrass in the late afternoon, left overnight, and GWW larval counts taken the following morning. Nocturnal feeding larvae came to the surface to feed and remained, since the board excluded light (Mitchell and Murdoch, 1974). Visual ratings of larval feeding within a randomly selected area (2 sq. ft.), replicated 4 or 5 times, have been used to estimate GWW damage. Researchers' visual ratings of GWW feeding in the turfgrass plots were averaged.

Tashiro et al. (1983) made comparisons of the boards, sprinkling can and submergence of an area with water alone and water containing either pyrethrins or a detergent. For submergence tests, three metal rings (each 8 in. in diameter and 8 in high) were compared to a rectangular metal frame 3 x 12 x 24 in. The metal forms, with the bottom edge tapered to a cutting edge, were forced through the turfgrass into the soil at randomly selected areas. Four liters of liquid were applied to each frame, allowed to stand for 10 minutes with continuous counting of the larvae coming to the surface. Number of larvae surfacing was compared with larval counts under the boards. Research indicated more than one gallon of liquid irritant per treated area may be needed to completely saturate the turf.

Liquid irritants tested were water alone, water with 0.0002% (v/v) pyrethrins and water with 0.25% (v/v) liquid detergent. The detergent used was a mixture of anionic and nonionic surfactant plus ethyl alchol (Joy, Procter and Gamble Co.).

Use of liquid irritants resulted in higher counts per unit area of turf. Approximately 3 times more larvae were forced to the surface within the 10 min. period than were found under plywood boards left overnight on the same turfgrass plots. Boards were 31% as efficient as pyrethrins and 25% as efficient as detergent Complete submergence with standing water for 10 min. was more effective than sprinkling solutions over the surface or utilizing boards.

To obtain accurate counts, continuous observation of the treated area for 10 min. was necessary. Not all larvae were forced to the surface within a 5 min. period but some larvae forced to the surface early reenter the turf before 10 min. period is up. It is recommended that a metal form, circular in shape (6 in. high and 20 in. diameter), be used as a sampling frame. Four liters of water containing either 0.0015% pyretrins or 0.25% detergent is poured within the frame and the number of larvae coming to the surface within ten minutes counted. The process is replicated 3 to 5 times. The Lawn armyworm (LAW), fiery skipper (FS), and black cutworm (BCW) larvae responded to liquid irritants in the same manner as the GWW. Short (1990) recommended mixing one fluid ounce of detergent in two gallons of water and drenching a 4 sq. ft. area with the solution. If no larvae are observed coming to the surface, examine other suspect areas and repeat.

ACTION (THRESHOLD) LEVELS: The action or threshold level is when the pest population or turfgrass damage level has reached the point that a decision must be made whether or not to treat with an insecticide. The decision will depend upon the population of pest per unit area, the vigor and condition of the turf, and the intended use of the turf. Decision to treat is purely subjective, as pest populations are so dependent upon available moisture, temperature and vigor of turfgrass. Pests in Hawaii are active throughout the year, but become inactive if the temperature goes below 61° F. Threshold levels for more valuable greens and tees will be lower than for fairway and rough areas.

A visual rating of 10% or greater damage to bermudagrass turf, with the presence of lepidopterous larvae, is considered the level at which a pest management control tactic (insecticide) must be applied (Mitchell and Murdoch, 1974). Grass webworm larval counts of 5 per 2 sq. ft.plot indicated that more frequent observations were needed to determine the impact. An average of 10 GWW larvae per 2 sq. ft. is considered the action level at which a pest management tactic must be considered. These action levels are a beginning and can be finely tuned with experience.

Bowen (1980) in California recommended control measures be initiated if pest populations exceeded 5 cutworms, 10 skipper larvae, 15 sod webworms, or 9 billbug larvae per square yard of turfgrass.

BIOLOGICAL CONTROL: A number of parasites and predators attack various stages of the GWW in Hawaii. Several of these beneficial organisms were purposely introduced for other lepidopterous pests, others arrived accidentally. Pathogenic organisms attacking the GWW have not been reported to date in Hawaii.

Egg parasite: Davis (1969) reported an accidentally introduced small wasp, *Trichogramma* sp., parasitized up to 96% of the GWW eggs from sea level to 2,000 feet (610 meters) elevation. An average of two parasites emerged from each GWW egg. The parasite was mis-identified as *T. semifumatum*.

Larval parasites: Three parasitic wasps and one fly have been recorded attacking GWW larvae (Table 2). Adult tachinid flies, *Eucalatoria armigera*, have been observed, in a wide range of field conditions, to be an effective parasite. The ichneumonid wasp, *Cremastus flavo-orbitalis* also ranked high in parasite emergences.

A single Chalcid wasp was reported parasitizing the GWW pupa. Data on the impact of the larval and pupal parasites is meager.

Both invertebrate and vertebrate predators have been recorded feeding on GWW larvae. The bigheaded ant, *Pheidole megacephala* (Fab.) (Family:Formicidae) was the most common insect. Avian predators included the cattle egret, *Bubulcus ibis* L.; the mynah bird, *Acridotheres tristis tristis* (L); the Brazilian cardinal, *Paroaria coronata* (Latham) and the Pacific golden plover, *Pluvialis dominica fulva* (Gmelin). Head capsules of the GWW have been found in the droppings of the giant toad, *Bufo marinus* (L.). The impact of these predators on GWW populations is not known.

Table 2. Grass webworm larval and pupal parasites.

Scientific name	Order	Family
Larval Parasites:		
Casinaria infesta (Cress)	Hymenoptera	Ichneumonidae
Cremastus (= *trathala*)		
flavo-orbitalis Cam.	Hymenoptera	Ichneumonidae
Meteorus laphygmae Viereck	Hymenoptera	Braconidae
Eucelatoria armigera (Coq.)	Diptera	Tachinidae
Pupal Parasites:		
Brachymeria sp.	Hymenoptera	Chalcidae

Biocontrol agents are effective in some situations. Accurate observations on the impact of beneficial organisms are essential in making the decision whether or not to apply additional pest management tactics on the GWW population.

CULTURAL CONTROLS:

Some of the cultivars of bermudagrass have shown differences in feeding injury by GWW larvae (Murdoch and Tashiro, 1976, Tashiro, 1976 and Reinert and Busey, 1983a) . Future genetic selections of bermudagrass may show resistance to GWW feeding. Good management practices, fertilization, irrigation, aeration, etc., which produces healthy turfgrass, allows the turf a better chance of recovery from GWW damage. Mowing at 1.5 inches and reduced use of nitrogen fertilizer has been recommended in Florida (Short, 1990). Short recommended using water insoluble (slow release) N and controlling thatch.

CHEMICAL CONTROL:

Insecticidal control is the first line of defense when there is a sudden widespread increase of defoliation by GWW or other turfgrass pests. There is no alternative but to depend upon a recommended insecticide. A number of insecticides for application to turfgrasses have been registered by the EPA and the Hawaii Department of Agriculture for use in Hawaii (Table 3). Even though a pesticide may be registered for turfgrass on the mainland U. S., it may not be used in Hawaii unless it is registered in Hawaii.

Insecticides are compounds that kill insects through their chemical action. All insecticides must be considered hazardous chemicals in handling, storage, application and post-application use. Pesticide users must understand the label to be sure that the pesticide is registered for use in Hawaii for turfgrass and for the particular site and pest in question. Directions for use, clean up, safety, precautions, storage, disposal, and symptoms of poisoning and emergency procedures should be clearly understood. For example, diazinon, and organic phosphate insecticide, CANNOT BE USED ON GOLF COURSES AND SOD FARMS, but may be used by homeowners on their lawns. The federal and state regulations change frequently and one must follow directions on the latest label. Information on the insecticides may be obtained from the basic manufacturer or his representative in Hawaii, University of Hawaii Extension Service, and Hawaii Department of Agriculture, Pesticide Division. Any problems with spills or accidents should be reported to the State Departments of Agriculture and Health, Occupational Safety and Health (OSHA).

Proper timing of a pesticide application directed against the most vulnerable stage is necessary for effective GWW control and may reduce the number of applications necessary per season. The most commonly used formulations are emulsifiable concentrates (EC), wettable powders (WP), soluble powders (SP), and granules (G). Granular formulations were more effective in reaching the crown of the grasses at the soil level and lasted longer than emulsifiable concentrates. Soluble powders and emulsifiable concentrates were easier to mix, apply, and in some instances more effective than the WP formulations. Pesticides selected should be biodegradable, non-phytotoxic, have a low leaching potential and a low mammalian toxicity. Extreme care should be taken in the selection of a pesticide to be applied to turf or pasture grasses for grazing cattle, horses or pets in order to reduce pesticide residue hazard.

Insecticides registered in Hawaii for control of turfgrass pests are listed in Table 3. Registrations for use are changing daily, so one should read and understand the label before applying the material to turfgrass. The insecticide selected must be registered for application to turfgrass in golf courses. If there is any question as to whether it can or cannot be used, check with the DOA, basic manufacturer or their representative. New materials may be added and present registrations may be withdrawn at any time by EPA, DOA, and the basic manufacturer.

Table 3. Insecticides registered for turfgrass insect control on golf courses in Hawaii†.

Common name	Trade name(s)	Use*	Classification**
Biorational:			
Bacillus thuringiensis	Dipel, Thuricide	I	G
Carbamates:			
Bendiocarb	Turcam	I	G
Carbaryl	Sevin 80S	I	G
Organic Phosphates:			
Acephate	Orthene Turf, Tree and Ornamantal spray	I	G
Chlorpyrifos	Dursban 50W	I	G
Ethion	Ethion 8 EC	I, A	R
Isofhenfos	Oftanol 2	I	G
Methomyl	Lannate	I	R
Trichlorfon	Dylox 80	I	G
Synthetic Pyrethoids:			
Fluvalinate	Mavrik Aquaflow	I, A	G

*Use: I = insecticide, A = acaricide, N = nematocide:
**Classification: G = general use, R = restricted use
†BE SURE TO READ THE LABEL BEFORE APPLYING PESTICIDES

Other insecticides that have been suggested for sod webworms and army worms in Florida are acephate, bendiocarb, *Bacillus thuringiensis* var. *kurstaki*, ethion, methomyl and trichlorfon (Short 1990, Reinert 1976, 1983a). These materials have not been tested against lepidopterous pests in Hawaii.

For the GWW and other lepidopterous larvae, chlorpyrifos (Dursban) emulsifiable concentrate or granular formulations and carbaryl (Sevin) soluble powders, wettable powders, and granular formulations have been very effective. Check the label for the rate of application. Treatments should be applied in the evening or late afternoon and not watered in. Repeat the treatment if necessary. Chlorpyrifos is normally tightly

sorbed onto the organic matter in the thatch and in the soil so that leaching is not a problem.

OCCASIONAL PESTS

LAWN ARMYWORM (LAW) *Spodoptera mauritia* (Boisduval) [Family: Noctuidae]

The LAW was first discovered in Hawaii in 1953 (Pemberton, 1953) and like the GWW is established on all islands. LAW is not known to occur in the continental United States. During the sixties it was the most important pest of turfgrass and in recent years the populations have stabilized, apparently due to actions of parasites and predators. Information on the biology and ecology of the LAW have been published by Tanada and Beardsley (1958), Marsden (1979b) and Tashiro (1987).

DAMAGE: The larval stage or caterpillar damages the turfgrass by feeding on the blade, crowns and stems. Young larvae may feed on the blades during daylight hours and the grass shows a silvering at the tips. Watch for this sign of feeding damage. As the larvae increase in size they eat all the leaves and stems in their path and greener portions of the crown leaving only the tough old runners. Damaged areas take on a brown, dried up appearance. Active infestations are characterized by having a sharply defined advancing front between defoliated and green undamaged turf. With large active populations the front may move as much as one foot each night. Normally the denuded area spreads out from around the bases of buildings or trees and shrubs where eggs have been deposited. Older larvae feed at night and hide in the grass during the day.

HOST RANGE: In Hawaii LAW damage was most severe to bermudagrass lawns. Tanada and Beardsley (1958) believed the large recorded host range may have been confusion in larval identification of other species of *Spodoptera*. They conducted host range and preference studies. LAW larvae have been reported to feed on sedges (*Fimbristylis tenera* Roemer and Schultes), two week old sugarcane seedlings and several grass species (Table 4). In the Orient the insect sometimes caused injury to rice.Survival of LAW larvae on these hosts ranged from 72 to 100 per cent in various tests.

DESCRIPTION OF THE LIFE STAGES: Descriptions of the life stages and the biology of the LAW have been published by Fletcher (1956), Marsden (1979a), Tanada and Beardsley (1958) and Tashiro (1987).

Adult. Moths are nocturnal and commonly attracted to lights. Adults are common grayish brown with a wingspan of 1.2 to 1.6 inches. Males are slightly smaller (1.3-1.5 inch wingspan) and more vividly marked than the females. The forewing of the male has a white diagonal mark in the anterior median area of the upper surface of the wing between the whitish or buff-colored orbicular spot and the dark bean-shaped spot. The female is slightly larger (1.4-1.6 inch wingspan) than the male and this area is dull greyish-brown and not much different from adjacent areas of the forewing. The dark bean-shaped spot is well defined. The hind wings of both sexes

Table 4. Host Range of *Spodoptera mauritia* in Hawaii

Common Name	Scientific Name
Bermudagrass	*Cynodon* spp.
McCoy grass	*Cyperus gracilis* R. Br.
Kyllinga	*Cyperus kyllingia* Endl.
Nutgrass	*Cyperus rotundus* L.
Henry's Crabgrass	*Digitaria adscendens* H.B.K.
Wiregrass	*Eleusine indica* (L.) Gaertn.
Dallisgrass	*Paspalum dilatatum* Poir.
Napiergrass	*Pennisetum purpurem* Schumach.
Bristly Foxtail	*Setaria verticillata* (L.)
Buffalograss,St.Augustine Grass	*Stenotaphrum secundatum* (Walt.) Ktze.
Manilagrass	*Zoysia matrella* (L.) Merr.

are pale with darker areas along the outer margins. The dorsum of the thorax is covered with greyish to reddish brown scales.

Adults mate within a day after emergence from the pupa and start to lay eggs about 4 days later. Oviposition begins shortly after dusk and is usually completed before midnight. When fed sugared water adults lived for 9-14 days.

Egg. Females usually deposit their eggs on the foliage of shrubs and small trees. Females rarely deposited their eggs on grass. Wooden and concrete structures, especially near outdoor lights allowed to burn in the evening or near a window from which light emanated, were used as ovipositional sites.

Eggs are deposited in flat, felt-like masses, elongate-oval in outline, covered with light brown hairs from the tip of the females abdomen. The eggs are not visible unless the female is old and her abdominal hairs are exhausted, the last egg masses may be nearly naked. Each egg mass consists of several layers and may contain 600-700 or more eggs. Eggs are light tan or greenish with a pearly luster and as development progresses turn to grey or dark tan prior to hatching. Eggs are circular, flattened and sculptured with fine lines. Eggs hatch within 3-5 days.

Larva. Caterpillars of the LAW have 7 or 8 instars in their development. First instar larvae are pale green, about 0.05 inch long, emerge from the eggs and spin a silken thread to reach the ground. First to third instar larvae remain predominantly green as soon as feeding begins. As the larvae continue to grow, they become brownish with a pair of pale stripes down their backs. Patterns and stripes are present in the fifth to seventh or eighth instars. Mature larvae are 1.5 inches long with a pair of prominent jet black marks on each body segment, with exception of the first thoracic and terminal segments, toward the center of the body inside the longitudinal yellow stripes. Spiracles are black. Development takes approximately 28 days.

Pupa. Pupation occurs in a loosely formed silken cocoon containing dirt, plant material and larval webbing. The pupa is normally found in the soil or grass debris at the base of the turf. It is reddish brown when fully hardened. Pupal period lasts from 10-14 days.

The entire life cycle takes approximately 42 days depending upon the temperature and

humidity. Adult moths have a preovipositional period of nearly 4 days, eggs hatch in 3 days, larval period lasts 28 days and the pupal period averages 11 days.

MONITORING METHODS: Methods for monitoring LAW populations are the same as described for the GWW. The use of liquid irritants or flooding the sample area with water forced the larvae to come to the surface. The liquid irritants were more efficient than the boards left overnight.

ACTION LEVELS: Larval populations of LAW have been low probably due to the impact of predators, parasites and pathogenic organisms. A general level of 5 LAW larvae per square yard indicates an increasing population and a pest management tactic should be considered. With more experience the action level may be fine tuned and more accurate.

BIOLOGICAL CONTROL: In Hawaii a number of natural enemies have made an impact on populations of LAW. Several of these beneficial organisms were introduced for other lepidopterous pests and others arrived accidentally with the host.

Microorganisms: A polyhedrosis virus attacking LAW was reported by Bianchi (1957). The virus has been observed in both young (second to fourth instar) and older larvae. The viral infection was most likely introduced by the insect. Tanada and Beardsley (1957) and Tanada (1960) described the virus as *Borrelinavirus* sp. The virus could infect all larval stages but was more pathogenic to the younger than older larvae.

A microsporidian, *Nosema* spp., was found in LAW eggs. The microsporidian was highly infectious but its impact on LAW populations has not been determined. A fungus and bacterial disease of LAW has been reported in Australia (Smith 1933) and Sri Lanka (Hutson 1920). Neither of these two microorganisms has been reported in Hawaii. Some of the microorganisms may show promise in microbial control of the LAW.

Egg Parasites. Two species of parasitic wasps, (*Telenomus nawai* Ashmead [Family: Scelionidae] and *Trichogramma minutum* Riley [Family: Trichogrammatidae]) attack LAW eggs. Parasitism of eggs ranged from 20 to 80 per cent. The heavy covering of hair and several layers of eggs appeared to hinder the egg parasites.

Egg-larval Parasite. The braconid wasp, *Chelonus texanus* (Cresson) was observed ovipositing in LAW eggs. The parasitoid was introduced into Hawaii from Texas to control *Laphygma exempta* (Walk.) (Bianchi 1944). The wasp larva emerges from fifth or sixth instar LAW larvae and pupates in a silken cocoon in ground litter. Thirty days are needed for completion of development from oviposition to emergence of the adult wasp.

Larval Parasites. LAW caterpillars attacked by braconid wasps are killed usually before they are half grown. One of the most important parasites of LAW larvae is *Apantales marginiventris* (Cress.). It was reared from early instar LAW larvae. The parasitoid larvae emerges from the hosts fourth instar caterpillar and forms a white cocoon, usually found on a grass blade. The life cycle of *A. marginiventrus* is completed is 12-18 days.

Three species of tachinid flies, *Chaetogaedia monticola* (Bigot), *Achaetoneura archippivora* (Williston) and *Eucelatoria armigera* (Coq.) have been found parasitizing LAW larvae. When parasitized by one of these flies the host is killed in the pupal or last larval stage. The emergence of the parasitoid in the later instars allows the larvae to do contribute materially to the damage of turfgrass before they die.

Predators. Both invertebrate and vertebrate predators have been observed in Hawaii feeding on LAW larvae or pupae. Two species of ants, *Monomorium floricola* Jordan and *Pheidole megacephala* (Fab.) attack LAW egg masses. The big-headed ant, *P. megacephala* has also attacked LAW larvae. Three species of coccinellid (ladybird) beetles, *Orcus chalybeus* (Boisd.) larvae and adults, and only adults of *Cryptolaemus montrouzieri* Mulsant and *Scymnus roepkei* Fluiter were feeding on eggs of LAW. Although data is lacking, other insects, such as lacewings larvae and wasps may also attack LAW larvae in the grass.

The major vertebrate predators of LAW larvae are the giant toad, *Bufo marinus* (L.), and the Indian mynah bird, *Acridotheres tristis* (L.). The toad is believed to be a valuable predator because its nocturnal feeding habits coincide with those of mature LAW larvae. In other parts of the world ducks, storks, cranes, herons, egrets, chickens and crows have been reported to be effective predators of the LAW.

The biocontrol agents are effective in some situations. Accurate observations on the impact of these natural control agents is essential in making the decision whether or not to apply an insecticide on the LAW population.

CULTURAL CONTROLS: One of the simplest methods is to brush off egg masses on ceilings and walls of buildings. Mow grass properly. Avoid the buildup of thatch and remove it when it is excessive. Larvae tend to hide in the thatch. Fertilize turfgrass properly for the increase in succulence of grass encourages an increase in insect attack.

CHEMICAL CONTROL: The insecticides suggested for GWW control are also effective in controlling LAW. The biorational, *Bacillus thuringiensis* var. *kurstaki* spores, is an effective larvicide. It is harmless to humans and safe to the environment. Its activity decreases with exposure to strong sunlight and extreme temperatures. Refer to the label for instructions on dosage rates, application information and precautions. An area treated with granular formulations should be watered down following application. Evening treatments are preferred and repeat applications may be necessary.

POTENTIAL PEST:

FIERY SKIPPER (FS) *Hylephila phyleus* (Drury) [Family: Hesperiidae]

The skipper butterfly was first discovered in Hawaii in 1970 (Kawamura and Funasaki 1971), has the potential to cause significant damage to turfgrass during warm periods. It is found on all islands with the exception of Lanai. The common name, fiery skipper, is due to the bright orange and brownish color and erratic, skipping flight pattern of the adults.

DAMAGE: Larvae are seldom seen and the first evidence of damage are small isolated round spots where single larvae have devoured the grass blades. The circular spots are 1-2 inches in diameter. These spots may coalesce into larger areas.

HOST RANGE: Larvae will feed on all common lawn grasses but appears to prefer bermudagrasses (*Cynodon* spp.), bentgrasses (*Agrostis* spp.), crabgrasses (*Digitaria adscendens*) and St. Augustine grass (*Stenotaphrum secundatum*).

DESCRIPTION OF LIFE STAGES: Biology of the fiery skipper in Hawaii has been published by Tashiro and Mitchell (1985) and Tashiro (1987).

Adult. Adults are more commonly seen flying about visiting flowers of lantana, honeysuckle, clover and other plants to feed on nectar. The FS has a wingspan of 1.0 inch or slightly larger. Males are predominantly bright orange-yellow above and pale yellow with black spots on the underside of front and hind wings. Females are predominantly dark brown with orange-yellow spots on the upper wing surface and similar coloration of the males on the undersurface of the wings.

Egg. Hemispherical eggs are deposited singly on the upper surface of the grass blades. Freshly deposited eggs are pearly white and as development continues change to powdery blue, then greenish blue within 1-2 days. Just prior to hatching the egg becomes nearly white again and the black head of the larva is visible through the chorion. Egg development may take 3-5 days.

Larva. Larvae are seldom seen since they remain concealed in lightly woven silken tubes in the thatch area. There are five larval instars in the development of FS. First instar larvae are pale greenish in color with a granular appearing surface over the body. The first two body segments behind the head are smaller than the rest, appearing as a strongly constricted neck. The "neck" is a distinguishing characteristic for all FS larval instars. The head is strongly constricted in the neck area and a black narrow shield over the prothorax is evident. The head is black and mottled or striped with brown and the body is covered with short setae for all five instars. Later instars the body becomes yellowish-brown to grayish-brown with a faint median longitudinal stripe. FS larvae are approximately 1.0 inch in length. Just prior to pupation the body becomes rigidly straight (prepupa). First instar larvae notch the edges of the blade and later instars consume the whole leaf. Third to the fifth instar larvae spin large quantities of strong silk webbing. Larval development at 81-84° F is completed in about 15.5 days

Pupa. Pupation often occurs in grass near the surface of the soil in a loosely woven cocoon covered with leaf litter debris. If debris is not available the pupa may be free in the grass-root zone. Young pupae have a light green head and thorax, and a light tan abdomen. As development progresses the pupa turns brownish-yellow with a conspicuous black dorsal line and is covered with rather thick bristly hairs. Pupae of FS are about 0.7 inch long. Pupal development at 81-84°F is completed within 7.6 days.

Development from egg to adult takes 48 days when reared at 75°F and fed bermudagrass. When reared at 81-84°F it took only 23 days.

MONITORING METHODS: Methods for monitoring FS populations are the same as described for the GWW. Larvae have been observed under boards as well as being forced to the surface with the use of irritating liquids.

ACTION LEVELS: Larval populations of FS have been low and present in few situations. We do not know the reason for such low populations but believe it must be due to environmental conditions and the impact of parasites or predators. Because of the low populations in Hawaii, action levels have not been developed for FS. Ten FS larvae per square yard as suggested by Bowen (1990) in California may be a starting point.

BIOLOGICAL CONTROL: Information on natural enemies of FS is lacking for Hawaii. In California a braconid wasp, *Apanteles* spp., and an ichneumonid wasp, *Amblyteles* sp., attack the larvae and pupae, respectfully.

CULTURAL CONTROLS:
Mow, fertilize and manage the turfgrass properly. Avoid the build up of thatch and remove it when it is excessive. Thatch provides a haven for the larvae to hide in and their populations may increase. Good management practices for good healthy turf requires fewer insecticide applications.

CHEMICAL CONTROL: Insecticide treatments may not be needed if the FS populations continue to remain low.The insecticides suggested for GWW and LAW are also effective in controlling FS. Refer to the label for rates of application, precautions and directions for use. Granular formulations should be watered down to move the toxicant down into the thatch and grass at the surface of the soil. Apply the pesticides in the evening or late afternoon. Repeat treatments may be necessary.

POTENTIAL PEST:

BLACK CUTWORM (BCW): *Agrotis ipsilon* (Hufnagel) [Family: Noctuidae]

Occasionally a larva of this noctuid moth will come to the surface of the turfgrass when monitoring for the key pests. Although the insect has been recorded in Hawaii since 1879, it has not developed into a serious pest of turfgrass but has the potential for serious outbreaks. It is also called the greasy cutworm.

DAMAGE: The common name describes the larval habits. Larvae feed at night on the leaves and crown of the turfgrass and may cut off plants near the soil surface. They may cut off one plant, not feed, move to an adjacent plant and repeat the process. During daylight the larvae hide in the thatch, ground litter or burrow into the soil.

HOST RANGE: In Hawaii is has been a serious pest of many garden vegetable crops by cutting the seedlings off at or below the ground level. It has damaged sugarcane and corn. It was recorded feeding on Sunturf bermudagrass, *Cynodon magennissii* Hurcombe experimental plots at Waimanalo. In particular situations it probably will attack other bermudagrass cultivars as well as other lawn grasses. They also feed on some weeds i.e. purslane, *Portulaca oleracea* L.. In California it feeds on dicondra and white clover.

DESCRIPTION OF LIFE STAGES: Descriptions of the developmental stages are published by Zimmerman (1958), Rings (1977) and Tashiro (1987).

Adult. Moths are dark grey to black or brown. Antenna of the male is pectinate and filiform for the female. In the forewing is a black reniform spot and a black bar extending toward the tip of the wing. The hind wings are nearly white, veins prominent without a medial band. Adults are active at night. Wingspan of the adults is about 1.0 inch. Adults are attracted to lights, especially black light. Adults may live 30 days.

Egg. Freshly laid eggs are naked, creamy white in color, dome shaped with a small circular depression at the upper pole from which radiate ridges down the sides to the base. As development progresses the eggs darken to tan, gray, dark brown and black before hatching. Eggs are deposited on the surfaces of leaves or stems near the soil

surface. Eggs may be deposited singly or close together in a batch. Development takes 2-4 days.

Larva. Like other lepidopterous pests, IPM programs are directed against the worm stage. The larvae are nearly a uniform dark greasy gray to black in color and paler underneath. Spiracles are black. The head and dorsal part of the segment behind the head is brown. Conspicuous tubercles appear as rows of brown dots. The larva molts five times in its development. Mature larvae are 1.75 inches long. The larvae actively feed at night and hide during the day in the thatch or beneath the soil or plant debris at the surface of the soil. Young larvae feed on the grass blades and later instars tunnel under the soil, cutting off the plants and pulling them down into the burrow. With crowded conditions the larvae are cannibalistic. Larval development takes 28-30 days.

Pupa. Pupation takes place in an earthen cell below the surface of the soil. It is about 0.75 inch long, medium brown color, with a dark dorsal band at the apex of abdominal segments 4 to 7. At the tip of the abdomen are two large tapering spines. The spines are black at the base and pale at the tip. Pupal development takes 10-14 days.

The entire life cycle from egg to adult may take from 40-48 days.

MONITORING METHODS: Methods for monitoring BCW populations are the same as described for the GWW. Liquid irritants or flooding the area forced the larvae to the surface to be counted.

ACTION LEVELS: Larval populations of the BCW have been low in our turfgrass experiments probably due to the impact of parasites and predators and environmental conditions. Because of the low populations action levels for BCW have not been ascertained. As a starting point an artificial control measure may be necessary if the larval population reaches 5 per square yard.

BIOLOGICAL CONTROL: A number of parasites and predators of the BCW have been recorded for Hawaii (Zimmerman 1958). Invertebrate parasites and predators of BCW are presented in Table 5. The invertebrate organisms attack both the larvae and pupae. Information on vertebrate predators is lacking. The mynah and other birds, the giant toad probably consume BCW larvae when feeding in the turfgrass. Data on the impact of these beneficial organisms is lacking.

CULTURAL CONTROLS: Mow the grass properly. Avoid the buildup of thatch and remove it when it becomes excessive. Larvae will hide in the thatch.

CHEMICAL CONTROL: The insecticides suggested for GWW and LAW are also effective for the BCW. Products containing *Bacillus thuringiensis* var. *kurstaki*, carbaryl, chlorpyrifos or trichlorfon are suggested for BCW application. Refer to the label instructions on proper application, dosage rates, and precautions. The biorational compound *B. thuringiensis* is a larvicide.

POTENTIAL PEST

BAGWORM (BW): *Brarachycyttarus* possibly *griseus* de Joannis

The bagworm was found in Kaneohe, Oahu in 1984. The common name "bagworm" is due to the bag-like silken case covered with pieces of grass in which the larva and adult female live (Heu et al. 1984).

Table 5. Invertebrate parasites and predators of BCW in Hawaii

Order	Family	Scientific Name
Parasites		
Diptera	Tachinidae	*Archytas cirphis* Curran
		Chaetogaedia monticola (Bigot)
		Eucelatoria armigera (Coq)
Hymenoptera	Braconidae	*Chelonus texanus* Cresson
		Meteorus laphygmae Viereck
	Eulophidae	*Euplectrus plathypenae* Howard
	Ichneumonidae	*Hyposoter exiguae* (Viereck)
		Pseudamblyteleskoebeli (Swezey)
		Pterocormusrufiventris (Brulle)
Predator		
Coleopteraa	Carabidae	*Calosoma blaptoides tehuacanum* (Lapouge)

DAMAGE: Similar to other lepidopterous pests, the larva is the damaging stage. The larvae chew off the blades of grass. Ragged appearance of the grass may be noticeable but the first evidence will most likely be the conical silken case hanging from branches of shrubs, buildings, or other structures. Large numbers of bags are often noticeable.

HOST RANGE: This is a new pest to Hawaii, and the host range is not well known. The larvae have been recorded feeding on bermudagrass, Hilograss (*Paspalum conjugatum*), foxtail (*Setaria* spp), Natal redtop (*Rhynchelytrum repens* (Wild) C. E. Hubb.), *Desmodium* sp., sensitive plant, (*Mimosa pudica* L.), green kyllinga (*Kyllinga brevifolia* Rottb.), and purple nutsedge (*Cyperus rotundus* L.). It has also been able to complete its life cycle on *Citrus* spp., Nishiki juniper, lima beans and Spanish needle (*Bidens pilosa* L.).

DESCRIPTION OF LIFE STAGES: Adult: Male bagworm moths have well-developed, grey colored wings and are about 0.2 inch long. Females are slightly longer than the male, wingless, legless, lacking eyes, antennae, and mouthparts. The females remain in the silken case made while it was a larva. The female attracts the male, probably with a pheremone, mating takes place without leaving the bag. Shortly after mating she lays several hundred eggs within the silken case and then dies.

Egg. The eggs are deposited within the silken case. They hatch and the young larvae crawl out of the bag, construct their own conical silken case that is carried upright.

Larva. The bagworm larva carries the silken case with it as it moves about. The bag protects the larva. As the larva matures, the surrounding bag increases in size and is positioned beneath the body while the larva clings to a surface with its thoracic legs. A mature larva case may be nearly 0.5 inch long.

PUPA: Pupation takes place within the silken case.

The life cycle is completed in approximately 11 weeks.

MONITORING METHODS: Monitoring methods have not been developed. First

evidence of a population is usually the silken bags hanging form the grass stems, vegetation, or buildings surrounding the turfgrass area.

ACTION LEVELS: Action levels have not been developed. The populations have not been sufficiently damaging to turfgrasses to warrant a research program.

BIOLOGICAL CONTROL: No information is known about beneficial organisms attacking this insect.

CULTURAL CONTROLS: Brushing the silken cases from buildings may provide a measure of control.

CHEMICAL CONTROLS: With the present population pressures, control with chemicals has not been researched. The insecticides suggested for GWW should be effective against bagworm larvae.

BEETLES
Order: Coleoptera

OCCASIONAL PEST:

HUNTING BILLBUG (HBB). *Sphenophorus venatus vestitus* Chittenden [Family: Cucurlionidae]

This snout beetle was first reported in Hawaii in 1960 infesting zoysiagrass. It has been reported from all islands with the exception of Lanai.

DAMAGE: First symptoms of hunting billbug damage are regular elongated or round areas of brown dead or dying grass. The turf can easily be pulled by hand and the root system appears to be cut off. Presence of the legless, white grub of the billbug near the border of dead and healthy grass will confirm the diagnosis. Young larvae feed on the stolons, crowns and new leaf buds. Older larvae attack the roots and runners to a depth of 3 inches or more. Adults and larvae damage turfgrass.

HOST RANGE: Billbug damage has been observed in lawns, turfgrasses and pasture grasses in Hawaii. Serious infestations have been in bermudagrasses of greens and tees. The list of hosts for Hawaii are presented in Table 6. Kikuyugrass pastures at 2,500-3,500 feet elevation on the island of Hawaii were damaged by the HBB (La Plante, 1967). Weevils were also damaging sugarcane and corn seedlings. Literature reports St. Augustinegrass, centipedegrass, crabgrass, signal grass, barnyardgrass (*Echinochloa crusgalli* (L.) Beauv.), leatherleaf fern and Pensacola bahiagrass (*Paspalum notatum* Flugge) as hosts. In Hawaii, zoysiagrass and bermudagrass cultivars were most seriously damaged.

DESCRIPTION OF LIFE STAGES:

Adult: The adult weevil is dark reddish brown in color about 0.4 inch long. A slightly curved beak at the front of the head bears a pair of stout mandibles for chewing grass stems and blades. When disturbed, the adults will feign death for short periods of time. Adults can fly and may live 6 months or longer.

HOST RANGE: The host range of the HBB is given in Table 6 below.

Table 6. Host range of the hunting billbug in Hawaii.

Common name	Scientific name
Bermudagrass	*Cynodon* spp.
Manieniegrass (Common bermuda)	*Cynodon dactylon* (L.) Pers.
Yellow nutsedge	*Cyperus esculentus* (L.)
Kikuyugrass	*Pennisetum clandestinum* Hochst. ex Chiov.
Sugarcane	*Saccharum officinarum* L.
Corn	*Zea mays* L.
Manilagrass	*Zoysia matrella* (L.) Merr.
Japanese lawngrass	*Zoysia japonica* Steud.

Biologies and descriptions of the HBB have been published by Woodruff (1966), Marsden (1979c), Tashiro (1987) and Johnson-Cicalese (1990).

Egg: Females bite a small hole in the stem, leaf or crown of the grass and then deposit a small, white elongate egg in the slit. Eggs are deposited singly and hatch in 3-7 days depending upon temperature.

Larvae: The larva or grub is legless, dirty white in color with a brown head. Mature grubs are about 0.4 inch in length. Upon hatching, the young grubs hollow out the stem and fill the space with frass. As the larva increases in size, the stem can no longer conceal it, and the grub feeds on the crown and moves to the roots. Mature larvae may be found in the crown, just below the thatch or just below the soil surface to a depth of 3 inches. Larval development takes from 3-5 weeks.

Pupa: Pupation takes place in an earthern cell in the soil. Development to the adult stage takes from 7-10 days.

The entire life cycle may take from 27-55 days depending upon the temperature.

MONITORING METHODS: A standard monitoring method has not been developed for the HBB because of its secretive habits.Turfgrass should be examined for irregular or circular brown spots of dying grass. These spots should be examined more closely for the presence of adult or larval HBB. First instar larvae are concealed inside the stem and easily missed. Frequent examination of suspect areas would find the later larval instars that are outside the stems. The use of irritating liquids forces a few adults to the surface but the legless grubs do not respond like the GWW, LAW and BCW larvae. If adult HBB are noticed crawling along walkways, curbs or paved areas, they are indicative of a potential problem.

ACTION LEVELS: Because of the cryptic habits of HBB, if 1 or more grubs per square foot are found, the turfgrass should be treated. Spot treatment may be all that is necessary.

BIOLOGICAL CONTROL: In Hawaii the billbugs appear to be free from many of the beneficial organisms. Mitchell (1966) reported adults killed by the fungus, *Beauvaria bassiana* (Bals.) Vuill. This disease attacks many insect species if conditions are optimum. A braconid parasite, *Bracon* sp. nr. *sphenophori* Mues. was released in 1968 (Chong, 1968). A mymarid egg parasite, *Patassion calendrae*

(Gahan) had multiple releases in 1929, 1963, and 1967 (Bianchi, 1968). Neither one has been recovered to confirm establishment. Scats of the giant toad, *Bufo marinus*, have contained large numbers of HBB adults (Habeck, 1962). Some HBB were alive in the fecal droppings. The toad feeds at night on HBB, GWW, LAW, and BCW.

CHEMICAL CONTROL: Insecticide applications are suggested because the HBB is free of effective parasites or predators. For effective control, the chemical must reach the larvae which are located in or below the thatch or under the surface of the soil. Most researchers suggest pretreatment irrigation of the area to soak the thatch layer and the upper surface of the soil. The wetting of the area will insure better penetration of the toxicants to the depth of the roots and the zone where adult and larval HBB exist. Post treatment irrigation is recommended when granular formulations are applied. Products containing chlorpyrifos, carbaryl, ethoprop, isofenphos, propoxur or trichlorfon have been suggested for HBB control in Florida (Short, 1982). Refer to the label to be sure the chemical is registered for the site and HBB control.

MEALYBUGS
Order: Hemiptera Suborder: Homoptera

Mealybugs are small elongate, oval, soft-bodied insects with well developed legs. They damage plants by sucking the juices from them. Their bodies are often covered with waxy secretions. Mealybugs produce honeydew which is attractive as food for other insects.

OCCASIONAL PESTS:

RHODESGRASS MEALYBUG: (RGMB): *Antonina graminis* (Maskell) [Family: Pseudococcidae].

The Rhodesgrass mealybug has been misnamed Rhodesgrass scale. The insect has been in Hawaii since 1910 and occasionally develops troublesome infestations in turfgrasses. It is found on all islands.

DAMAGE: Rhodesgrass mealybug damage to grasses is difficult to see because the insects are small and located at the bases of the grass stems and under old leaf sheaths. Active infestations produce large quantities of honeydew, a sweet sticky secretion that is highly attractive to honeybees, ants and other insects. Bee activity in the grass or being stung while walking barefoot in the grass are often the first indications of the development of a mealybug population. Closer examination of the turfgrass will reveal small, reddish, globular insects enclosed in white felt-like waxy masses, near the bases of the stems and under old leaf sheaths. Larger populations of RGMB cause the infested grass to become unsightly and weak in appearance. The bases of the infested plants, including crowns, leaf axils, etc., appear to be covered with tufts of cotton. Injury is most severe during extended hot, dry periods.

HOST RANGE: The insect has a worldwide distribution and has been reported infesting over 100 species of grasses. In Hawaii, it has been recorded on sugarcane, bermudagrasses, caribgrass (*Eriochloa polystachaya* (H. B. K.) Hitch.), torrid panicgrass (*Panicum torridum* Guad.), *Paspalum* spp., rhodesgrass (*Chloris gayana* (Kunth.) and pineapple roots (Zimmerman, 1948).

DESCRIPTION OF THE LIFE STAGES: Adult: The small mealybug adults are inside the white, cottony, waxy secretion that the insect produces. All adults are females. Reproduction is by parthenogenesis, and males are unknown. The adult is a globular, dark purplish, reddish-brown, saclike body about 0.125 inch diameter. Mealybugs are found clustered about the bases of the plants. Mealybug feed by sucking plant sap through a long, hair-like proboscis which is inserted into the tissue of the grass plant.

Egg: Females give birth to living young (nymphs or crawlers). Elongate, cream colored eggs can be seen if dissected from a female.

Nymph or Crawler: Young, larvae, nymphs or crawlers, are produced in large numbers by the female. They are minute, flat, brownish insects with well-developed legs and antennae. The infestation is spread in the turfgrass by these tiny crawlers moving from plant-to-plant. Crawler and adult feeding cause cells to collapse and reduce vigor of the plant. Once the crawlers have started to feed they become sessile, loose their appendages, become saclike and look like adult females but are smaller in size.

The life cycle from crawler to reproductive adult may take as much as 45-50 days depending upon the temperature.

MONITORING METHODS: A standardized monitoring method for RGMB has not been developed. If white cottony masses are observed in the turfgrass and there is considerable activity of honeybees and ants feeding on the honydew there is most likely an infestation developing. Further close inspection of the turfgrass is suggested.

ACTION LEVELS: We do not have an action level for RGMB. If people are being stung, by bees feeding on the honeydew, as they walk across the turf a pest management tactic is suggested.

BIOLOGICAL CONTROL: In Hawaii one encyrtid parasite, *Anagyrus antoninae* Timberlake, has been recorded attacking RGMB. The parasite has effectively controlled RGMB populations in some situations. Failures have probably been due to parasite mortalities from insecticide applications.

CULTURAL CONTROLS: Grass mowed at 1.5 inches or more is less prone to injury than grass that has been cut shorter. Proper irrigation and fertilization aides in preventing damage. Do not spread grass clippings from an infested area to uninfested areas.

CHEMICAL CONTROL: Insecticidal control has not been very effective because of the waxy secretions protecting the mealybug. In Florida malathion in combination with volck oil has been reported to give satisfactory control. In Hawaii the insecticides suggested for GWW control have also prevented population increases of RGMB. Timing of the insecticide application is important to contact the crawler stages.

SCALE INSECTS
Order: Hemiptera Suborder: Homoptera

The pest of turfgrass is an armored scale. They are generally small, flat disc like organisms without legs and antennae. They live under a scale (armor) formed of wax

secretions of the insect and cast skins of immatures. The scales vary in shape, size and color. Scale insects also produce honeydew.

POTENTIAL PEST:

BERMUDAGRASS SCALE (BGS). *Odonaspis ruthae* Kotinsky [Family: Diaspididae]

This insect was first discovered in Hawaii in 1910 (Zimmerman 1948). It is also called Ruth's scale. It may be found wherever bermudagrass is found.

DAMAGE: In Hawaii, the scale seldom causes serious damage to bermudagrass but is most injurious when the turf is under stress. Adults and immatures suck plant juices from the plant and may reduce vitality and growth of turf. Heavily infested turfgrass takes on a brown, dry appearance and new growth is retarded. The scale does well in shade and heavily thatched turf.

HOST RANGE: As the common name implies, the host range is limited to bermudagrass and its hybrids.

DESCRIPTION OF THE LIFE STAGES: Adult. The adult scale (0.06 inch long) is oyster or clam-shaped and chalky white found beneath the leaf sheaths, clustered around the nodes and occasionally on the leaves. Scales have not been reported on the roots.

Egg. Eggs are deposited by females under their oyster-shaped scale.

Nymphs or Crawlers. These are the active mobile stage in the life cycle. Crawlers move out from beneath the scale and spread the infestation. They soon settle down, loose their legs, insert their piercing sucking mouthparts into the grass, start to feed and become sessile. In molting they loose their appendages, secrete the waxy covering and remain there for several months before producing eggs and repeating the life cycle.

MONITORING METHODS: Methods for monitoring have not been developed. Close examination of the turf for the white oyster or clam-shaped scales will indicate the presence of the scale.

ACTION LEVEL: The scale has not developed into sufficient populations to determine an action level.

BIOLOGICAL CONTROLS: As with the mealybug only a single encyrtid wasp, *Adelencyrtus odonaspidis* Fullaway, has been recorded parasitizing BGS. Data on its effectiveness is lacking.

CULTURAL CONTROLS: Keep the turfgrass in a healthy condition. Do not spread grass clippings from an infested area into uninfested areas.

CHEMICAL CONTROLS: Infestations in Hawaii have not required pesticide applications. The insecticides suggested for GWW control should also be effective for control of this pest. Timing of the application is important so that the crawlers come in contact with the insecticide. The waxy covering protects the scale from the sprays, therefore an adjuvant or volck oil may be incorporated into the spray to overcome this problem.

SOUTHERN CHINCH BUG
Order: Hemiptera Suborder: Heteroptera

OCCASIONAL PEST:

SOUTHERN CHINCH BUG (SCB). *Blissus insularis* Barber [Family: Lygaeidae]

The southern chinch bug is an recent arrival in Hawaii. If was found infesting St. Augustinegrass in Nuuanu Valley in August 1990. Under certain conditions this insect may be a limiting factor in the culture of St. Augustinegrass and its cultivars.

DAMAGE: Both adults and nymphs suck juices from the turfgrass. They insert their needle-like mouthparts, suck sap and in the process inject saliva that interferes with water conducting system of the plant. Damage begins as patches of yellowing grass which later turn brown. If the grass is under stress and the yellowing continues to spread the grass may be killed. Activity is greatest in hot, open areas. Shaded areas are not usually damaged unless the SCB populations are very large. By parting the grass runners, adults and nymphs can be seen crawling through the loose debris on the surface of the soil.

HOST RANGE: Its major host is St. Augustinegrass, *Stenotaphrum secundatum*. Other grasses in close proximity to St. Augustinegrass that have been slightly damaged by SCB are zoysiagrass, centipedegrass, bahiagrass, and bermudagrass. Some selections of St. Augustine grass are resistant to SCB.

DESCRIPTION OF THE LIFE STAGES: Adult. Adults are 0.2 inch long, black with shiny wings that are held flat over the back. The white wing covers are marked with a black triangular patch at the middle of their outer margin. Legs are reddish to reddish yellow. Fully winged (macropterous) and short winged (brachypterous) adults may be found in the population.

Egg. Eggs are deposited in the leaf sheaths and in the ground on roots. The eggs are nearly cylindrical, are three or four times longer than broad, whitish when freshly deposited. As development progresses the color changes to yellow and a deep red prior to hatching. Egg development takes about 2 weeks.

Nymph. There are five wingless instars in the development of SCB. The first two instars are red in color, with a white band on the first two abdominal segments. The basic color changes from red to orange in the third instar, orange brown in the fourth and black in the fifth instar. Wing pads are visible in the fifth instar. Nymphal development takes 30 days or longer depending upon temperature.The complete life cycle from egg to reproductive adult may take 6-8 weeks.

MONITORING METHODS: Sampling methods described for sampling the GWW are effective for SCB. Flooding of an area with water or irritating liquids will force the adults and nymphs to the surface to be counted.Ten minutes of continuous counting is advised.

ACTION LEVELS: Action levels for the SCB have not been developed for Hawaii. Populations have been scarce and limited to the island of Oahu. Reinert (1982) recommended treatment if 22-28 SCB were observed per square foot.

BIOLOGICAL CONTROLS: The infestation is so recent in Hawaii, no information is available on beneficial organisms here. One biorational, *Beauvaria*

bassiana, and a number of parasites and predators have been recorded elsewhere (Tashiro 1987).

CULTURAL CONTROLS: St Augustinegrass is the preferred host for the SCB. A number of varieties have shown resistance to chinch bug feeding. Publications by Busey and Coy (1988), Busey and Center (1987), Busey (1990), discuss the vulnerability of St. Augustinegrass and the genetics of resistance. Floratam and accessions FA 108 and TX 33 have exhibited resistance to SCB feeding. We do not know if the cultivars of St. Augustine grass being sold commercially in Hawaii are tolerant to SCB feeding. Control of thatch will reduce SCB numbers. Reduced amounts of nitrogen should result in less chinch bug problems.

CHEMICAL CONTROLS: To preserve any beneficial organisms spot treatment of the damaged area and a ten foot swath surrounding it is suggested. Refer to the label for directions on dosage rates, application methods, precautions etc. Insecticides containing chlorpyrifos, ethion, ethoprop, isofenphos or propoxur are suggested. Irrigation of the turf prior to application will allow the pesticide to reach the SCB below the thatch and at the surface of the soil. In some area phosphate resistance has developed in the SCB (Reinert and Portier, 1983). We do not know if a phosphate resistant population of chinch bugs is present in Hawaii. Resistant cultivars is the best control of SCB.

BERMUDAGRASS MITE
Order: Acarina

OCCASIONAL PEST:

BERMUDAGRASS MITE (BGM). *Eriophyes cynodoniensis* Sayed [Family: Eriophyidae]

This eriophyid mite, also called the bermudagrass stunt mite, was first detected in Hawaii in 1966. It has spread to all islands. It can be a serious pest of bermudagrasses under certain conditions. It is a more frequent problem in grasses under stress and in new plantings.

DAMAGE: Damage is characterized by a yellowing of the tips of the leaves, a turning upward and inward of the leaves and shortening of the internodes and a rosetting or tufting of the grass (Kerr and Brogdon, 1968). When rosettes are numerous the area looks clumped without internodes. Walking over the area the turf feels lumpy. With heavy infestations the grass turns brown and dies. Adults and immatures suck plant juices.

HOST RANGE: As the name implies, the host range is limited to bermudagrasses and the cultivars or hybrids. Cultivars have varying degrees of resistance to feeding by the mite.

DESCRIPTION OF THE LIFE STAGES: Adult. Adults of the mite are extremely small and with difficulty can be seen with a 10X hand lens magnifier. They are worm like, creamy white to yellow in color and have four legs near the head end. They are found behind the leaf sheath sucking plant sap.

Eggs. Eggs are spherical, transparent to opaque white and deposited singly or in groups behind the leaf sheaths.

Nymphs. Nymphs resemble the adults in being microscopic in size, about two-thirds the size of the adults, longer than broad with two pair of legs at the head end. The nymphs may be observed behind the leaf sheath sucking plant sap. Upon hatching the nymphs molt twice (2 instars) and molt again into a sexually mature adult. All stages of development may be found behind the leaf sheath. Major means of dispersal are by wind, grass clippings and riding on other insects or birds. During warm weather the life cycle of the BGM may only take 5-10 days.

MONITORING METHODS: Look for tufted or rosetted plants. With the aide of a dissecting microscope pull away the leaf sheath from the stem and examine the inside of the sheath for eggs, nymphs and adults.

ACTION LEVELS: An action level has not been developed for BGM in Hawaii. If damage continues to increase and the turf show evidence of decline, thinning etc. a pest management tactic must be considered.

BIOLOGICAL CONTROLS: Information on parasites or predators of BGM in Hawaii is nil. Two predacious mites, *Neocunoxoides andrei* (Baker and Hoffman) [Family: Cunaxidae] and *Stenotarsonemus spirifex* (Marchal) [Family: Tarsonemidae] have been reported reducing BGM populations in Florida and Arizona, respectively (Butler 1963. Johnson 1975).

CULTURAL CONTROLS: Several cultivars, Midiron, Tifdwarf, Tifgreen 328, Tifway 419 exhibited degrees of resistance to BGM (Reinert 1982, 1985). New selections are currently being developed.The normal maintenance operation, mowing, may spread the mite on clippings to uninfested areas. Reduce mowing height.

CHEMICAL CONTROLS: Insecticidal control of the mite with chlorpyrifos has been erratic in Hawaii. The insecticide-miticide, fluvalinate is recommended in Florida. Reinert and Cromroy (1981), Reinert (1985) and Butler (1963) have reported on BGM resistant cultivars and the effectiveness of various miticides.

PLANT DISEASES OF BERMUDAGRASS TURF IN HAWAII

Diseases of turf in Hawaii have been chronic problems over the years. There are several reasons for this. Some diseases are not well defined because of overlapping symptoms. Because of this, some turf managers can be confused as to the exact nature of the causal agent. If the sample is not submitted for laboratory analysis, even the specialist can have difficulty in the diagnosis with only a field identification. Table 7 lists the various causal agents of bermudagrass diseases and disorders reported in Hawaii with comments on their nature and potential.

Table 7. Biotic and abiotic diseases and disorders of bermudagrass turf in Hawaii.

Common name	Scientific name	Comments on disease potential
BIOTIC DISEASES:		
Anthracnose	*Colletotrichum* spp.	Minor-- weak pathogen
Bacterial stripe	*Xanthomonas* sp.	Minor-- limited reports in 1982
Brown patch	*Rhizoctonia solani*	Major-- can be serious
Drechslera leaf spot	*Drechslera gigantea*	Minor-- in cool areas above 2000 ft.
Fading out	*Curvularia* spp.	Minor/Major-- weak pathogen, can be serious in turf under stress
Fusarium blight	*Fusarium* spp.	Minor-- weak pathogen, can be serious in turf under stress
Grease spot (Pythium root rot)	*Pythium* spp.	Major-- Serious in wet, warm weather, (serious in wet cool weather)
Melting out	*Bipolaris cynodontis*	Major-- can be serious at times
Nematode decline	Several genera and species	Minor-- problem in turf under chronic moisture stress
Rust	*Puccinia* spp.	Minor-- usually not a serious problem
BIOTIC DISORDERS		
Algal scum	Algae, green	Minor-- aesthetically unpleasent, a problem in poorly drained areas
Black layer	Bacteria, anaerobic	Minor-- problem in poorly drained soils
Fairy ring	Basidomycetes	Minor-- aesthetically unpleasant, a problem in some areas
Insects	Various	Minor-- several insects are serious periodically
Slime mold	*Physarum* and *Mucilago* spp.	Minor-- aesthetically unpleasent, of local importance only

A key for recognizing the above common bermuda turfgrass diseases and disorders in Hawaii is given below.

KEY TO BIOTIC DISEASES AND DISORDERS OF BERMUDAGRASS TURF IN HAWAII

1. Turf develops large dark green circles .... **Fairy ring**
   Large dark green circles are not found 2
2. Disease or disorder associated with turf generally thinning out in small to large areas 3
   Disease associated with turf is in spots or patches 10
3. Thinning out usually sharply demarcated from healthy turf, pinkish insects found in white, powdery masses inside leaf sheaths ...... **Rhodesgrass mealybug**
   Thinned out areas usually have an irregular margin 4
4. Surface covered with a blackish-green scum .... **Algal scum**
   Surface not covered with a blackish-green scum 5
5. Subsurface core is heavily thatched and has a black strata, smelling of hydrogen sulfide (h_2S) (rotten egg smell) .... **Black layer**
   Subsurface core without black strata and distinct odor 6
6. Thinned area with chlorotic rings .... **Mottled spot**
   Thinned area without chlorotic rings 7
7. Thinned area with very small, root-knots or galls, devitalized root tips, root lesions or reduced root system .... **Nematode decline**
   Thinned areas without roots so affected 8
8. Thinned area with leaf spots primarily on older leaves .... **Fading Out**
   Thinned area with small, purplish spots on younger leaves and irregular spots with dark margins on older leaves 9
9. Disease occurring in warmer areas below 2,000 ft. elevation .... **Melting Out**
   Disease occurring in cooler areas above 2,000 ft. elevation .... **Drechslera leaf spot**
10. Causal agent usually infects younger leaves 11
    Causal agent usually infects older leaves 14
11. Infection of young leaves produces a blight 12
    Infection of young leaves produces elongate spots 13
12. Small greasy spots are formed in turf which produce abundant white mycelium under very humid conditions .... **Grease spot**
    Leaves in small spot or patches seem to wilt or collapse and turn tan to brown. In humid weather tan colored mycelium may be seen like cobwebs over the surface of dead grass .... **Brown patch**
13. Small chlorotic spots become elongate and develop an interveinal transluscence .... **Bacterial stripe**
    Small chlorotic spots become elongate between veins. Spots swell as spores are produced. The swelling (pustule) ruptures, exposing shiny orange to red colored spores .... **Rust**
14. Older, weakened leaves are attacked and become yellowed, tan and brown.. **Fusarium blight**
    Older leaves become yellowed, turn tan and produce tiny, black fruiting bodies (ascervuli) in the tan leaves .... **Anthracnose**

Damage of bermudagrass turf observed and collected from golf courses, parks and home lawns, submitted to the Plant Disease Clinic at the University of Hawaii over a period of 12 years was studied and the results are presented in Table 8. Because of the several categories of causal agents assigned, it is evident that collectors are often confused as to the exact nature of the causal agent. Further, problems associated with a given causal agent can vary in occurrences in different seasons of the year.

Table 8. Bermudagrass damage in Hawaii evaluated for probable causal agents and based on percentage of occurrance during various seasons of the year during a twelve year span.

Season of	Diseases**					Other causes***				
year*	BrPa	FaOt	GrSp	MeOt	SuTo	UnDe	InRe	Phys	SuTo	GrTo
Jan.-Apr.	6	5	2	13	26	5	5	5	15	41
May-Sept.	6	5	1	5	17	5	5	4	14	31
Oct.-Dec.	5	3	1	9	18	4	5	2	11	29
Total	17	13	4	27	61	14	15	11	40	101

* = Three seasons based on environmental factors
** = Major diseases of bermudagrass turf: BrPa = Brown patch (*Rhizoctonia* spp.) FaOt = Fading out (*Curvularia* spp.GrSp = Grease spot (*Pythium* spp.) MeOt = Melting out (*Heliminthosporium* = *Bipolaris* &*Exerohilum* spp.) SuTo = Subtotal of percentage of disease related problems
*** = Other causal agents of damage: UnDe = Undetermined causes, unable to find causal agent; InRe = Insect related, symptoms disease-like:Phys = Physiological, associated with chemical or cultural problems SuTo = Subtotal of percentages of "other causes" related problems *** GrTo = Grand total of percentages of all causes exceeds 100% because of rounding.

For diseases to occur, three factors must be present in their most favorable state, i.e., a susceptible plant, a causal agent of disease and an environment conducive for the disease. The degree of plant susceptibility, the virulence and abundance of the causal agent, and environment beneficial to both the plant and causal agent all interact to bring about a level of disease. The more favorable that each of the three factors are, the higher or more intensive the disease becomes. For this reason, Integrated Pest Management (IPM) is essential. Further, it is then necessary to have golf course personnel who are knowledgeable about turfgrass pests and their management and are dedicated to carrying out the precepts of IPM.

For the most part, bermudagrasses (common and its hybrids) (*Cynodon* spp.) are less susceptible to disease than other turfgrasses such as bentgrass (*Agrostis* spp.). This advantage can be somewhat lessened because of many different ecological sites on which golf courses are located. In Hawaii, no two golf courses are the same although some hole layouts can be similar. Therefore, each golf course manager can have disease problems peculiar to his golf course. On each island in Hawaii the environment varies along sites on each isothermal line as well as with changes in altitude. Specific cultural practices preferred by a manager can also have an influence on disease dynamics.

CAUSAL AGENTS OF PLANT DISEASES, DISORDERS OR INJURY

Causal agents of disease are classified on their ability to infect plant tissue and are called **infectious**. Living causal agents capable of infecting are grouped as biotic and are also called **pathogens** if they cause a measurable disease. Major types of biotic causal agents are: **fungi, bacteria, viruses, and nematodes.**

Noninfectious causal agents are listed as **abiotic** (nonliving) or **biotic**. They can also be called **physiological** because they interfere with the normal growth function of the plant. Generally the term disease is reserved for those instances when the damage to the plant is caused by a living causal agent whereas **disorder** is used when the growth impairment is not continuous and the damage can be ameliorated. The term injury is used when an effect is noticed in or on the plant tissue and its condition was brought on quite suddenly. The onset of plant damage from disease or disorders can take several days or longer to become apparent. Another group of plant disease is that of diseases of unknown origin. The causal agents for these diseases have not yet been determined.

CAUSAL AGENTS OF PLANT DAMAGE

Noninfectious Diseases and Disorders

ABIOTIC AGENTS

Environmental Agents

Those factors involved in growth of turf will be briefly discussed as to how they can adversely affect its development if found in an imbalance with the plant's requirements. It is often difficult to separate the impact that each environmental factors independently has on the plant as they are frequently interrelated in their ecology.

Temperature

Extremes in temperature can adversely affect turf depending on the physiological status of plants at the time when imbalance occurs. Low temperatures cause warm season turf such as bermudagrass to go into dormancy. Prolonged low temperatures can occur when dew remains on the grass in early morning. Soft winds blows over the wet grass causing evaporative cooling. High temperature, related to solar radiation, speeds up the processes of leaf transpiration and root respiration. Grass can become scalded under objects which trap the heat and moisture given off by transpiration of the leaves or from soil or when immersed in water for a period of time. Excessive root respiration depletes the soil of oxygen and can increase accumulation of toxic gases around the roots because of increased activity of soil microorganisms.

Moisture

Extremes in availability of water is a problem which is most troublesome for a golf course manager as it involves quantity, distribution, timing and sometimes quality. Low moisture extremes in the plant causes wilting, lack of growth, and to be more prone to mechanical damage. Footprinting occurs when the grass blades do not have enough moisture in them to rebound after being stepped on. In such cases the turf is under moisture stress and should be syringed, which involves a light application of water. Localized dry spots, which are hard to wet, occur in some areas of a green. This is because of microbial activity in sand or sandy loams or poor mixing of the media. This condition can be corrected with periodic coring or aerification.

Excessive water results in plant damage through poor root growth. Suboxidation (lack of oxygen necessary for root respiration) along with build up of toxic gases can ultimately cause death of the turf. Water that stands in low spots for extended periods can also cause suboxidation. Excessive water percolating through the soil causes leaching of soil nutrients.

Soil compaction

Soil areas where heavy foot or vehicle traffic occurs will become compacted, especially if the soil is moist and/or it is of fine texture. Soils that are heavily compacted

penetration in compacted soils are hampered. Management and renovation of these areas must be addressed as to the practicality of methods and alternatives for corrective measures. If not too heavily compacted, maintenance methods such as coring and slicing can be an adequate remedy.

Soil depth and uniformity

In Hawaii, care must be taken to assure that all large rocks within four to six inches of the soil surface have been removed. Turf growing on rock outcroppings will exhibit moisture stress sooner than surrounding rock-free areas. If fill soil is used, it is preferable that it be of the same type as the existing site to insure the same water-holding capacity.

Thatch

Thatch management is another troublesome problem with which golf course managers have to deal. Thatch is not greatly affected by leaf clippings, which are removed or fall back into the turf, as these are quickly decomposed by microorganisms. The more woody stolons, rhizomes, and roots require a much longer time to decay. Thatch can be kept under control with periodic verticutting and aerification. Thatch can build up whenever top dressing is used instead of verticutting and aerifying or when using too much top dressing after aerification. Thick layers of thatch interfere with penetration of air, water, fertilizer and pesticides into the soil. Further, escape of harmful gases such as hydrogen sulfide from the soil is impaired. Because of this hostile environment in the thatch, existing roots become nonfunctional and new roots cannot penetrate the layer except through the holes made by an aerifying machine and filled with top dressing material.Culturally, roots tend to form in the moist upper thatch layer. This renders turf more vulnerable during high temperature stress,because of adverse moisture fluctuations the young roots desiccate and die off. Dense thatch can cause the turf to be hydrophobic.

Landscape plants

Landscape plants and trees, which have shallow root systems, compete with turf for water and nutrients. Dense plantings of trees and shrubs near tees and greens shade out shade-intolerant bermudagrass. Coconut palms planted close to greens are the worst offenders with respect to competition and shade. Tall trees and bushes should not be planted close to the green on the east and south side. Trees and shrubs should be deeply fertilized and watered to avoid competition with the turf for water and nutrients.

Mechanical Agents

Certain poor maintenance and mowing practices can lead to injury of the turf.

Mower injury

Dull reel mower blades cause a tearing or shredding of leaf blades. Injured leaf tips will die in a few days and show a brown color at the turf surface. Dull rotary mower blades will leave the cut grass with a grayish-green cast due to frayed leaves and in a few days will resemble the injury with dull reel mowers. During wet weather, the turf is predisposed to infection.

Scalping injury

When grass is mowed so short that the green, chlorophyll-containing parts of the turf is removed, yellow and brown stems are exposed; this is a condition called scalping.

There may be several causes of scalping. Too infrequent mowing for rate of growth of turf is one of the most common causes. Turf maintained at very low mowing heights, such as putting greens and tees must be mown frequently to prevent removing too much of the leaf surface. A common rule of thumb of determining mowing frequency is to mow frequently enough that no more than one-third of the leaf is removed at one time. Scalped areas may occur when a mower wheel drops into a depression. Scalping can occur when mower speed is excessive for the contour of the terrain. Scalping on golf greens most frequently occurs in the peripheral cut. A scalped appearance is generally noted on greens, tees, and fairways following an extended rainy period, when mowing is impossible and the mowing height is not gradually adjusted to reach the proper mowing height.

Abrasion Injury

Leaves and crowns of turf are injured by excessive usage or traffic. This injury occurs on greens when cups are not rotated frequently enough. The same is true of tee markers, especially during wet weather. This injury is seldom permanent, but the more the abrasion, the longer it will take for turf to recover. Motorized golf carts and maintenance vehicles on wet turf, if used abusively, can be particularly damaging.

Chemical Agents

Chemical spills

Any number of chemicals used in the operation of a golf course can cause injury to turf, e.g., fuel, oil, cleaning fluids and plant health compounds. For the most part, their contact with turf is accidental, such as a broken hydraulic fluid hose, which can cause severe damage if not detected soon enough. An early application of detergent, brushing, flushing with water, and subsequently treatment with an absorbent material such as activated charcoal will reduce damage. Be wary of soil from pineapple or sugarcane fields, which can contain persistent herbicides.

Fertilizer excesses and deficiencies

Proper fertility takes into account the season, amount of traffic expected and distribution. Low fertility can be as harmful as excessive applications. Areas with excessive fertility can be scalped during mowing. This can occur when there is an overlap in the fertilizer application swath. Dry fertilizer applications on wet turf can cause leaf burn. Soluble fertilizers should always be watered into the soil if leaves are wet at the time of application. To avoid over-application of some fertilizer elements, soil should be analyzed periodically to determine the correct amount to apply.

Salt Injury

Plants take moisture into their roots by the process of osmosis. This process is dependent upon the concentration of the soil solution outside the plant root being less than the concentration of protoplasm in the root hairs. If the concentration outside the root is greater, for a period of time, the roots become dehydrated and die. This latter process is called **exosmosis**. Excessive applications of soluble fertilizers can cause high salt concentrations either in the soil solution or on turf leaves themselves in the case of wet turf. Excessive salts can accumulate from constant usage of brackish water, if rainfall is insufficient to leach the excess salt from the soil. In some cases a light film of salts can be seen on or around the dead grass. Animal urine contains high concentrations of urea and other soluble salts. Deposition in one spot is sufficient to kill the grass. Later, one can

notice that the grass at the margin of the dead spot is much greener than surrounding turf.

Pesticides

It is very important to precisely follow application instructions found on the label of a pesticide container. This applies to rate of application as well as the recommended quantity of water to mix with the pesticide to be applied to a specified area. Some herbicide precautions state that the turf must be in good vigor at time of application. To do otherwise can result in injury to turf. In some cases, instructions specify that the pesticide must be washed off leaf surfaces in order to achieve maximum efficiency. Care in application is extremely important so overlapping does not occur or an area is left untreated. It is also important not to exceed numbers of applications or lessen the interval between each.

BIOTIC AGENTS OF NONINFECTIOUS DISEASES OR DISORDERS

All damage described in this section is associated with living causal agents. Therefore, the causal agent, along with the plant are affected by the environment. Basically then, it is the environment which influences the severity of the damage. As such, we attempt to alter the environment so as to manage the occurrence of the damage. Study of the factors which influence severity of the disease or disorder is called epidemiology.

Algal Scum:

The problem of algal scum in Hawaii is widespread. Occurrence of these small, single-celled green or blue-green primitive plants is generally more common during late fall and early spring. Algae, like those which produce a scum on ponds during warm weather, feed on the break-down products of decay near the soil surface. They do not infect the green plant tissue since they have chlorophyll and can produce their own food.

Symptoms: Usually turf which is thinning out for one reason or another is a candidate for algae to flourish. Algae feed on organic breakdown products of turf on the soil surface. Algae produce a thick layer of greenish-black scum on the soil surface. When conditions are highly favorable for disease development, algae can be found on the green leaves. When the scum layer dries, a crust which is impervious to water penetration is formed and gas exchange between the soil and atmosphere is impaired.

Epidemiology: Algal growth is favored during periods of wet, cloudy weather or under shaded conditions. Abundant growth is encouraged by applications of organic nitrogen fertilizers.

Management: Areas which have a healthy, vigorous stand of dense turf by mid-fall will not have an algal problem if kept that way through the winter months. Turf aerification should be made prior to this time to assure good soil drainage. Adequate light penetration and good drainage are critical. Heavy applications of organic nitrogen fertilizers should be avoided. Attention should be given to timely management of diseases such as fading out, grease spot and melting out, as well as insects which may thin the turf. At the first signs of thinning out, application of mancozeb at the rate of 6 oz./1000 sq. ft. should be made. If improvement in turf growth is not noticed in seven days, apply cupric hydroxide at the recommended rates and intervals. If a crust has formed on the soil surface, the area should first be spiked or sliced before making applications of the algacide. A combination of mancozeb and cupric hydroxide may be used in severe cases.

Black Layer

Black layer is a below-ground phenomenon consisting of the occurrence of a stratum (or strata), black in appearance. This condition has been referred to by some as "black layer" and by others "black plague".

Symptoms: First indication of black layer may be a thinnning out of the turf, not unlike the symptoms observed during the disease progress of melting out or fading out. Indeed, causal agents of these infectious diseases may be present to some extent, however, in the role of weak pathogens. Taking a core 1 inch in diameter and 1 foot deep in the turf will reveal a thick thatch layer with black strata and having a mild to strong odor of hydrogen sulfide (rotten egg smell).

Epidemiology: Black layer occurs in sod, on the greens or elswhere that is poorly drained for one reason or another. An anaerobic condition is caused by the retention of water, which severely limits oxygen. Lack of adequate oxygen is harmful to roots as it limits root respiration. Further, lack of oxygen causes elements such as iron, sulfur and manganese to change to their reduced states of sulfides. Roots absorb these compounds which become toxic at high levels. Also, anaerobic bacteria are favored by water-logged soils. These bacteria produce toxins such as methane which also adversely affect plant growth.

Management: Black layer is harmful to plant growth and is symptomatic of poor cultural practices which brought it about. The first consideration should be to avoid it by carrying out regular maintenance aerification procedures. If greens have a heavy thatch problem, mancozeb for control of foliar or root diseases should be used sparingly, as this fungicide is high in manganese as well as sulfur, which are two components of the black layer. Frequent aerifications and proper top dressing applications are recommended to restore the balance of adequate oxygen in the soil.

Fairy ring

Fairy ring is usually listed as a disease, however, the effect on the turf is indirect rather than direct. The turf is not infected except in a saprophytic sense. The causal agents involved belong to a class of fungi whose fruiting structures are either mushrooms or puffballs (Basidomycetes). These fungi derive their nutrition from decaying organic matter such as thatch and buried wood, e.g., lumber, tree stumps and/or roots.

Symptoms: The disorder is called fairy ring because of the dark green circles of grass in which, on occasion, mushrooms or so-called toadstools occur in them during wet periods, following seasonal drought. An area of thin, dormant and/or dead grass along with weeds can develop in the center of the ring. In some cases, the central area of the ring will appear near normal. In others, a ring of lush green grass will grow on the outer rim of the circle. Size of the rings can vary from a few inches to many feet in diameter. Sometimes the rings are incomplete and resemble arcs of a circle. In other cases, the rings coalesce producing larger forms of superimposed rings. Some rings enlarge annually from a few inches up to nearly two feet.

Epidemiology: Fairy ring is generally more severe on light textured or sandy soils than the heavier clay soils. Low fertility and low soil moisture also favor ring development. Because adequate fertility and moisture are provided to the greens, one seldom sees fairy rings in them. However, on the fairways, it is a different matter. Rings suddenly disappear in some cases . The fungus develops a dense mat of fungal material. This mat is hydrophobic or somewhat impervious to the penetration of moisture. For this

reason, grass in the center of the ring appears impoverished and sometimes dies, this area may become weedy. This impervious layer can penetrate the soil to a depth of 6 to 12 inches.

Management: Better management of fairy ring has been obtained with cultural rather than chemical methods. Initially, it may be preferable to mask the symptoms by piercing the affected area with a pointed tool, fertilize, then water every 3 to 7 days. If more serious, frequent boring of holes in the fungus matted area, then fertilizing and watering with a light solution of detergent will help get moisture and nutrients down to the desired depth. This helps competitive microorganisms become established.

A method which is labor intensive involves removing all the sod and soil from the matted area down to six inches below where the white mycelial threads of the fungus can be seen and in a zone extending out about 18 inches beyond the outer green ring and filling the hole with new, unaffected soil and sod. In some cases, deeply rototilling the area and fumigating with methyl bromide can give desired results. Methyl bromide must be applied by a licensed applicator.

Insects

Insects cause damage to turf which may be easily confused with symptoms of disease. It is important that the golf course manager investigate these possibilities before disease management measures are taken. Certain detection techniques are explained in the section on insects. A 10X (power) hand lens is very useful to trained personnel to distinguish between insect disorders and injury and the symptoms of disease.

Slime molds

Slime molds are not plant parasitic but are not aesthetically pleasing on a golf course.

Symptoms: Initially a white to yellow, slimy growth emerges from the soil and grows up on any erect surfaces in its vicinity whether they be grass, weeds or other objects nearby. After reaching a lighted, airy site, the slimy mass changes into reproductive structures. There are two major genera, *Physarum* and *Mucilago*. The former appears somewhat grayish with purple-brown spore masses, whereas the latter is more whitish with a black spore mass.

Epidemiology: Abundant decaying leaves and thatch form a suitable medium for growth. In cool, humid weather, spore germination is stimulated and swimming spores are produced. The fungus can survive as spores for long periods of time. The slime mold usually reappears in the same area year after year. The duration of occurrence is usually for 1 to 2 weeks.

Management: The area should be raked to remove leaves and thatch in the off season when the slime mold appears. This should not be done in wet weather, as the spores will be spread and new infections will start. If the problem is unmanageable with cultural methods, spraying with any general fungicide will prevent its reappearance.

FACTORS WHICH INFLUENCE THE SEVERITY OF BERMUDAGRASS TURF DISEASES IN HAWAII

Generally, four major factors are necessary for plant growth and development, i.e., proper temperature, moisture, sunlight, and plant nutrients.The process by which a plant makes the food necessary for its functions is called photosynthesis. These factors and additional ones, peculiar to bermudagrass turfgrasses, which influence the severity of their diseases is presented (Table 9).

Temperature

Bermuda turfgrasses are classified as warm season grasses. They are generally shade intolerant. Therefore, at the lower temperatures (50 to 60 ° F) which occur during the winter months, or at higher elevations, growth of bermudagrass is retarded and goes into semidormancy. This puts the plant under stress. For the most part the pathogens are also adversely affected.

Low (50 to 65° F)

Because of growth retardation in the lower temperature range, bermudagrasses are generally predisposed to the weaker pathogens, especially those causing Anthracnose, Fading out, Fusarium blight and Melting out. A species of *Pythium* which causes root rot is also favored by low temperature.

Moderate (70 to 80° F)

Major turfgrass diseases may occur in the moderate temperature range. Bipolaris leaf spot is the major disease of bermudagrass turf in Hawaii which is so affected.

High (85 to 95° F)

Brown patch and Grease spot can be serious if other environmental factors necessary for the disease are present. Fading out can become serious if high temperatures persist.

Moisture:

Some moisture at critical periods is necessary for all fungal diseases to occur, since all fungi need free moisture on the leaf surface for spore germination and fungal penetration into the leaf. Sustained moisture over a given period of time is required for the fungus to sporulate and build up. An abundance of spores, above the threshold level, is necessary for the disease to become severe.

Humidity

High air humidity is generally necessary for diseases caused by bacteria and fungi. In Hawaii, high atmospheric humidity generally occurs in the absence of wind, night or day. In the presence of suitable temperatures, fungi may germinate within two hours and then take another two hours to penetrate the leaf surface. Once the tissue is infected, moisture is no longer a requirement for disease development. However, high humidity is necessary for the production of spores and the subsequent infection of new leaves.

Table 9. The role of combinations of environmental and cultural factors highly favorable and/or contributory to major turfgrass fungal diseases

Environmental and cultural factors	Diseases			
	BrPa	FaOt	GrSp	MeOt
1. Temperature				
a. Low (50-70 F)	+	++	++	++
b. Moderate (70-85 F)	++	++	++	++
c. High (85-95 F)	+++	+++	+++	+
2. Moisture				
a. Humidity, air, high	+++	+++	+++	+++
b. Prolonged leaf wetness	+++	+++	+++	+++
c. Excessive soil moisture	++	++	+++	++
d. Low soil moisture	+	+++	o	+++
3. Sunlight, low	++	+++	++	+++
4. Nitrogen fertility				
a. Excessive	+++	+++	+++	+++
b. Low	+	++	o	++
5. Thatch, excessive	+++	+++	+++	+++
6. Poor maintenance	++	+++	++	++
7. Nematodes (plant stress)	+	+++	o	++
8. Insects (plant stress)	o	+++	o	++

* Diseases: BrPa = Brown patch (*Rhizoctonia* solani) FaOt = Fading out (*Curvularia* spp.) GrSp = Grease spot (*Pythium* spp.) MeOt = Melting out (*Bipolaris cynodontis*)
**Role of each factor:
(o = none, + = minor, ++ = moderate, +++ = major)

Prolonged leaf wetness

Prolonged leaf wetness predisposes turfgrass to fungal and bacterial diseases. Morning dew must be removed from the turf surface as soon as possible. This can be accomplished by mowing, watering or using a detergent. Particular attention should be given to greens during extended cloudy periods. Prolonged leaf wetness is encouraged by lack of air movement and/or shade. Freshly cut leaves are vulnerable to more rapid infection. Turf areas which are located in a ravine or gulch or in the shade of a mountain remain cooler longer in the morning because of the lack of air movement, which circulates the warmer air and dries the leaves. Cooler temperatures have an adverse effect on the growth of bermudagrasses. Thick hedges or dense tree plantings near greens can block the movement of air. These must be thinned out or opened at the bottom to provide adequate air circulation. Disease problems will occur where the morning sun is blocked by trees, terrain, buildings, etc. Shade not only deprives the plant of sunlight necessary for maximum growth, but also causes prolonged leaf wetness. The growth problem is compounded by reduced temperatures on the leaf blade because of convection cooling.

Excessive soil moisture

Excessive moisture in soils over extended periods can be harmful to grass because of the reduction of oxygen, when normal air spaces in the soil are filled with water. Oxygen in soil is essential for the roots of turf to carry out the important function of respiration and produce new roots. This places the turf under stress and makes it more vulnerable to attack by weak pathogens. The condition of reduced oxygen in the soil is called **suboxidation.**

Excessive soil moisture also favors growth, reproduction and infectiveness of fungi such as *Pythium*, the cause of Grease spot.

Low soil moisture

Chronic moisture stress is responsible for poor root and leaf development, which places the turf under stress, predisposing it to attack by weak pathogens. Diseases such as Melting out, Fading out Anthracnose and Fusarium blight are frequently found where turf is under moisture stress, but night dew is sufficient for infection.

Low soil moisture is often the result of light waterings where water does not percolate to sufficient depth for deep root penetration.

Fertility:

Low fertility can be as harmful as excessive applications. Where traffic is high, applications of fertilizer should be sufficient to compensate for the additional wear.

Low fertility

Insufficient amounts of total fertilizer and water will cause shorter internodes and smaller leaves. Generally, the grass will be a lighter green. If specific fertilizer elements, e.g., nitrogen, phosphorus, potassium, iron, etc. are deficient, turf will show symptoms of the element a plant is in greatest need of, when in fact, more than one element may be deficient to a lesser degree. Symptoms at times can be confusing, e.g., a purplish cast to the leaves may indicate a phosphorus deficiency, a reaction to low temperature or general stress.

Nitrogen

Nitrogen is essential for formation of the chlorophyll molecule which gives the plant its green color. This molecule is involved in the process of photosynthesis, which converts the sun's energy into compounds the plant can utilize for its growth and development. When nitrogen is limiting, the green color becomes lighter, then finally yellowish. This change in color is called "chlorosis", the symptoms of which may be confused with those causes by root disorders or leaf diseases.

Phosphorus

Although turfgrass requires phosphorus in lesser amounts than either nitrogen or potassium, it is important as it is associated with food storage and energy containing compounds by which the plant carries out respiration. Plants deficient in phosphorus may be predisposed to the weaker pathogens which attack the plant under stress.

Potassium

Plants deficient in potassium may be more susceptible to wilting and disease attacks. Potassium is associated with water relations in the plant and the plant's disease tolerance. The need for potassium in the plant is almost equal to the requirement for nitrogen.

Excessive fertility

High fertility, especially nitrogen, produces lush growth which may predispose the turf to severe attacks of Brown patch, fading out, Grease spot or Melting out. Further, excessive amounts of fertilizer will burn the plant tissue and cause other damage such as drawing moisture out of the roots to produce symptoms of water stress.

Excessive thatch

Thatch predisposes turf to many diseases because it produces a moist environment for build-up of pathogens as well as an ideal situation for infection of leaves, crowns, and roots. Heavily thatched turf also tends to be shallow rooted, placing the plant under additional stress.

Poor maintenance

Certain poor maintenance practices or mistakes may lead to disease occurrence on an increase in disease severity.

Mowing

Dull mower blades cause injury to leaves. Injured leaves will die in a few days and show a brown cast to the turf. During periods of prolonged leaf wetness injured leaves are more susceptible to infection by fungi, especially weak pathogens.

Soil compaction

Excessive vehicle and foot traffic causes destruction of soil structure and compression of the soil. Compression of the soil results in a reduction of large pore space in the soil and poor percolation of water and exchange of gases between the soil and atmosphere. Oxygen may become limiting for root growth under these conditions.

Nematodes:

Under Hawaiian environmental conditions, attack by some plant parasitic nematodes have not resulted in significant observable damage. Although population levels of nematodes are sufficient to cause growth retardation under stress conditions, optimal maintenance is sufficient to ameliorate the observable suppressing effects of nematodes. Nematode damage could contribute to plant stress under poor maintenance, which could predispose the turf to weak pathogens.

Insects:

The attack of certain insects such as the Rhodesgrass mealybug resemble effects of Fading out or Melting out. However, advance of the thinning-out margin in the turf, as a result of an attack by these insects appears to move on a relatively linear front, which is atypical for the turf symptoms of the previously mentioned fungal diseases, which are more irregular. An inspection of the turf with a hand lens should reveal presence of mealy bugs in the older leaf sheaths of the grass along the interface of good and poor turf. This affected turf is much more susceptible to weak pathogens.

Weeds:

Weeds compete with turf for water and nutrients. Certain weeds are more aggressive, therefore can render turfgrasses more susceptible to attack by weak pathogens.

BIOTIC CAUSAL AGENTS OF MAJOR INFECTIOUS DISEASES IN HAWAII

BROWN PATCH (Rhizoctonia blight)

The causal agent of brown patch disease is a fairly commonly occurring fungal pathogen. Its disease association with bermuda turfgrass in Hawaii has often been as a leaf blight or a root rot in nature rather than having the classical smoke ring symptoms. This disease can be of major concern during mid- to late summer wet periods.

Symptoms: Patches or rings of grass die out suddenly during periods of warm, humid weather. On closely mowed turf, which, when very wet for extended periods of time, small to large irregular patches or rings occur, ranging in size from a few inches to about three feet in diameter. The margin of affected areas may have a grayish-brown to purplish 1 to 2 inch band (smoke ring) around the edge, especially in early morning when the turf is covered with dew. Smoke ring is somewhat unreliable as a diagnostic character. Usually, infected leaves appear wilted and may be covered by a cobwebby fungal growth, and is visible only in early morning while grass is moist. Blighted areas soon turn a light brown color. Changes in predisposing conditions or effective fungicidal control will allow new growth to be formed. Persistent attacks by the fungus will result in a crown and root rot.

Causal agent: *Rhizoctonia solani* and other *Rhizoctonia* spp. This fungus does not produce spores in its normal infective state. Previously, identification was made based on mycelial characteristics. More recent work indicates the necessity to stain young fungi to determine whether or not the cells of the fungus are binucleate or multinucleate. The fungus is able to survive in soil by formation of small hardened masses of mycellium, called **sclerotia**, which are dark brown to black in color.

Epidemiology: Although brown patch can occur over a wide range of temperatures (50-100° F) it is generally most serious in termperatures above 83° F. Outbreaks of disease occur during hot, humid weather, although some Rhizoctonia spp. are able to infect in cooler temperatuires. Dense, soft turf growth, as encouraged by high nitrogen is particularly susceptible. Prolonged periods of leaf wetness are necessary for severe damage to occur. The fungal pathogen may be carried from green to green or course to course on soil-contaminated shoes or equipment.

Management: Cultural practices to reduce leaf wetness, especially in early morning should be followed. Water only in early morning. Adequate but not excessive fertilizer applications should be made prior to periods of high disease potential. Adequate levels of phosphorus and potassium are essential to maintain the highest level of resistance in the plant. Reduce thatch to less than one inch. Increase soil drainage to its maximum. Spray with an appropriate fungicide when disease occurrance exceeds the threshold level.

FADING OUT (Curvularia blight)

Although the causal agent of Fading out is not considered to be a strong pathogen, its effect on turfgrass can be serious under conditions of cultural or environmental stress or when plant tissue is weakened by other diseases. If these predisposing factors are not removed or lessened, *Curvularia* spp. will take on a major role in the decline of turfgrass. Diseases caused by *Curvularia* spp. are similar and can be confused with those associated with *Bipolaris* and *Exserohilum* spp.

Symptoms: Generally, the first symptom seen is a decline of turfgrass which results in thinning out. This may begin in small patches which may enlarge. Spots can coalese to form larger areas. Turfgrass may take on a chlorotic or light green, motled appearance. A closer inspecton of the leaves will show a tip burn or yellowing on the basal leaves on the sprig. Infected leaves will turn tan and later grayish brown. Usually at the stage where only 3-4 green leaves remain on a sprig of Tifdwarf bermudagrass is Fading out visable.

In some cases, distinct leaf spots are seen. These spots can be irregular or elongate. Some spots have a reddish or brown margin between the green and yellowed leaf tissue. They may occur on the tip, margin, inside the margin or in the axis of the leaf or on the leaf sheath. During prolonged wet periods, infection can take place on the cut end of the leaf blade.

Causal agent: *Curvularia* spp. are variable in their ability to cause disease. The fungus is able to survive saprophytically, therefore abundant spores are available when conditions for the disease is favorable. All common turfgrass species are susceptible to *Curvularia* spp.

Epidemiology: Disease is favored by any condition of culture or environment which prolongs leaf wetness. Low light intensity, because of shade, cloudy weather, etc., makes turfgrass more susceptible. Mowing lower than the recommended height also predisposes the turf to Fading out. High nitrogen levels also contribute to increased disease incidence. Hormonal herbicides and fungicides can also predispose turf to attack by this causal agent. Excessive thatch provides a food source for *Curvularia* spp. to grow and produce spores abundantly.

Management: Particular attention should be paid to the avoidance of Fading out. This involves environmental and cultural control followed by prudent use of fungicides. Any method or combination of methods to lower or avoid periods of prolonged leaf wetness should be employed. Reduce morning shade as much as possible. Manage fertilizer applications to increase phosphorus and potash while keeping nitrogen at its optimum. Avoid excessive use of systemic fungicides and herbicides. Employ a thatch control program through spring, summer and early fall. Fungicides are available for leaf protection and reduction of spore production in the upper thatch layers.

GREASE SPOT (cottony blight, Pythium blight, Pythium root rot)

Various names that diseases associated with *Pythium* spp. are given, indicate the different stages or forms that a disease can take. Of all diseases that attack turfgrass, grease spot is the one that brings most concern to golf course superintendents. This is because of the short time span for the disease to reach epidemic proportions. For this reason many prudent golf course managers keep a supply of the specialized systemic fungicide, which controls this disease, on hand as an insurance against the time when conditions may be favorable for a severe outbreak, although this may not occur once in 2-5 years. Minor disease incidents may occur more frequently.

Symptoms: During warm-to-hot, humid weather; purplish, water-soaked spots about the size of a quarter can appear on the grass, which later turn tan or brown. New spots can increase in size at a rapid rate. After a heavy rain the disease can spread over the grass in directions of the slope. Streak patterns of spots can also occur when mowing or other equipment spread the fungal spores. Initially, spots appear as though scalded with boiling water. The name grease spot was given because the water-soaked leaves in the spot felt slimy or greasy. In early morning, spots appear dark and if the humidity has been high, whitish, cottony webbing (fungal mycelium) can be seen on the dead, matted leaves of the spot, hence the name, cottony blight. Large areas become blighted when drainage water from surrounding areas run over or flood the area. In such cases, whole greens may be lost in the matter of a few days.

Root rot associated with *Pythium* spp. occurs more frequently than the leaf blight phase. Symptoms of root rot are almost indistinguishable from those of many other causes, infectious or non-infectious. These cause thin and/or chlorotic patches which may be small or can cover almost a whole green.

Causal agent: *Pythium aphanidermatum* (blight), *P. splendens* and others (root rot). *Pythium* is known as a water mold because it is more tolerant of moisture saturated soils than other microorganisms. Then too, it produces mobile spores which swim in water. Therefore, the pathogen has a distinct advantage for the infection process. The fungus also produces thick-walled spores in soil as well as in plant tissue which are capable of surviving in soil for up to ten years with only a portion of the spore population germinating each year. Although *P. aphanidermatum* is best known for its leaf blight during warm, humid weather, it can also cause root rot if conditions for disease persist. *P. splendens* is mostly associated with root rot during extended periods of cool, wet weather.

Epidemiology: A disease epidemic does not occur unless there is an abundance of the pathogen. Grease spot becomes severe if two or three days of weather conducive of spore build up occurs. Favorable temperatures for *P. aphanidermatum*, along with wet weather, are 84-95° F during the daytime and no lower than 68° F at night. In Hawaii, these conditions may occur in late summer to mid fall in the lull between two low pressure fronts or during the period preceeding and following a hurricane which is moving at a slow speed and there is little or no wind to dry off the leaves. Location of a green at a site surrounded by protective vegetation or in a valley can create environmental conditions highly conducive to an outbreak of *Pythium* blight.

Management: Since excessive moisture is most important in severe disease outbreaks, water or moisture management is critical in avoiding this disease. Control starts with the construction of greens or other turf areas. Care must be taken to provide good surface and subsurface drainage. Subsequent management of thatch is a substantial contribution to control of this and other diseases. Provide for good soil aeration and air drainage. Avoid morning shade on tees and greens. Water only in the morning and when necessary. Control turf growth, fertilize when necessary. An early application of an appropriate fungicide will be beneficial in control.

MELTING OUT (Going out, Helminthosporium leaf spots, brown blight, leaf blotch, and crown and root rots *Bipolaris* and *Exserohilum* leaf spots)

The genus *Helminthosporium* has recently been divided into four genera, i.e., *Bipolaris*, *Drechslera*, *Exserohilum*, and *Helminthosporium*. These pathogens are commonly associated with a number of turfgrass diseases. The disease associated with

Drechslera will be discussed under "Biotic causal agents of minor infectious diseases of Hawaii".

Symptoms: Symptoms of Melting out can involve leaf spot, blotch, eye spot and crown and root rots. Initial spots start as a pin-point, purplish, somewhat water-soaked spot. As spots enlarge, the center becomes necrotic (dead) then turns brown, tan, and later grayish. Usually a dark, reddish brown margin borders the necrotic area of the spot. Depending on size and location of the spot, the portion of the leaf towards its tip may turn yellow and then brown. Leaf sheaths can become severly affected either because spores germinate in a droplet of water that collects in the axis of the leaf and infects the leaf or when a droplet of water is held by surface tension between a leaf and an adjacent leaf sheath. Leaf blotches occur when a spot enlarges or two or more spots coalesce. When the disease is extensive over a small or larger area of turf, the disease is referred to as a blight. An eye-spot refers to a leaf spot that has a tan or gray center surrounded by a dark margin and a band outside the dark band which is chlorotic. Melting out may develop slowly or may progress rather rapidly depending on favorable environmental conditions. If, after initial infection of a given area, the environmental conditions turn unfavorable for continued disease development, a static period occurs. Upon the onset of ideal conditions for disease resumption, the disease outbreak will seem as though it occurred over-night. In severe disease outbreaks, crowns and roots of the plant become infected, turn brown and rot.

Causal agent: *Bipolaris cynodontis* is specific for causing disease among the genus *Cynodon* (the bermudagrasses). Other species of *Bipolaris* have a wider host range.

Epidemiology: *B. cynodontis* infects leaves of bermudagrasses primarily from late autum to spring during cool, wet periods. Root and crown rots occur in summer and early fall during warm and dry periods. Fungal spores need high humidity and a fine film of water on the leaf surface in order to germinate and infect. High humidity is not necessary for disease development in the leaf, however, high humidity is essential for production of more spores. This process is known as the disease cycle.

Management: Essentially the same conditions that favor Fading out caused by *Curvularia* spp. are similar to those favoring Melting out. However, *Bipolaris* is considered to be a stronger pathogen than *Curvularia* but *Bipolaris* does not require the higher temperatures to predispose the plant to disease. Management procedures for Fading out should also be considered for controling Melting out.

BIOTIC CAUSAL AGENTS OF MINOR INFECTIOUS DISEASES IN HAWAII

ANTHRACNOSE

Anthracnose is a name given to diseases in which the spores are produced in specialized structures (ascervuli) which appear as tiny black dots in the dead tissue. The fungus is found world-wide and commonly invades senescing plant tissue.

Symptoms: During cool, wet periods, stolon lesions, which are initially water-soaked are formed. These spots become bleached, girdle the stem, which can cause individual plants or small patches of turf to become chlorotic and die. During warm weather the fungus readily attacks the older and senescing leaves when atmospheric conditions are very humid. Leaves die and turn tan. Black fruiting bodies (ascervuli), which resemble flecks of pepper, are found abundantly embedded in the necrotic tissue. Patches of dead turf, several inches to several yards across can be formed.

Causal agent: *Colletotrichum graminicola* attacks a wide range of grass species. It is reported that *C. graminicola* has pathogenic races in other graminicolous hosts, therefore it is possible that isolates that attack turfgrasses may also have or can develop host specificity. Generally, this fungus is considered to be a weak pathogen on bermudagrass.

Epidemiology: Usually those conditions unfavorable for the growth of the turfgrass plant enable this disease to become serious. Spores of the fungus are abundant in thatch when moisture is sufficient for their production. When atmospheric humidity is high and leaves have a film of water on them, infection takes place readily on the stressed plant.

Management: Adequate (but not excessive) soil moisture and balanced fertility are crucial in avoiding this disease. Water deeply and infrequently to avoid drought stress. Fertilize regularly except during drought or periods of high temperatures. Use fungicides only to protect the new foliage when plants are going into stress and when recovering.

BACTERIAL STRIPE

Several years ago bacteria causing symptoms of bacterial stripe were isolated from turf from a few locations in Hawaii and it has not been found since. The disease did not develop to the point where serious damage was done. It is not known how or when the pathogen arrived in Hawaii. Cultural management of the disease was recommended.

Symptoms: Infected turf appears as scattered, faint yellow mottled areas which may die out in patches. Leaves have an interveinal transluscence to them, which appears yellowed or somewhat clear when light is passed through the leaf blade. No wilting of the turf was observed.

Causal agent: *Xanthomonas* sp.

Epidemiology: Bacterial diseases are favored by high humidity and free surface water. Bacteria enter the plant through small openings on the end of veins, stomata (microscopic openings through which gas exchange occurs) or wounds. Wounds are most commonly caused by mowing, vehicle and/or human traffic. Although bacteria reproduce abundantly between 80-90° F, disease can be severe in cooler temperatures. Bacteria could be spread most effectively by mowing.

Management: The key to control of bacterial disease is reduction of free moisture on and in the turf. Presently there is no bactericidal chemical control recommended. Particular attention is directed to exclusion and keeping out new grasses from coming into Hawaii except through established quarantine procedures.

FUSARIUM BLIGHT

Fusarium blight symptoms, in many respects, are similar to those of Anthracnose. The management procedures also apply. The Fusarium causal agent is a weak pathogen, but contributory to over-all decline of bermudagrass turf.

Symptoms: During conditions stressful to growth of bermudagrass turf, the fungus attacks weakened or senescent leaves. Leaves become yellowed and then tan and brown.

Causal agent: *Fusarium* spp. (Fusaria are ubiqitous fungi).

Epidemiology: See Anthracnose.

Management: See Anthracnose. Fungicides are recommended during the recovery phase. Benomyl is more effective against Fusarium than some other fungicides.

DRECHSLERA LEAF SPOT

Symptoms of Drechslera leaf spot resemble those for Melting out. The management practices are also similar to those recommended for Melting out. However, because of the lower temperatures required for its activity, Drechslera is found on golf courses in Hawaii at elevations above 2,000 feet. It is therefore unlikely that this disease will ever be serious at the Lihi Lani site.

Symptoms: General symptoms are similar to those described for Melting out. Leaf spots begin as tiny brown spots which enlarge to become elongate. The central part of the leaf turns a light tan. These lesions may girdle the whole leaf. As the lesions enlarge rapidly, concentric bands of tan and dark brown appear, this gives rise to the symptom type, zonate eye spot. Severely affected turf thins out as the leaves become necrotic.

Causal agent: *Drechslera gigantea*

Epidemiology: Infection of bermudagrass usually occurs during the fall and winter when cool temperatures slow the growth of the turf. The pathogen survives unfavorable periods for growth and development as spores as well as dormant mycelium in plant debris. Upon rewetting, spores are produced on the dead tissue. The fungus sporulates at temperatures between 38-81° F, with an optimum of 59-64° F. Infection takes place readily in a cool, wet environment. Periods of prolonged leaf wetness favors the disease.

Management: Cultural and environmental management of this disease is similar to that recommended for fading out and melting out. Fungicidal control should be applied during peak infective times in late fall and winter to protect the leaves from entry by the pathogen.

RUST

The name of the disease comes from the color of the fungal spores which are produced in the leaf. After abundant spores are formed, the epidermis ruptures, exposing tiny reddish-brown spores which may be seen with a hand lens. In cereal crops, rusts can be very destructive. Famines have been associated with rust epidemics of wheat. In Hawaii leaf rust has never been considered highly damaging to bermudagrass turf.

Symptoms: Initial symptoms of rust are tiny yellow or purplish flecks on the leaf. As the disease progresses, the spot will elongate parallel to the length of the leaf blade. The infecting fungus will produce spores inside the maturing lesion and rupture along the length of the spot, which is called a pustule, exposing hundreds of orange to reddish-brown spores. These spores are easily disloged and adhere to anything that brushes them. They can be carried by the wind to another infection site. When disease is severe, the infected area of turf may appear reddish-brown. Leaves which are heavily infected with rust will turn chlorotic, wither and turn brown.

Causal agent: *Puccinia cynodontis* and *P. graminis graminis*. Another genus of rust is reported to infect *Cynodon* in China. Generally rust fungi are host-specific. *P. cynodontis* infects only *Cynodon*, but *P. graminis graminis* attacks both *Agropyron* and *Cynodon*. The rust fungus is an obligate parasite, which means that it needs a living host on which to reproduce. All other fungi which infect bermudagrasses in Hawaii are able to survive saprophytically, which enhances their longivity and spore production.

Epidemiology: In Hawaii, rust spores can survive in dead leaves for long periods of time without loss of infectivity. Rust spores, as those of other fungi, require a film of water in which to germinate and optimal temperatures for infection, growth and reproduction. Although requiring high humidity for host infection, unlike other pathogens, rust fungi can produce new spores in moderate humidity. As in many other bermudagrass diseases, stress on turf predisposes plants to infection. These stress factors include shade, nutritional deficiencies, drought, and low mowing.

Management: Improve cultural practices to avoid growth stress. Improve sunlight penetration and air drainage to avoid prolonged leaf wetness. Do not irrigate in the evening. If necessary, spray a suitable fungicide to protect against new infection.

NEMATODE DECLINE

Worm-like plant parasitic nematodes are obligate parasites that feed primarily on the roots of plants. They thrive in a cultural system that provides abundant food for their reproduction. They are microscopic, about 0.02 inch long and around 20 to 25 times longer than wide.

Symptoms: Symptoms produced by nematodes often go unnoticed in turf because of the size of the root that they attack. Even swellings of the roots escape the eye of the highly trained, except under a microscope. Therefore, symptoms appearing directly on the roots are of little help in field diagnosis. Indirect symptoms of growth decline, thinning out of the grass that does not respond to improved culture or applications of fungicides indicate that one should look further.

Nematodes are seldom distributed evenly in turf, but rather in patches. Because of their below-soil activity, their effect on turf will appear in scattered spots. However, growth decline of turf appearing as stunted, chlorotic growth may not be noticed if the grass is adequately watered and fertilized.

Some direct symptoms associated with nematodes found in turf in Hawaii are:
Root-knot nematodes; swelling of the root, sometimes a globular inflation of the root tip, and reduced root system.
Lesion nematodes; faint brown lesions on white roots and progressive browning of the root system until it appears rotted.
Spiral nematodes; usually no perceptible symptoms in a fiborous root system such as that of grasses.
Stubby root nematodes; a reduced root system where lateral roots are typically short.
Ring nematodes; as for Spiral nematodes.

Causal agents: All plant parasitic nematodes have a hollow, spear-like structure through which they pierce cell walls, inject a saliva containing enzymes, then suck back the partially digested cellular contents into their esophagus. Nematodes can be grouped based on their feeding habits, i. e., ectoparasitic (feeding from the outside of the root or to the depth of a few cells), and endoparasitic (penetrating the root before commencing feeding). Each of these feeding groups include those that are migratory throughout their life and those who become sedentary after beginning the feeding process. Nematodes may complete their life cycles in about 21 days, more or less, depending on optimal temperatures, as they are cold-blooded animals. The typical life cycle of a nematode consists of four molts. The first stage larva develops in the egg. It molts and the second stage breaks out of the egg case. The nematode becomes motile and infective. After three more molts, they become adults. Nematodes prefer saturated humidity soils rather than water saturated soils. They

are more active in well aerated soils.

Root knot nematodes: *Meloidogyne* spp.-endoparasitic/sedentary.
Lesion nematodes: *Pratylenchus* spp.-endoparasitic/migratory.
Spiral nematodes: *Helicotylenchus* spp.-ectoparasitic/migratory.
Stubby root nematodes: *Trichodorus* spp.-ectoparasitic/migratory.
Ring nematodes: *Criconemoides* spp.-ectoparasitic/sedentary.

Epidemiology: Although plant parasitic nematodes are motile, if left undisturbed in turf they may move only a few inches in a year's time. Movement of nematodes of greater distances usually requires outside assistance such as, surface run-off water or in soil carried on equipment, earth moving or shoes. Nematodes are usually most active in the temperature range of 68-86° F and in association with plants which are in the process of producing new roots. Nematode activity slows down when the plant is under growth stress. It is at this time when their presence and pathogenic activity is most noticable on the turf.

Management: Cultural practices which favor good turfgrass growth will compensate for feeding effects of nematodes to a certain extent. New cultivars should never be imported into Hawaii without going through the established procedures of the Hawaii Department of Agriculture Plant Quarantine Division. Turf from the Southeastern United States is especially suspect, as a devastating nematode, *Belonolaimus longicaudatus*, the sting nematode, is widespread there and has not as yet been reported in Hawaii.

If chemical control is recommended, there are both fumigant types, to be used prior to planting turf (preplant) and systemic or contact types that can be applied to growing turf (postplant). Since these types are generally highly toxic, extreme care in handling should be followed. Currently, no postplant nematicides are registered for use in Hawaii golf courses.

DISEASES OF UNKNOWN ORIGIN

MOTTLED SPOT

A problem to which considerable attention has been devoted in Hawaii is a condition referred to as mottled spot. Mottled spot occurs on putting greens which have been established for several years. The condition has been observed on both Tifdwarf and Tifgreen putting greens. Mottled spots occur most frequently during the winter months.

Symptoms: Areas of turf of various sizes on greens thin out beginnning with the onset of cool, wet fall weather. In the spring the spots may disappear or some may persist. Mottled spot takes on the appearance of turf under stress with symptoms similar to those of fading out. In some cases the spots appear as if reticulated with only chloritic rings to outline the affected area.

Causal Agent: The causal agent for the mottled spot condition remains unknown. Numerous isolations yielded *Curvularia, Fusarium, Bipolaris*, and *Acremonium*. The frequency of any one genus was insufficient for a tentative indictment. No pathogenicity tests were conducted with the isolates.

Epidemiology: Mottled spot occurs most frequently during the onset of cool weather. Turf under low fertilization programs also appeared to have a higher incidence of the condition.

Management: Increased fertilizer application going into winter months appeared to have reduced the problem. However, this conjucture is based on circumstantial evidence.

MONITORING METHODS FOR TURFGRASS DISEASE POPULATIONS

Diagnosing diseases and determining their causal agents continues to be a problem for golf course superintendents and their personnel, first because of the microscopic size of the causal agent and secondly, similarity of disease and disorder symptoms associated with various causal agents. It requires a highly trained technician with many years experience to identify plant pathogens. Many times, in the final analysis, identification of the organism to species is inadequate to prove pathogenicity. Inoculations with a pure culture of an organism, constantly associated with a disease onto a healthy host must be made. Subsequently comparison of the inoculated organism with the one recovered from an inoculated, diseased plant must show that they are the same. Often morphological similarity is insufficient, since the pathogenic and non-pathogenic strains look alike under the microscope. Training of the golf course superintendent and his aides in the locale of his course by a plant disease specialist will help the learning and understanding of diseases. The knowledge of the factors and conditions which predispose turfgrass to disease will be invaluable in making identifications. The golf course superintendent and his aides must be schooled in the use of a 10 power (10X) hand lens and learn how to look for signs of the causal agent. They should learn how to surface-sterilize diseased tissue, incubate it and scan for telltale spores. In finding a greasy looking spot on a green after a period of extended wetness, taking a sample and placing it in a closed plastic bag overnight should help identify the cottony blight symptoms caused by *Pythium* spp. He should be able to immediately take steps for arresting the spread of the disease. However, he should always have these actions corroborated by a specialist for verification. Identification kits for *Pythium* are available but the superintendent usually does not have the materials or expertise to prepare the fungus for processing.

The ability of the golf course personnel to identify disease in its earliest stages is critical to the success of any IPM for turf disease.

ACTION LEVELS (ECONOMIC THRESHOLD) FOR DISEASES

Because of the microscopic size of the pathogens, it is impossible to ascertain the level of inoculum present. One must rely on the degree of infection and the conduciveness of the predisposing cultural and environmental factors present to determine the urgency of implementing a management practice. Presence of visible disease symptoms is usually sufficient evidence that control measures must be undertaken, at least for the site where symptoms are observed. The superintendent must then make a judgment decision if prevailing environmental and cultural factors conducive to the rapid development of the disease warrant application of control measures at other locations on the golf course. Value of training and experience in identifying and recognizing the earliest stages of diseases again must be emphasised.

BIOLOGICAL, NATURAL, AND NON-PESTICIDAL CONTROLS

In most soils a biological balance is established among all competing organisms. In turfgrass we know of no antagonistic organisms that could be exploited to benefit the control of the more pathogenic species. However, when fumigating soils with methyl bromide, or other broad spectrum pesticides, care must be taken in the period immediately following removal of the sealing tarp, so that soil-borne pathogens such as *Pythium* and *Rhizoctonia* are not introduced before the beneficial antagonistic soil flora has an opportunity to become established. These two pathogens have the ability to rapidly colonize a soil in the absence of competing microorganisms.

The most effective, least expensive, most environmentally acceptable form of disease control is precisely following cultural procedures for growth of healthy turfgrass. Further, a modification of the environment so that conditions which favor the disease are supressed should be the first IPM consideration for turf diseases. It should always be remembered that a favorable environment is essential for the outbreak and sustained presence of turfgrass disease.

INTRODUCTION TO TURF DISEASE MANAGEMENT

Unlike animals and human beings, the individual plant generally has little value; it is the crop one seeks to save. Therefore, two basic economic considerations must be made before any plant disease management practice can be employed: 1) the value of the crop, and 2) the extent of the disease or anticipated loss. The objective of plant disease management is to employ any one or combination of measures to profitably reduce crop losses. Disease control measures are directed toward the host, pathogen and/or environment. Because of a complexity of these three interacting factors, which are present at disease onset and development, the implementation of a single type of control measure is generally not adequate. Successful disease control is most frequently a management system which involves two or more types of control measures. For example, good sanitary practices often determine whether or not disease control through chemical protection will be effective. Today more than ever, turf management specialists, entomologists, plant pathologists and weed scientists conduct cooperative studies with the aim of maximizing production while at the same time trying to minimize the application of pesticides in an integrated pest management system.

NON-CHEMICAL TURF DISEASE MANAGEMENT

EXCLUSION

Exclusion has for its purpose the prevention of pathogens from entering and establishing themselves in new areas. This method of disease control is carried out through programs of quarantine and certification.

Quarantine: This is a legal restriction on movement of commodities for the purpose of preventing or delaying establishment of plant pests and diseases in new areas. It is accomplished through:

1. Interception and destruction of infected or infested plants material.
2. Disinfection or disinfestation of plants or plant parts.
3. Post-entry quarantine of seed, vegetative cuttings or plants.

Currently in Hawaii there is a restriction that vegetative parts of grass plants must spend 12 months in quarantine because of the possibility of introducing viruses carried by grass plants.The period may be shortened to 6 months if certain conditions are met. Vegetatively propagated grasses passing through this rigorous test are used to start sod nurseries.

Certification: Most states have a seed certification program. Certain important information must be stated on the label of the seed container. The species and cultivar of seed, the minimum guaranteed purity of the seed, the minimum guaranteed percent germination of the seed, amount of weed seed, amount of noxious weeds, amount of other crop seeds, amount of inert matter are all stated on the seed label. If planting some bermudagrasses, which may be planted by true seed, obtaining the best seed possible is insurance of having the healthiest seedlings possible. Seed should be treated with a fungicide to prevent seedling diseases during a very vulnerable stage of plant development. Many states have programs of sod certification as well as seed certification.. Seed certification does not imply freedom from diseases or pathogens. If seed, true or vegetative, is free from specific diseases, it is so stated. A statement of the presence of some disease, in low percentage, may also be made. Nurseries are inspected to ensure that the variety is as advertised. Unfortunately, Hawaii has no sod certification program, indeed, the sod industry in Hawaii is so small that it is not efficient to have a sod certification program. Golf courses, especially new ones, which desire to plant vegetatively propagated cultivars for which no seed are available, should either establish their own sod nurseries from known cultivars well ahead of anticipated planting time or contract with reputable sod nurseries to grow a predetermined amount of sod to be delivered at a predetermined time. Clean stolons of hybrid bermudagrasses, which is attested to purity of cultivar are available in Hawaii in limited quantity. If a developer waits until just before planting time to find stolons, the supply will likely be insufficient to plant the entire golf course.

AVOIDANCE:

Avoidance tactics in managing turf diseases makes use of practices which are directed principally at manipulations of the environmental or cultural factors which influence inoculation, incubation, germination, infection and sporulation of the pathogens. Many routine practices in golf course management influence or predispose turf to disease. Both the above and below-ground environment will be considered here. Many aspects of turfgrass disease management which have their basis in avoidance have already been discussed under a previous section, "factors which influence the severity of bermudagrass diseases in Hawaii"

1. **Planting site** -- air drainage is most important.

2. **Selection of planting material** -- planting material should come from a pathogen- free nursery.

3. **Windbreaks** -- windbreaks should protect an area from excessive transpiration, but must be open enough to prevent prolonged periods of leaf wetness of the turf.

4. **Fill soil** -- soil from old sugarcane fields is not desirable for golf courses because of similarity of pathogens, both fungal and nematodal.

5. **Soil drainage** -- one of the most important factors in disease avoidance in all areas of the golf course is adequate soil drainage.

6. **Irrigation** -- optimum moisture for plant growth without excessive water, which reduces soil oxygen content is key to a good soil moisture/aeration balance.

7. **Fertilization** -- soil should be tested periodically for nutrients and soil reaction (pH).
Proper balance of nutrients promotes plant vigor.

a. too much nitrogen enhances certain diseases.
b. low fertility predisposes plant to weak pathogens.
c. adequate phosphorus and potassium increases disease tolerance.

8. **Soil compaction** -- roots need oxygen to function properly, excessive vehicle and foot traffic cause severe compaction. Heavy soils should be aerated often.

9. **Shade** -- greens should be constructed, landscaped, and maintained as open as possible. Morning shade is particularly damaging, as leaf blades remain wet for long periods of time.

10. **Leaf wetness** -- prolonged leaf wetness is a serious management problem and must be diligently avoided.

11. **Injury** -- mower blades should be kept sharp to avoid leaf injury. Tee markers should be moved often to prevent excessive injury and wear.

12. **Run-off water** -- greens should be constructed so that water from the surrounding area does not run across the green depositing pathogens or silt, which will create new problems in the future

SANITATION:

One of the often neglected forms of disease management is sanitation. The purpose of sanitation is to reduce the numbers of disease organisms that a plant is exposed to. Pathogens may be spread from infected areas to uninfected ones by maintenance equipment. Mowers are especially effective is spreading diseases. Cut leafblades are an ideal entry port for new infections. Care should be taken to use equipment on areas showing disease symptoms last. Equipment should then be washed down before using on uninfected areas. Grass clippings should be disposed of in places where they will not be a source of contamination. Excessive clippings, such as are present when rainy weather has prevented mowing for long periods, should be removed from all areas of the golf course, as heavy clippings shade the turf and predispose it to disease attack. Clippings should always be removed from greens. Weed control reduces competition with turf for nutrients, water and space and increases turf vigor.

RESISTANT CULTIVARS

Currently we know of no bermudagrass cultivars which demonstrate a measurable difference in tolerance to the bermudagrass diseases present in Hawaii.

CHEMICAL IPM OF TURF DISEASES

The prudent use of chemicals in management of turfgrass diseases helps the golf course manager offset unpredictable changes in the environment which may lead to a sudden increase in inoculum density, favorable conditions for infection development, or predisposition of turf to attack by weak pathogens.

ERADICATION

Eradication is an ideal that is seldom, if ever attained. An attempt at eradication which is incomplete, is sanitation because the ultimate that can be hoped for is a reduction in the numbers of pathogens. In the minds of many, eradication, like "control" is an absolute. Eradication is practically unattainable because of the small size of the pathogen, large size of the area involved, limitations of methods available for use and the cost involved in its removal and subsequent exclusion from re-entering. The rule is, "Start Clean, Stay Clean".

PROTECTION

Protection involving the use of pesticides is misunderstood by many. Protection involves application of a suitable chemical to a plant or its parts to prevent infection. After infection has taken place, no amount of pesticide sprayed onto the plant will kill the pathogen (except for systemic fungicides, discussed later under therapy). The mode of action of most of the fungicides used on turf is contact. It is therefore necessary that the fungicide is in place on the leaf before the fungal spore arrives. Some of the more commonly used fungicides for protection of turf in Hawaii are listed in Table 10.which also classifies the types of pesticides used for turfgrass disease management as to whether contact or systemic, protective or curative and general or restricted use.The signal word assigned to the pesticide's level of toxicity, its LD_{50} for acute oral and dermal dosages will be found in the section on "Safe and Effective use of Pesticides".

Table 11 lists pesticides suggested for use for disease management in Hawaii according to their common name and indicates the diseases for which they are used. Further, the causal agents of the various diseases are ranked as to their disease potential, i.e., key pests, occasional pests, or potential pests. There is one suspected disease that was found two years ago at about 500 feet elevation during a cool, wet period. It appeared to be a downy mildew. The weather turned warm and the disease disappeared before pathogenicity studies could be conducted. This disease caused a blight of the leaves and seemed to be more serious on common bermuda than on Tifgreen in the fairways.

Table 10. Turfgrass disease pesticides registered in Hawaii, their site of action, type of action and general classification.

Common or chemical name	Site of action*	Type of action†	General class.§
anilazine	con	pro	gen
benomyl	sys	pro & cur	gen
chlorothalonil	con	pro	gen
cupric hydroxide	con	pro	gen
etridiazole	con	pro	gen
iprodione	con	pro	gen
mancozeb	con	pro	gen
metalaxyl	sys	pro	gen
triadimefon	sys	pro	gen

* = Site of action - con = contact fungicide, sys = systemic fungicide.
† = Type of action - pro = protective, cur = curative.
§ = General classification - gen = general use, res = restricted use.

Table 11. Pesticides suggested for use for disease management in Hawaii and the potential for each disease.#

Pesticide Common or Rust chemical name	Diseases reported in Hawaii† AlSc	Anth	BrPa	DrLs	FaOt	FaRg	FuBt	Grsp	MeOt
anilazine			+	+					
benomyl									+
chlorothalonil		+	+	+	+				
iprodione									+
			+	+	+		+		+
mancozeb	+		+	+					
+							+	+	+
metalaxyl§								+	
triadimefon		+	+						
+							+		
DISEASE POTENTIAL¶	OP	OP	KP	PP	OP	OP	OP	KP	KP

\# = Although several pesticides are recommended for the same disease, not all are equally effective in all areas because of environmental differences. It is best to settle on 2 for each disease, then alternate their use. Be entirely familiar with the label before using any pesticide. Check periodically with the manufacturer's representative as a pesticide may be withdrawn by EPA without prior notice.
† = Diseases currently reported in Hawaii for which pesticides are recommended: AlSc = Algal scum, Anth = Anthracnose, BrPa = Brown patch, DrLs = *Drechslera* leaf spot, FaOt = Fading out, FaRg = Fairy ring, FuBt = *Fusarium* blight, GrSp = Grease spot, MeOt = Melting out, Rust = *Puccinia* rust
§ = Metalaxyl is not effective against the root rot phase of Grease spot, nor does it retard the formation of spores.
¶ = DISEASE POTENTIAL: KP = Key pest, OP = Occasional pest, PP = Potential pest.

FACTORS INFLUENCING THE EFFECTIVENESS OF FUNGICIDES

Several factors influence the effectiveness of pesticides when used as contact sprays. Some of these are:

Timing: Protection of the plant must be when it is most susceptible to infection. Spray applications must begin before the disease has reached an advanced stage. Early detection of a disease will facilitate timely protection.

Coverage: Adequate coverage of the plant or its parts is essential to good control. It is impossible to predict where a spore will land. In order to provide effective protection, the fungicide must provide good coverage of the plant. A complete film of fungicide on the leaf is more effective than a few large drops. Spray adjuvants, such as surfactants, decrease water tension, increase surface wetting, and aid in retaining the pesticide on the leaf increase coverage of the plant.

Phytotoxicity: A fungicide must kill or retard the pathogen but not injure the plant. Instructions for spraying, printed on the label must always be followed (by law). Although it may be more efficient to add two or more plant health chemicals to the same spray mix, some combinations may be either phytotoxic or rendered ineffective when spray mix, some combinations may be either phytotoxic or rendered ineffective when mixed. Compatability charts are available, which indicate the safety of mixing various plant protection chemicals.

Residual action: Spray adjuvants (things added to sprays to make them more effective) may be needed to assist in helping pesticides remain effective for a sufficient period to protect the plant. Wetting agents reduce water tension and prevent spray droplets from beading up and rolling off waxy leaves. Stickers help to retain the spray on the leaf and also slow the weathering process. The active ingredients in most fungicides are insoluble in water and cannot be formulated as solutions. Most are formulated as wettable powders. The powders are very fine and form a suspension when mixed with water. These suspensions will have less than 2% of the active ingredient in solution, therefore the liquid phase is relatively non-toxic. After the spray mix dries on the leaf it will be difficult to readily wash the fungicide off the leaf. Golfers should not be permitted on the course until the spray has dried, usually one hour after spraying on a sunny day or on a cloudy day with wind. If it rains before the spray has dried, the fungicide must be reapplied.

Types of spray equipment: Usually power sprayers with pressure between 20-1000 pounds per square inch (psi) and capacity of 50-200 gallons are used. Boom sprayers are used on fairways, roughs, and some tees. Hose sprayers attached to the sprayer are generally used for some tees and the greens.

THERAPY

Therapy includes all methods which can be considered to affect the pathogens after they have entered the plant. The pesticides used are considered to have systemic action. Such pesticides appear to be highly desirable but they do have their drawbacks. Because the pathogen is exposed to this pesticide during a longer span of time, sometimes at a sub-leathal dosage, there is an opportuntiy for the pathogen to mutate and develop strains which are resistant to that pesticide. Some mutations, in fact, have been found which require certain pesticides for growth.

Benomyl, a fungicide which is effective against Fusarium and metalaxyl, effective against Pythium, are examples of systemic fungicides.

IPM - WEEDS OF TURFGRASS IN HAWAII WITH SPECIAL REFERENCE TO LIHI LANI

CONCEPTS OF WEED MANAGEMENT:

Serious weeds in turfgrass are those that can grow and reproduce themselves in management conditions specific to turfgrass. The factors illiciting the most influence on the kind of weeds that persist in turf are close and frequent mowing, and the fact that the soil remains undisturbed once the seedbed is prepared. Thus, of hundreds of weeds in Hawaii only about 30 become serious turfgrass pests when turfgrass is reasonably well-managed. Those species likely to be present at the proposed golf course site are well-adapted to Hawaii's climatic regime (temperature, humidity, precipitation, sunlight; up to about 2000 feet in elevation). The specific weeds will be described in this report.

Many weeds that were abundant at the proposed golf course site such as sida (*Sida spinosa*), and various vervains (*Stachytarpheta cayennensis, Verbena* spp.) would

gradually disappear in turfgrass culture because it cannot withstand constant mowing.

The concepts of weed management differ from the concepts of insect or disease management. For example, it is often desirable to have a low population of an insect pest present, as they provide a source of food for parasites or predators that attack them. At these low populations, these insect pests often do no harm. For turf weeds, there is little to no significant predation that occurs by either insect predators or disease-causing organisms, thus there is no benefit in having any weed present. While biological control is important with certain weeds in Hawaii, none of the important weeds of turf are significantly affected by biological control. In addition, when weeds mature, they can produce large quantities of seeds or vegetative propagules which enable them to reproduce themselves. Thus, if one was serious about a zero threshold level for a weed in turf, one could control weeds before they produce reproductive propagules (seeds, tubers, etc) and eventually substantially reduce propagules from the germination zone in soil.

WEED IDENTIFICATION AND DESCRIPTION:

For the purpose of this discussion, three types of weeds will be discussed: 1) grasses; 2) sedges; 3) broadleaves. Grasses and sedges usually have narrow or slender leaves, and the leaf veins are parallel to each other. It is difficult to identify grasses and sedges by their leaf shape, and their flower must be used to identify them. Grasses can be distinguished from sedges by their stems; grasses have round or flat stems while the sedge stem is triangular. In addition, leaves of grasses originate from two sides of the stems, while leaves of sedges originate from three sides of the stem. Broadleaves usually have wide or broad leaves, and the leaf veins are netted. The leaves of broadleaves are quite distinguishing, and one can often identify broadleaves by their leaf shape.

It is useful to recognize the duration of the life cycle of weeds, and that information will be provided in the weed descriptions. An annual arises from seed, produces vegetative growth and more seed, and dies in less than one year. A perennial arises from seed or a vegetative propagule (tuber, bulb, stem), produces vegetative growth and seeds/vegetative propagules, and lives for more than two years.

Recognition and identification of a weed species is greatly aided by separating weed species into grasses, sedges and broadleaves. The descriptions of the weed species presented here will provide a guideline for recognizing weeds of turfgrass. We have also presented our best estimate of the most common weed pests in turfgrass that would be present at the proposed golf course site at Pupukea. As indicated previously, only about 30 species are expected to be common once the turfgrass becomes well established.

There are several books that one can use to identify weeds in Hawaii. The best one available is "The Handbook of Hawaiian Weeds", by Haselwood, Motter and Hirano (2nd Ed., 1983). There are line drawings of most of the turfgrass weeds in that reference. The descriptions provided below are largely summarized from that reference source. Some information comes from " In Gardens of Hawaii" (Neal, 1964).

Grasses:

Key Pests:

Goosegrass. *Eleusine indica*. Annual or perennial. Persists daily mowing at green height (3/8 inch or less). Present on greens, tees, fairways and roughs. Can grow up to 2 feet high. Tufted growth with branching at the base. Leaves boat-shaped, flowering head with 2 to 6 fingerlike branches. Invades compacted turf area and areas with poor soil. Propagates by seed. Its tufted growth habit creates an unattractive appearance, and affects normal club head swing. Goosegrass is perhaps the most important weed in turfgrass in Hawaii, but there are good management tools to control it.

Henry's crabgrass. *Digitaria adscendens* Perennial. Present in fairways and roughs; rarely on greens. Leaves blue-green. Creeping habit, but tends to form circular dense mats from a few inches to a few feet in diameter. It can completely crowd out bermudagrass, and establishes to nearly a solid stand. Flowering head with 2 to 4 short (1 to 2 inches) compressed branches. Propagates by seed and creeping stems. Once established, it can only be controlled by chemicals. Fortunately, selective chemicals can control Henry's crabgrass, but repeated applications are usually necessary.

Hilograss. *Paspalum conjugatum* Perennial. Present in fairways and roughs. Leaves light green under nitrogen deficient condition to dark green with high nitrogen. Leaves somewhat broad (1/4 to 1/2 inch wide). Creeping habit in various directions; can form a mat. Flowering head with mostly two slender branches 2 to 4 inches long. Propagates by seed and creeping sterms. Hilo grass stems sprouts better at low soil pH conditions than at neutral pH. Grows well in full sun and shady conditions, but tends to be a more serious problem under conditions of high rainfall and poorly drained soils. If soil pH is low, liming may suppress its growth, relative to growth of bermudagrass. Hilo grass can be controlled by selective chemicals, but repeated applications are necessary.

Smutgrass. *Sporobolus poiretii* or rattail grass *Sporobolus africanus.* Both species are perennials, are similar in appearance, and will be described together. Present in fairways and roughs. Erect growth in small clumps. Flowering head can be up to about 15 inches long with the branches closely compressed to the main axis. Propagates by seed. These species may be important because they are already abundant in the plateau areas at the proposed golf course site. Once established, these weed species are difficult to control because the selective herbicides only suppress these weeds. Complete control by chemicals can only be accomplished by spot applications of nonselective chemicals.

Occasional Pests:

Annual bluegrass. *Poa annua.* Annual or perennial. Present on greens, tees, fairways and roughs. Tufted growth, leaves light green, with short spreading branches. Prefers moist, cool areas. May become more prevalent during winter months and under partially shady conditions. Propagates by seed. In Hawaii, annual bluegrass is mainly a problem on greens, tees and aprons. While there is a good selective chemical for annual bluegrass, it cannot be used on greens. Once on greens, hand-weeding may be necessary.

Dallis grass. *Paspalum dilatatum.* Perennial. Present in fairways and roughs. Leaves somewhat broad (1/4 to 1/2 inches wide), dark green. Clumped growth, can be 2 feet in diameter with repeated mowing. Flowering stem with 3 to 5 spreading branches. Propagates by seed. Once established, this weed can only be controlled by chemicals. Selective chemicals do control Dallis grass, but repeated applications are necessary. (Another related *Paspalum* spp. was observed in high quantities at the proposed golf course site. It may become a problem like the Dallis grass.).

Lovegrass. *Eragrostis* spp. Annual. Present in fairways and roughs. Stems spreading, tufted growth. Flower heads with numerous delicate branches about 1 to 2 inches long. Propagates by seed. This weed has become quite common only in the last few years. It appears to tolerate the selective herbicides.

Stargrass. *Chloris divaricata.* Perennial. Present in fairways and roughs. Creeping habit, branches freely and can form a mat. Leaves bluish green. Flowering stem with 4 to 7 branches resembling a star, sometimes mistaken with common bermudagrass, but with bristles on seed. Propagates by seed and creeping stem. Once established, it is very difficult to control. Selective chemicals do not appear to affect stargrass, and nonselective spot treatments may be required. Although this weed is similar in appearance to bermudagrass, there is a distinct color and texture difference if present alongside bermudagrass. If that difference is tolerated by management, no chemical control measures may be required. More frequent mowing may be required, as stargrass will usually protrude above the bermudagrass turf.

Swollen fingergrass. *Chloris barbata.* Annual. Present in fairways and roughs. Stems generally erect, tufted growth. Flowering heads with purple, fingerlike branches 1 to 2 inches long. Persists in dry areas. Propagates by seeds. This weed tends to be a problem in poorly maintained turf.

Vasey grass. *Paspalum urvillei.* Perennial. Present in fairways and roughs. Very similar in appearance and behavior to Dallis grass, except that the flowering stem has many (10 to 20) branches that are closely compressed to the flowering stalk. Propagates by seed.

Potential Pest:

Sandbur. *Cenchrus echinatus.* Annual. Mainly present in roughs. Stems spreading, grows in clumps. Flower stalk contains numerous spiny burs clustered around the tip (1 to 3 inches long) of the flowering stalk. Propagates by seed. This is not a common problem of turfgrass, but once established, is a serious problem because of its spiny burs.

Sedges:

Key Pests:

Green kyllinga. *Kyllinga monocephala.* Perennial. Present on fairways and roughs, sometimes on tees, rarely on greens. Leaves resemble purple nutsedge. Each new plant can arise from a horizontal stem creeping at or slightly below the soil surface. Unlike purple nutsedge, there is no swollen structure at its base. Flowering head is a roundish structure about 1/4 inch in diameter at the end of a flowering stalk. The flowering head is green in appearance which turns brown and disengages from the plant at maturity. Propagates by seed and creeping underground stems. Selective chemicals can be used for its control.

Purple nutsedge. *Cyperus rotundus.* Perennial. Present in fairways and roughs, sometimes on tees, rarely on greens. Leaves upright initially, spreading later. All leaves arise from a triangular stem with new plantlet usually arising from 1/2 to 2 inches away. At the base of the stem is a swollen structure referred to as a basal bulb or corm. Flowering branches up to about 2 inches long, and arising from the end of the flowering stalk. Flower head has a dark brown color. Propagates by underground tubers (nuts), which are formed along the creeping underground stem. Seeds do not appear to be a means of propagation. Therefore, once observed, the infested area should be marked, because the weed can only spread by creeping laterally. This weed can be controlled by selective chemicals. Because the selective chemicals cannot get to all of the underground tubers which remain dormant, a new flush of growth may appear a few weeks after treatment. Repeated treatment will result in a reduction of the infestation to near zero levels.

Occasional Pest:

White kyllinga. *Cyperus brevifolius.* Perennial. Present in fairways and roughs, sometimes on tees, rarely on greens. Virtually identical in appearance, propagation and habit as the green kyllinga, except that the flowering head has a white roundish structure instead of a green one.

Broadleaves:

Occasional Pests:

Alternanthera. *Alternanthera repens.* Present on fairways and roughs. Creeping, prostrate growth habit, with a tendency to form near solid stands. Seeds have spiny structure. This species tends to persist under dry conditions. Propagates by seed.

Asiatic pennywort. *Centella asiatica.* Annual or perennial. Present on fairways and roughs. Creeping habit. Leaves round to heart-shaped arising from creeping stems. Larger than marsh pennywort with leaves from 3/4 to 2 inches in diameter. Flowers are white, inconspicuous and often covered by the turfgrass. Propagates by seed and creeping stems. Easily controlled by selective herbicides.

Broad-leaved plantain. *Plantago major.* Perennial. Present on fairways and roughs. Broad leaves, 1 to 10 inches long, originating from a short, thick stem. Flowers are greenish on a long slender spike. Propagates by seed. A similar species with narrow leaves, narrow-leaved plantain or buckhorn plantain, *Plantago lanceolata*, tends to be less prevalent in Hawaii.

Buttonweed. *Borreria laevis.* Annual or perennial. Present on fairways and roughs. Generally erect, but prostrate tendency with mowing. Leaves oblong to oval about 1 inch long forming on opposite sides of the stem. Flowers white in small clusters at the leaf axils. Propagates by seed.

Creeping indigo. *Indigofera endecaphylla.* Annual or perennial. Present on fairways and roughs. Creeping habit with the ability to form a dense mat. Stems have a tendency to become thick and slightly woody. Flowers purplish. Propagates by seed. Early control is suggested; once a dense mat forms, the bermudagrass growth is severely curtailed.

Dandelion. *Taraxacum officinale.* Perennial. Present on fairways and roughs. This very common broadleaf weed on the mainland is only occasionally found in Hawaii. Leaves arise from a short, thick stem with bright, yellow flowers. Propagates by seed and crown. Controlled by selective herbicides.

Drymaria. *Drymaria cordata.* Annual or perennial. Present on fairways and roughs. Prostrate and creeping habit. Leaves small (about 1/4 inch in diameter), round to heart-shaped, borne on opposite sides of the stem. Small white flowers on branches. Propagates by seed, and also by creeping stems.

Garden spurge. *Euphorbia hirta.* Annual. Present on fairways and roughs,

Garden spurge. *Euphorbia hirta.* Annual. Present on fairways and roughs, occasionally on tees. Generally upright growth, but tends to prostrate habit with mowing. Oval leaves 1/2 to 1 1/2 inches long) originating on opposite sides of the stem. Leaves often with blotchy darker coloration. Flowers small in leaf axils. Milky sap. Propagates by seed. Somewhat difficult to control with selective herbicides.

Kaimi clover. *Desmodium canum.* Annual or perennial. Present on fairways and roughs. Trailing, creeping habit. Leaves oblong to ovate with white markings along the midrib. Stems often woody at maturity with deep root system. Lavender to red flowers. Seed pods flat on one side and indented around each seed on the other side. Propagates by seed. There are other similar species that can become weeds in turfgrass. Perhaps the most common one would be spanish clover, *Desmodium sandwichense.* Kaimi clover and related species were abundant in the plateau areas of the proposed golf course site.

Marsh pennywort. *Hydrocotyle sibthorpioides.* Annual or perennial. Present on greens, aprons, and tees, rarely in fairways and roughs. This is a common broadleaf species on greens. Creeping habit. It has small (about 1/4 to 1/2 inch in diameter) roundish to heart-shaped leaves which arises from creeping stems. There appears to be several ecotypes exhibiting different degrees of hairiness on the leaf surface. Persists under moist damp soil conditions. Propagates by seed and creeping stem. Marsh pennywortn can be controlled by selective herbicides, but some ecotypes are reportedly tolerant to these herbicides.

Prostrate spurge. *Euphorbia prostrata.* Annual. Present on tees, fairways and roughs. Prostrate, freely branching, oval to oblong leaves green or purple. Leaves small (about 1/4 inch long) originating on opposite sides of the stem. Flowers small in leaf axils. Milky sap. Propagates by seed. Somewhat difficult to control with selective herbicides.

Purslane. *Portulaca oleracea.* Annual or perennial. Present on fairways and roughs. Freely branching succulent, prostrate stems, reddish or dull green appearance. Small single flower formed along the stem. Propagates by seed or by stem pieces. A mature cut stem can root when moisture is provided, even if the cut stem was previously left in the sun for 6 weeks.

Sensitive plant. *Mimosa pudica.* Annual or perennial. Present on fairways and roughs. Creeping habit, stems thorny, leaves will close with touch or at night. Flower heads pink to purplish, round appearance. Propagates by seed. Early control is suggested because of its thorny stems.

Synedrella. *Synedrella nodiflora.* Present on fairways and roughs. Generally upright, but becoming prostrate with mowing. Opposite oval leaves, often hairy and with 3 distinct veins. Flower heads small, yellow. Propagates by seed. A similar smaller-statured species, *Synedrelopsis* spp. is also prevalent in turf. These species tend to be present in poorly maintained turfgrass.

Yellow wood sorrel. *Oxalis corniculata.* Annual or perennial. Present on fairways and roughs, occasionally on tees. Generally prostrate and creeping habit. Leaves trifoliate 1/2 to 1 inch in diameter borne on a stem whjich generally originates from the creeping stem. Flowers yellow, forming an oblong fruting capsule about 1/2 inch long. The fruiting capsule explodes at maturity, sending seeds a few feet away. Propagates by seed and creeping stems. Leaves are easily defoliated by selective herbicides used for grass and sedge control, but regrowth occurs.

Potential Pest:

Pink wood sorrel. *Oxalis martiana.* Perennial. Present on fairways and roughs. Tufted appearance because all leaves arise from underground bulbous portion. Leaves are trifoliate 1 to 1 1/2 inch in diameter and are borne on the end of a stem. Flowers pink to red-purple. Propagates by seed and underground bulbs. Very difficult to control, but usually not a widespread problem.

MONITORING/ACTION LEVEL FOR WEED SPECIES:

The level of weed invasion that would trigger an action is dependent upon many factors, such as the management (greens committee), locale (greens, tees, fairways or rough), type of weed species, site that is being maintained (shady, poorly drained areas), and other factors.

In general, the action level for weeds on greens should be anything above zero, because weed growth substantially alters the smooth ball roll and normal grain of the green. However, the level of tolerance of weeds on greens depends on the playing members, and a few weeds are often found even on exclusive country clubs in Hawaii. Progressively higher action levels would be typical as one moves from the greens to the aprons, tees, fairways, and finally to the roughs. On tees, aprons, fairways and rough, both visual appearance and the influence of the weed species on clubhead impact on the golf ball is important. For example, clubhead impact with goosegrass or dallisgrass would be much more difficult to execute than with Henrys crabgrass, and the action level for the former species should be lower than the latter species, if the basis for the action level is the interference of the golf swing. If visual appearance is a factor, all weed species may have similar action levels.

Unlike insect pests, there is a distinct advantage to reduce weed pests to near zero populations. The advantage rests with the reduction of the reproductive ability of the weed species. Each mature weed species has the ability to produce dozens, hundreds, or even thousands of seeds once mature, or numerous underground propagules (creeping stems, tubers, bulbs). Once produced, these serve as the means by which new weeds can propagate for many years. Typically, the potential from any seed lot is nearly depleted about about 5 years (but there are many exceptions, such as purslane, sensitive plant, probably kaimi clover, creeping indigo, etc.), but small amounts can sometimes persist much longer. Thus, if weeds can be removed before they become mature, the future primary source of reproduction is depleted.

In turfgrass culture, the soil is undisturbed once the seedbed is prepared. Weed seeds are typically present in high quantities at any site. However, once the seedbed is prepared, only those weed seeds in the upper few inches of soil will ever germinate, and once a dense turfgrass cover exists, very few seeds from the native population will germinate. If germination occurs, these may not penetrate the dense turf. Since the soil is typically not disturbed in turfgrass culture, the viable population of weeds in the surface zone of soil can be greatly depleted after about 5 years. If new weed seeds or vegetative propagules are not added to the site, the management of weed pests can be made substantially easier by judicious removal of weeds in the early years of a golf course. However, this would mean very low action levels during the first few years of the golf course. Serious consideration should be given to this idea. It would result in more chemicals applied during the first few years, but probably result in a substantial reduction of chemicals required in subsequent years. It may require a slightly larger labor force to provide the level of weed management during the first few years, but a reduction in labor requirement during subsequent years.

Although no published guideline for action levels in golf course settings are known to the author, the action levels suggested here (Table 12) are based upon golfer perception and characteristics associated with weed species in turfgrass. The action levels proposed here will likely not result in a depletion of the weed seed and propagule reservoir suggested as an alternative course of action. However, the action level suggested would result in a rather immaculate golf course setting.

Weed species have been monitored by various means. Typically, density is measured by counts and/or weight per unit area. Most weeds with a tufted growth habit (goosegrass, rattailgrass) should be counted individually. For weeds that have a creeping habit and/or has the ability to form a dense mat (Henry's crabgrass, Hilo grass, kyllinga), the mat size or weed patch should be at least 6 inches in diameter to be counted. Weeds may be counted per unit area or the number of times it transects a line strung across a test site. More complex methods to characterize distribution are also used. For the purpose of the golf course manager, we suggest using a quantifiable unit for uniformity. The unit suggested here would consist of about a 6 foot swath (measured by holding both arms horizontal to the ground) by 300 feet long (by stepping off one hundred paces, 3 feet per pace) for a unit area of 1,800 square feet.

NONPESTICIDAL CONTROL METHODS:

A vigorous turf cover is the best preventive control method for weeds in turf. A dense turfgrass stand reduces seed and propagule germination by reducing light, and dampening the soil temperature fluctuation. In addition, those propagules and seeds that germinate may not be able to penetrate the dense turf cover. Thus all factors that promote a dense cover assists the weed management process. These include the proper turfgrass cultivar, mowing height and frequency, fertility, irrigation, drainage, insect and disease control. These are covered in other sections of this report.

The most likely areas for new weed invasion are in areas where turf is thin and/or weakened by less than adequate cultural practices or poor insect/disease management practices. In many cases, it is very important to correct these practices first before applying corrective chemical control practices.

There are a few cases where special cultural practices may aid in the control of certain weed species, and these are discussed below by weed species.

Goosegrass. Goosegrass typically invades bermudagrass in areas where the soil becomes compacted and the turf becomes thin. Especially vulnerable are areas where the golf cart leaves the cart path. There might be consideration given to designing a landing area (perhaps a 300 square feet circular area at the end of a cart path) where special practices might be done to prevent compaction. This can be accomplished by using a landing area with a very high proportion of silica sand or fine crushed basalt rock (mansand) as the media for turfgrass in the cart landing area.

Hilograss. Hilograss tends to grow relatively better than bermudagrass under conditions of low soil pH. Where Hilograss is noted to be especially troublesome, a soil test to determine pH should be conducted. If soil pH is low (less than 5.0), lime should be applied to increase soil pH to about 6.0.

Hilograss, kyllinga, marsh pennywort, pink wood sorrel, drymaria. These species tend to persist under poorly drained soils or where there is abundant rainfall or irrigation. In cases where drainage is poor, corrective measures to increase the drainage of the soil can aid in reducing the ability of these weed species to become serious problems.

Table 12. Suggested action level for weeds in different golf course areas in Hawaii.

Weed species	Golf course area			
	greens	tees	fairways	roughs
	Number of weeds per 1,800 sq. ft.			
Grasses:				
goosegrass	1	5	10	20
smutgrass	-	1	10	20
annual bluegrass	1	10	10	20
swollen fingergrass	-	5	10	20
sandbur	-	5	10	20
lovegrass	-	5	10	20
Dallis grass	-	1	10	20
Vasey grass	-	1	10	20
Henrys crabgrass	1	5	10	20
Hilo grass	-	1	10	20
Stargrass	-	5	10	20
Sedges:				
Purple nutsedge	1	5	10	100
Green kyllinga	1	5	10	100
White kyllinga	1	5	10	100
Broadleaves:				
Marsh pennyworth	1	10	20	100
Asiatic pennyworth	-	10	20	100
Prostrate spurge	-	5	20	100
Garden spurge	-	5	20	100
Yellow wood sorrel	1	5	10	100
Pink wood sorrel	-	1	5	20
Drymaria	-	5	10	100
Kaimi clover	-	1	10	100
Creeping indigo	-	1	10	100
Sensitive plant	-	1	5	5
Broad-leaved plantain	-	1	10	100
Synedrella	-	5	10	100
Dandelion	-	1	10	100
Alternanthera	-	1	10	100
Purslane	-	5	10	100
Buttonweed	-	5	10	100

CHEMICAL CONTROL MEASURES:

In order to reduce the herbicides used, only corrective chemical treatments should be applied in established turf areas. These herbicides are referred to as postemergence herbicides.

There is a group of herbicides that are referred to as preemergence herbicides which are used before weed seeds germinate. Because weed seeds can germinate all year round in Hawaii (in contrast to a specific flush during the spring months on the mainland U.S.), one strategy is to apply these herbicides several times a year to kill weeds as they germinate. However, a dense turf cover may be just as effective as a preemergence herbicide, and in the interest of reducing the agrichemical load to the environment, our strategy is to avoid preemergence herbicides, except if desired by the contractor in the establishment phase.

Another strategy to reduce the agrichemical load is to treat only areas where weeds are visible. This is referred to as a spot treatment or spot-sweep treatment. This practice does require a highly skilled person, as it is easy to apply excessive quantities of herbicides if one is improperly trained and monitored. This practice could be done with a small tank (such as a knapsack), or with a short boom mounted on a tractor if larger patches are being treated. Because of the higher level of skill and responsibility involved, a higher level of compensation might be considered to attract and retain such an individual. At low weed population levels, a substantial reduction of chemicals can be realized if the spot-sweep treatment practice is used in the manner that it should be practiced. A list of useful postemergence herbicides, and those products that are registered in the state of Hawaii for 1990 are listed below:

Common name	Trade names	Restricted use herbicide
MSMA	Weed Hoe 108	no
CAMA	Super Dal-E-Rad/Calar	no
Metribuzin	DuPont Lexone DF Herbicide	no
Imazaquin	Image Herbicide 1.5 LC	no
Pronamide	Kerb 50-W in Water Soluble Pouches	no
Simazine	Princep 80W	no
Glyphosate	Roundup	no
Dicamba	Banvel Herbicide	no
2,4-D	Rhone-Poulenc Formula 40 Herbicide	yes
2,4-D mixture (+dicamba +mecoprop +dichlorprop)	SUPER TRIMEC BROADLEAF HERBICIDE	yes
	TRIMEC SOUTHERN BROADLEAF HERBICIDE	yes (> 1 qt.)
	TRIMEC (CLASSIC) BROADLEAF HERBICIDE	yes
	TRIMEC BROADLEAF HERBICIDE	yes (> 1 qt.)

Suggested corrective chemical control action for selected species on greens and tees.

Weed species	Greens (Suggested chemical for control)	Tees (Suggested chemical for control)
Goosegrass	MSMA, CAMA	MSMA, CAMA
Annual bluegrass	MSMA	Pronamide, MSMA
Henrys crabgrass	MSMA, CAMA	MSMA, CAMA
Purple nutsedge	MSMA, CAMA	MSMA, CAMA
Green kyllinga	MSMA, CAMA	Imazaquin MSMA, CAMA
White kyllinga	MSMA, CAMA	Imazaquin MSMA, CAMA
Marsh pennywort	2,4-D Mixtures	Imazaquin 2,4-D Mixtures
Yellow wood sorrel	MSMA, CAMA	MSMA, CAMA

Suggested corrective chemical control action on fairways and roughs.

Weed species	Control (selective)	Suppression only (selective)	Spot treat (non-selective)
Goosegrass	MSMA	Metribuzin (or combination)	
Smutgrass		MSMA+Metribuzin	Glyphosate
Annual bluegrass	Pronamide		
Swollen fingergrass		MSMA+Metribuzin	Glyphosate
Sandbur	MSMA		
Lovegrass		MSMA+Metribuzin	Glyphosate
Dallis grass	MSMA		
Vasey grass	MSMA		
Henrys crabgrass	MSMA		
Hilo grass	MSMA		
Stargrass		MSMA+Metribuzin?	Glyphosate
Purple nutsedge	MSMA+Imazaquin		
Green kyllinga	MSMA+Imazaquin		
White kyllinga	MSMA+Imazaquin		
Marsh pennywort	2,4-D Mixtures		
Asiatic pennywort	2,4-D Mixtures		
Prostrate spurge		2,4-D Mixtures	
Garden spurge		2,4-D Mixtures	
Yellow wood sorrel	MSMA Simazine Metribuzin?		
Pink wood sorrel	MSMA?		Glyphosate
Drymaria	2,4-D Mixtures		
Kaimi clover		2,4-D Mixtures	
Creeping indigo		2,4-D Mixtures	
Sensitive plant	Simazine Metribuzin?		
Broad-leaved plantain	2,4-D Mixtures		
Synedrella	2,4-D Mixtures		
Dandelion	2,4-D Mixtures		
Alternanthera	2,4-D Mixtures		
Purslane	2,4-D Mixtures		
Buttonweed		2,4-D Mixtures	

Because of the importance of non-target impacts of all pesticides, certain key information for the herbicides that are commonly used will be ranked according to the topics listed below. The rankings are approximations. There may be differences with soil types and conditions, test organism used, etc.

1. Mammalian toxicity: 2,4-D Mixtures > MSMA > Dicamba > Metribuzin >Simazine > Pronamide

2. Leaching potential: Dicamba > 2,4-D Mixtures > Metribuzin > Simazine >Pronamide > MSMA

3. Potential for damage to fish and wildlife: 2,4-D Mixtures > Simazine > Metribuzin > Dicamba > Pronamide > MSMA

(Simazine is considered to have low toxicity)

This information can be used by the superintendent to reduce agrichemical loading that may result in contamination to the ground water. For example, simazine and metribuzin may leach to the ground water, and if they did, they would likely be present in very low quantities and below the EPA action level, if used as recommended by the manufacturer. Both simazine and metribuzin can enhance control of weeds like goosegrass when used in combination with MSMA. Instead of using the normal use rate of metribuzin to control goosegrass by itself, the metribuzin rate could be reduced by one-third to one-half and used in combination with MSMA to obtain goosegrass control. MSMA is rapidly inactivated once it contacts soil and would not be expected to be present in the ground water.

There is additional information on the mammalian toxicity, potential for leaching and surface contamination, toxicity to fish and wildlife, as well as other characteristics such as mode of action in the HERBICIDE HANDBOOK of the WEED SCIENCE SOCIETY OF AMERICA (6TH EDITION, 1989). In addition, the label provides specific information on use rates, conditions of applications, etc. Because the label may change from time to time, it is imperative that label instructions be read each time pesticides are used, and the directions followed explicitly. In addition, procedures to follow after accidental exposures, spills, etc. are provided on the label. Another source of information is the Poison Center, 1319 Punahou St.; their telephone number is 941-4411.

Some pesticides available for use in turfgrass on the mainland may not be available in Hawaii because it may not be registered for sale in Hawaii. A manufacturer or distributor would simply need to register the material for sale with the Hawaii Department of Agriculture for the material to be used in Hawaii, which is the main agency responsible in Hawaii. The Department of Agriculture also regulates pesticide use in Hawaii. OSHA is only peripherally involved when issues of worker safety is involved. For example, if respirators are utilized for the spraying process, OSHA requires that everyone using respirators must have a medical examination to ascertain that an individual is permitted to use a respirator. The Department of Health becomes involved when there are special health risks, such as pesticides in water.

In some cases, an herbicide may be registered only for a specific state with the registrant being an association. One such case is diclofop or Hoelon, which is registered for use in Florida with the registrant being the Florida Turfgrass Association. In such a case, a local association may petition the EPA to serve as a registrant. However, the manufacturer must support such a registration. In addition, the manufacturer can be asked to register the material for Hawaii, as is being done with Hoelon.

In other cases, a pesticide may be found to be effective on a certain turf pest, but is not registered for turfgrass. In such cases, the manufacturer or IR-4 program can be asked to assist in the registration process. Data to support its efficacious use must be presented with concurrence obtained for its registration by the manufacturer.

SAFE AND EFFECTIVE USE OF PESTICIDES

One of the basic tenets in IPM is the precise and judicious use of chemicals in the management of turfgrass pests. Pesticides are to be used only when needed and the timing is based upon action threshold levels of the pest. In some instances, pesticides are

absolutely necessary for the production of high quality turfgrass.

Pesticides are compounds that kill insects, weeds, rodents, disease causal agents, etc., through their chemical action. Pesticides are beneficial to man if properly used, but can be poisonous to man if abused. Misuse can be expensive and lead to contamination of the environment and a hazard to man.

Pesticide is an all inclusive term defined as "killer of pests". The terms ending in "*icide*" (from the Latin cida-to kill) are classes of pesticides. In legal terms it is classed as an "economic poison" by both federal and state laws. A list of pesticide classes and their use is presented in Table 13.

Table 13. List of pesticide classes and their use†.

Pesticide class	Pests to be controlled
Acaricide	mites, ticks
Algacide	algae
Bactericide	bacteria
Fungicide	fungi
Herbicide	weeds
Insecticide	insects
Miticide	mites, ticks
Molluscicide	snails, slugs
Nematicide	nematodes
Ovicide	destroy insect and mite eggs
Rodenticide	rodents (mice, rats)
Chemicals classed as pesticides not bearing the "*icide*" suffix:	
Attractant	attracts insects, etc.
Chemosterilant	sterilize insects, etc.
Defoliant	removes leaves
Desiccant	rapid drying of plants
Growth Regulator	stimulate or retard plant growth
Pheromone	attract insects
Repellent	repels insects, animals, mites, etc.

†Adapted from Ware, 1980.

Federal [Environmental Protection Agency (EPA)] and State [Hawaii Department of Agriculture (DOA), Hawaii Pesticide Laws] regulations require all pesticides be classified into one of two categories: I. **GENERAL USE** - These can be purchased and applied according to label directions by anyone. II. **RESTRICTED USE** - These can only be purchased and applied under the direct supervision of a certified applicator. Hawaii's list of restricted pesticides will include the federal list and any additional ones determined by DOA.

Certification of Pesticide Applicators for Hawaii is under the jurisdiction of DOA. The Extension Service, University of Hawaii, Pesticide Training Office, assists in teaching and preparation of personnel wishing to take the examination for certification. Golf course superintendents and their leading personnel should be certified applicators in the "Ornamentals and Turf Pest Control" category.

HOW PESTICIDES WORK:

Pesticides are designed to control pests through their chemical action. Most control the pest by poisoning. Unfortunately, these compounds are also poisonous to humans. The poison can be absorbed through the skin (dermal or contact), by ingestion through the mouth (oral or stomach) or inhaling or breathing dusts, spray particles, mists or gases.

HAZARD AND TOXICITY:

These two words are different and often confused when discussing pesticides. HAZARD means the probability of injury to man, animals or the environment through use of the pesticide. Hazard depends more upon how the chemical is used rather than upon its toxicity. TOXICITY means "how poisonous" the pesticide is. Toxicity is the killing power of the pesticide. All chemicals can be poisonous at a given dosage.

SIGNAL WORDS:

Signal words and label warning statements are also used to alert pesticide users of the toxicity of a pesticide. Label warning statements are based upon acute oral and dermal toxicities, eye irritation and inhalation hazards. The categories, signal words and LD_{50} parameters are presented in Table 14. The signal word on the package will always indicate the hazard with the lowest category rating (greatest toxicity).

Table 14. Label warning statements and signal words for the different pesticide categories.

Category	Signal word required on label	Acute LD_{50} (mg/kg) categories Oral	Dermal
I (Highly Toxic)	Danger, Skull & Crossbones	0-50	0-200
II (Moderately Toxic)	Warning	51-500	201-2,000
III (Slightly Toxic)	Caution	501-5000	2,001-20,000
IV (Relatively Non-Toxic)	Caution	>5,000	>20,000

Some compounds are very poisonous (toxic) and can kill or seriously injure humans. Some chemicals are dangerous after one large dose (acute toxicity) while others are dangerous after a series of small repeated doses (chronic toxicity). The standard measure of toxicity, LD_{50}, is expressed as the amount of toxicant (dosage) in milligrams per kilogram (mg/kg) of body weight of the test animal required to kill fifty percent of the test animals. The lower the LD_{50}, the more poisonous the pesticide. The experimental animals used in determining toxicity levels are usually rats and rabbits. Doses of the pesticide are fed to the animal (Acute Oral) or applied to the skin (Acute Dermal). Mammalian toxicity levels for insecticides registered for use on turf in Hawaii are presented in Table 15.

PRECAUTIONS:

The most important document concerning a pesticide is the LABEL. Each Label is

prepared by the basic manufacturer and is based upon toxicological, experimental, and efficacy research results of scientific workers and regulatory officials throughout the country. The label contains the costliest advice, instructions, precautions, safety recommendations etc. ever attached to a product container. LABELS ARE FOR YOUR PROTECTION AND, IF FOLLOWED PRECISELY, WILL PREVENT PROBLEMS FROM USE OF THE PESTICIDE. Read the label every time the pesticide is used. Labels on new containers of a given pesticide may be different from those on old containers. Labels can be amended at any time.

Safe use of pesticides has four main concerns; personal safety, safe application, safe handling (transport and storage), and safe disposal. Brief discussion of each aspect will be made below.

Personal safety:

Read and understand the information presented on the label. If you need help ask for it. Information may be obtained from the pesticide manufacturer's representative, DOA, your certified applicator or the Cooperative Extension Service. Use the prescribed protective clothing (recommended respirator, protective clothing, etc.). Protective clothing is very important when mixing and filling equipment.

Keep a written record of the date, time of day, weather conditions, name of the pest to be controlled, exact name and formulation of the pesticide used, area to be treated, amount used per gallon or applied per unit of area, EPA registration number, application equipment used, names of individuals supervising and making the application, safety precautions taken, any spills, clean up procedures used, etc. The more detailed information, the greater the value in analyzing the situation if control is not obtained or if complaints of misuse occur. Follow label specification for "reentry times", if any. Do not let people enter the treated area until the prescribed time has passed.

Safe application:

Use a chemical that is specifically registered for use on golf courses Measure the precise amount designated on the label.

Do not overdose, excessive rates will not result in better control (in some cases, the control may be less with excessive rates) and may cause phytoxicity to the turfgrasses or other environmental impacts.

Use the recommended formulation. A different formulation of the same chemical may cause plant injury or ineffective control of the pest.

Apply the pesticide according to instructions on the label. If applications are to be made within a certain range of temperatures, at a specific time of day or stage of plant growth, be sure to follow specific directions.

Table 15. Mammalian toxicity levels of pesticides registered in Hawaii for turfgrass pest control on golf courses.*

Common name of Pesticide	Representative Trade names**	LD_{50} (mg/kg)† Acute oral	Acute dermal
	Insecticides		
acephate	Orthene 75	866-945	>2,000
carbaryl	Sevin 80S	500-850	>7,000
trichlorfon	Dylox 80	560-630	>2,000
fluvalinate	Mavrik Aquaflow	261-282	>20,000
ethion	Ethion 8EC	208	-
chlorpyrifos	Dursban 50W	135-163	500-2,000
bendiocarb	Turcam	40-156	566-800
isofenphos	Oftanol 2E	28-38	>1,000
methomyl	Lannate	17-24	>5,000
	Fungicides		
benomyl	Tersan 1991	>10,000	>10,000
chlorothalonil	Daconil 2787	>10,000	>10,000
mancozeb	Dithane M-45, Fore	>8,000	>10,000
anilazine	Dyrene	>5,000	>5,000
iprodione	Chipco 26019	3,500	>2,500
etridiazole	Terrazole 35 WP	1,100	
cupric hydroxide	Blue Shield	1,000	
metalaxyl	Subdue 2 E	669	>3,100
triadimefon	Bayleton 25	313-568	>1,000
	Herbicides		
pronamide	Kerb	5,620-8,350	>3,160§
glyphosate	Roundup	5,600	>5,000§
simazine	Princep, Drexel Simazine	>5,000	>3,100
imazaquin	Image	>5,000	>2,000§
metribuzin	Sencor, DuPont Lexon	2,200	>20,000
dicamba	Banvel	1,707	>2,000§
MSMA	Drexel MSMA, Weed Hoe, Clean Crop MSMA, Dal-E-Rad 120	900	
2,4-D	DMA-6 Weed Killer, Weedar 64, Clean Crop Amine, Weedone 638	375	>1.60

* There are other pesticides registered by EPA for application to turf in other states.

** Trade names selected for this Table are representative of pesticides used in Hawaii. Failure to mention other proprietary names is for brevity only and does not imply a preference of the preparers of this document for any commercial product identified by a specific common name.

†LD_{50} is the dose (milligrams of toxicant/kilogram of body weight) that kills 50% of the test animals. (LD_{50} values are from Agrochemical Handbook, 1987 ed., Royal Society of Chemistry, Info. Services, Nottingham, England).

§ The test animals were rabbits.

Do not mix pesticides unless the combination of pesticides is determined to be compatible. Follow label instructions on precautions of mixing pesticides. Plant injury or failure of controlling the pest can result from mixing incompatible chemicals.

Use the application method specified on the label. This is essential for effective pest control and safety to the applicator and the environment. Follow the directions on pressure, types of nozzles, speed of power equipment, etc. Never smoke, eat, drink or chew while applying pesticides. Do not spray with defective connections or leaky hoses. Apply pesticides with the wind at your back. Follow label recommendations about maximum windspeed at which the pesticide can be applied. Do not contaminate streams, ponds, drainage or irrigation ditches and other water bodies. Stop application of pesticide if weather conditions are not favorable. Do not feed pesticide-treated turf clippings to animals.

Transportation of full or partially filled pesticide containers should never be transported in a passenger car or in a truck loaded with foodstuffs, clothing, feed, etc. Never transport a leaky container. Never remove the manufacturer's label from a container, even if it is empty. Transport pesticides in a truck that is designed for securing pesticide containers to prevent spillage and movement. Never allow pesticides to be delivered unless a responsible person is present for each delivery until it can be moved into locked storage.

Storage of pesticide containers should always be in locked storage. The storage area should be well marked, well ventilated, cool and dry. Keep pesticides in their original containers, tightly closed, with the label in a readable condition. Keep different types of pesticides (insecticides, fungicides, herbicides, etc.) in separate areas. Keep pesticides separate from fertilizers and other types of chemicals used on the golf course. The storage area and the area where pesticide application equipment is filled should be on an impervious material, such as concrete and bermed to contain possible spills.

Disposal of pesticide containers requires special treatment and observation of federal and state regulations. Pesticides should always remain in the original containers bearing the label. Follow directions on the label for disposal of the empty pesticide container. Proper instructions for disposal of empty containers can be obtained from the manufacturer's representative, DOA, or Hawaii Department of Health. Suggestions are to triple rinse, with soapy water, non-returnable plastic, glass and metal containers. Rinse water should be poured into the spray tank and not down a drain to contaminate water supplies or contaminate the environment. Puncture or break containers so that they cannot be reused. Store empty containers in a secure area until you can dispose of them safely.

Following a pesticide application wash any respirator and other protective clothing with warm, soapy water, allow them to dry and store under proper conditions. Do not store respirators in the pesticide storage area. Shower and change clothes after applying pesticides.

ENVIRONMENTAL HAZARDS OF PESTICIDE USE

One of the main objections of use of certain pesticides is the possibility of detrimental effects on the environment, ground- and surface-waters and fish and wildlife in the area. The Acute Oral and Dermal toxicities discussed in previous sections are important in determining the hazard of pesticides primarly to applicators of the pesticide in the case of golf courses where there is no food product consumed to which the pesticide has been applied. Of equal or perhaps greater importance is the likelihood that a pesticide may contaminate groundwater or surface water or create a hazard to wildlife exposed to pesticides used. This section will discuss the properties of pesticides labeled for use on golf courses in Hawaii in relation to potential impacts on surface and groundwater and their toxicity to fish and wildlife.

The presence of agricultural chemicals in groundwater at many locations in the State of Hawaii (Honolulu Star Bulletin, Aug. 13, 1989) is reason for caution in the use of chemicals on golf courses, as well as in agriculture. It is important to recognize, however, that detection of a chemical in water bodies, even in potable water, does not necessairly constitute a health hazard as defined by the U. S. Environmental Protection Agency (EPA). EPA has set "Lifetime Health Advisory Levels" (HAL) (concentrations in drinking water) for many chemicals. EPA estimates these levels from available human and experimental animal data. HALs are considered tentative and are updated as new information becomes available. HALs vary widely. Generally chemicals with high oral toxicity have lower HAL values. Because chemicals are highly toxic does not necessairly indicate that they will create hazards for ground and surface waters. Many pesticides are tightly sorbed on soil organic matter and have little potential to move to groundwater. Many pesticides decompose rapidly in soil (by hydrolysis and/or microbial activity) and therefore create no hazard to ground or surface waters. Management factors in golf course operations can have a large influence on the likelihood of hazards to ground and surface waters also. Chemicals are moved to groundwater by leaching. There would be no possibility of leaching if evapotranspiration (water evaporated plus water transpired by plants) exceeded rainfall throughout the year. Careful management of irrigation water and timing of pesticide applications to coincide with dry seasons of the year will reduce the potential of contamination of groundwater by pesticides greatly.

The hazard of chemicals also increases with the acreage to which they are applied. In the case of agricultural chemicals in Hawaii's drinking water, it should be pointed out that these chemicals have been applied to thousands of acres over several decades. Golf courses are relative small in comparison. It is estimated that the average golf course is approximately 150 acres in size. Not all the area in a golf course is treated with chemicals. Only the greens, tees, fairways and a small part of the roughs are treated. It is estimated that the total maintained for the Lihi Lani golf course to which pesticides might be applied totals only 90 acres (4 acres of greens, 4 acres of tees, 46 acres of fairways and 36 acres of maintained rough). The total chemical application to areas of this size would be much less likely to create hazards to ground and surface waters than those applied to extensive agricultural crops.

Some of the properties important in determining their potential for contamination of ground and surfcae water and potential hazards to fish and wildlife are presented in Table 16 and discussed below. In all cases, if there is a choice of equally effective pesticides, the one with the least potential for leaching to groundwater or contamination of surface water and least effects on fish and wildlife should be used.

Water solubility:

The solubility of a pesticide in water will strongly affect the ease of washoff from leaves of the turf. It may or may not indicate the ease with which it moves through the soil by leaching. Pesticides also vary greatly in the degree to which they are sorbed (attached to) by soil organic matter. In general, pesticides with solubilities of 1 ppm or less will remain at the soil surface. They may be washed off the field in sediment when heavy rainfall causes runoff. In the case of turf, however, there is much less movement of sediment than with field crops.

Half-life in soil:

The Half-life, given in days, is the time required for a pesticide to be degraded in the soil to the extent that its concentration decreases by one-half. Pesticide degradation can be calculated by assuming that each successive Half-life will decrease the concentration by half. Two Half-lifes will therefore reduce the concentration to one-fourth the amount initially applied. Half-life in soil will vary depending on soil moisture, temperature, oxygen status of the soil, soil microbial activity, etc. For the Lihi Lani site the warm soil temperatures and favorable soil moisture and oxygen status which will be provided by turfgrass culture will maximize soil degradation of pesticides. Pesticides with short Half-lives will likely create little or no hazard for contamination of surface of groundwater or to fish and wildlife.

Soil Sorption Index:

The Soil Sorption Index is a measure of the sorption of the pesticide to the soil. The value used is the Koc value (an index of the chemical and/or physical bonding of chemicals to soil particles or organic matter). The higher the Koc value, the more strongly the pesticide is attached to the clay or organic matter in the soil. Pesticides with Koc values above 500 have little tendancy to move from the site of application. They would be more likely to move with sediment in the case of heavy rainfall causing washing of soil particles or with wind-blown dust.

Runoff Potential:

The runoff potential is an indication of the potential for movement of the pesticide with sediment in runoff. A pesticide which is tightly sorbed to soil particles may move in sediment if heavy rainfall creates erosion. The likelihood of this occuring is much less likely in the case of pesticides applied to turfgrasses than those applied to agricultural crops because of the erosion protection provided by the extensive root system of turfgrasses and the lack of bare soil which is subject to movement by water.

Leaching Potential:

The leaching potential indicates the tendency of a pesticide to move in solution with water and leach below the root zone before it degrades. Leaching potential is largely determined by the Soil Sorption Index and Half-life of a pesticide. Those with low Koc and short Half-life have minimum Leaching Potential.

Table 16. Selected properties of pesticides used on turf in Hawaii related to environmental hazards.†

Pesticide common name	Representative Trade names§	Solubility in water (ppm)	Half-life in soil (days)	Soil Sorption Index (Koc)	Surface loss potential	Leaching loss potential	Toxicity to fish & wildlife
			Insecticides				
acephate	Orthene Turf, Tree and Ornamental spray	650,000	3	100	small	small	-
carbaryl	Sevin 80S	40	7	229	medium	small	moderate
trichlorfon	Dylox 80	154,000	27	2	small	large	moderate
fluvalinate	Mavrik Aquaflow	0.005	50 E*	1,000,000 E*	large	small	-
chlorpyrifos	Dursban 50W	2	30	6070	large	small	high
bendiocarb	Turcam	40	7	-	-	-	-
isofenphos	Oftanol 2	24	-	-	-	-	-
methomyl	Lannate	57,900	8	28 E*	small	medium	-
			Fungicides				
benomyl	Tersan 1991	2	100	2,100	large	small	low
chlorothalonil	Daconil 2787	0.6	20	1,380	large	small	low (birds) mod. (fish)
mancozeb	Dithane M-45	0.5	35	1,000 G**	large	small	low
anilazine	Dyrene 4	10 G†	1	3,000	small	small	low
iprodione	Chipco 26091	13	20 G**	500 E*	medium	small	low
etridiazole	Terrazole 35	50	20 G**	10,000 E*	large	small	-
cupric hydroxide	Blue Shield	-	-	-	-	-	-
metalaxyl	Subdue 2E	7,100	7	16	small	medium	low
triadimefon	Bayleton 25	260	21	273	medium	medium	low
			Herbicides				
pronamide	Kerb 50W	15	30	990	large	small	low
glyphosate	Roundup	1,000,000	30	10,000 E*	large	small	low (fish) mod. (bird)
simazine	Princep 80W, Drexel Simazine	3.5	75	138	medium	large	low
imazaquin	Image 1.5 LC	160,000	60	20 E*	small	large	-
metribuzin	Lexon DF	1,220	30	41	medium	large	moderate
dicamba	Banvel	800,000	14	2	small	large	low

Continued on next page

Table . Continued

Pesticide common name	Trade name	Solubility in water (ppm)	Half-life in soil (days)	Soil Sorption Index (Koc)	Surface loss potential	Leaching loss potential	Toxicity to fish & wildlife
MSMA	Drexel MSMA, Weed Hoe, Clean Crop MSMA, Dal-E-Rad 120	1,000,000 E	100	10,000 E*	large	small	low
2,4-D (amine)	Dal-E-Rad 120, DMA-6 Weed Killer, Weedar 64, Clean Crop Amine, Weedone 638	300,000	10	109	medium	medium	high

† = References: Wauchope, R. D. 1988. USDA, ARS Interim Pesticide Properties Data Base, Version 1.0.; Agrochemical Handbook, 2nd. Ed. Royal Soc. Chem. Info. Serv., Nottingham England; Smith, G. J. 1987. Pesticide use and toxicity in relation to wildlife: organophosphates and carbamates. Res. Pub. #170. U. S. Dept. of Interior, Fish and Wildlife Service. 171p.
* E= Estimated value; probable error is 2X to 3X for Half-life, 3X to 5X for Solubility and Koc (Wauchop, 1988)
** G = Guess value; Probable error is 5X for Half-life, 1 to 2 orders of magnitude for solubility and Koc (Wauchop, 1988).
§ Trade names selected for this Table are representative of pesticides used in Hawaii. Failure to mention other proprietary names is for brevity only and does not imply a preference of the preparers of this document for any commercial product identified by a specific common name.

Additional information on safe use of pesticides may be found in (but not limited to) the manufacturer's special publications and technical data sheets, federal and state extension publications, Ware (1980), Tashiro (1987), and Golf Course Superintendents Association of America publications.

WHEN USING PESTICIDES, PROTECT YOURSELF, OTHERS, AND THE ENVIRONMENT BY USING COMMON SENSE AND FOLLOWING THE DIRECTIONS ON THE LABEL. LEARN THE SAFETY PRECAUTIONS. CARELESSNESS CAN BE DISASTROUS.

CALIBRATION OF PESTICIDE APPLICATION EQUIPMENT

Pesticides must be applied uniformly, at the proper rate and time in order to be effective. Pesticide laws (EPA and DOA) also require that pesticides be applied at the proper rate. In some cases the dilution of the spray is also specified.

There are several types of pesticide application equipment. The type to use will generally depend upon the type of pesticide formulation being used, the size of the area being treated and the confidence of the individual golf course manager in using certain types of equipment. Regardless of the type of equipment used, it must be used correctly and maintained properly and on a regular schedule. The most common types of pesticide application equipment used on golf courses are discussed below.

Spray equipment:

Sprayers are perhaps the most commonly used types of pesticide applicators. They are designed to dilute the concentrated pesticide formulations and spread them uniformly over an area. Types of pesticides used in spray epuipment include; solutions, emulsfiable concentrates, soluble powders, wettable powders, flowable powders and dispersable granules.

The most common type of pesticide sprayer used on large areas of the golf course delivers a low-to-moderate volume of spray (usually 20 to 100 gallons per acre (gpa). Low pressures (30 to 40 psi) are sufficient for spraying most pesticides to large areas but higher pressures (200 to 400 psi) may be required for spraying trees. Sprayers are usually mounted on tractors or turf utility vehicles. Tank sizes are usually 50 to 200 gallons capacity. They have a pump to produce the pressure required for spraying, agitation of the suspension and may apply the spray through a boom or a hose and handgun.

Tanks:

Because some pesticide formulations are corrosive, spray tanks should be made of corrosion-resistant material. Suitable materials include stainless steel, polyethylene plastic and fiberglass. Aluminum, mild steel or galvanized tanks should not be used as some materials may react with these causing reduced activity of the pesticide and/or corrosion of the tank. Tanks should be kept clean and free of rust, scale and dirt which can damage the pump and nozzles, clog nozzles, clog strainers and restrict flow through strainers. Tanks should be flushed with clean water after spraying is completed. Be sure to follow all requirements for safe disposal of wash water when cleaning tanks.

The capacity of tanks must be known in order to add the correct amount of pesticide. Most new tanks have capacity marks or other means of determining how much water is in the tank. If the tank does not have capacity marks, construct them by filling with a measured amount of water and marking the level at graduated intervals. A clear plastic tube mounted on the end of metal tanks, graduated in gallons, makes an excellent sight gauge. On plastic or fiberglass tanks, marks can be placed on the side of the tank. Be sure the sprayer is sitting on a level surface when reading the volume of solution in the tank. Incorrect volume readings cause improper amounts of pesticide to be added to the tank which can result in poor pest control, turf injury, or environmental contamination.

Tank agitators:

An agitator in the tank is essential for mixing the spray material uniformly and to

keep certain formulations in suspension. The need for agitation varies with the formulation of pesticide used. Liquid concentrates, soluble powders, and emulsfiable concentrates require little agitation. Wettable powders require intense agitation to keep the particles in suspension. Either a jet type or mechanical agitator is required. The jet type agitator is operated by a return pressure line connected directly behind the pump. Do not install a jet agitator on the pressure regulator bypass line as low pressure and intermittent flow will produce poor agitation. A mechanical agitator consists of a shaft with connected paddles which runs from the power supply of the sprayer. Mechanical agitators should operate at speeds of 100 to 200 RPM. Higher speeds may cause excessive foaming of the spray solution, especially ones containing a surfactant. WHEN SPRAYING WETTABLE POWDERS, ONLY MECHANICAL AGITATORS ARE EFFECTIVE IN KEEPING THE MATERIAL IN SUSPENSION.

Pumps:

Pumps may be centrifugal, roller, gear, piston, or diaphragm. Each type of pump has special advantages and performances. Centrifugal pumps are limited to low pressures (30 to 40 psi). They have a high output (up to 130 gpm or more). Roller pumps can develop pressure up to 300 psi and deliver up to 50 gpm. Gear pumps provide low to moderate volume (5 to 65 gpm) and low to moderate pressures (20 to 100 psi). Piston pumps can develop up to 600 psi pressure and deliver up to 25 gpm. Diaphragm pumps are excelent general purpose sprayers as they are capable of producing high pressure (up to 800 psi) as well as high volume (60 gpm or more). For sprayers which are used on trees and other areas where high pressure is required, only piston or diaphragm pumps are suitable. Abrasive materials, such as wettable powders, should not be used in roller or gear pumps, as these pumps are highly susceptable to wear. Rollers for the roller pump are replacabie, the parts for gear pumps are usually not.

Strainers:

Three types of strainers are commonly used on agricultural sprayers. Strainer numbers (e.g., 20 mesh, 50 mesh, 100 mesh, etc.) indicate the number of openings per square inch. The larger the number, the smaller the openings in the strainer. Coarse basket strainers are used in the tank filler opening to prevent debris from entering the tank as it is being filled. A 16 to 20 mesh is usually used. Line strainers are used on the suction side of the line between the tank and pump. Suction strainers before centrifugal pumps must be coaser than the diameter of the suction line. A second line strainer (usually a 50 mesh) should always be used on the pressure side of the pump to protect the nozzles. Nozzle strainers should always be used. The size of the strainers will vary, depending on the size of the nozzle openings. Smaller nozzle openings require finer mesh (higher number) strainers. Nozzle strainers for most agricultural sprayers are either 50 or 100 mesh. Consult the nozzle manufacturer's publications for the recommended strainers to use with specific nozzles.

Distribution system:

Hoses, booms, and nozzles are used to distribute the spray. Select hoses and fittings to withstand the chemicals used at the spray pressure and spray volume range encountered. Peak pressures are often encountered that are higher than average operating pressure. Hoses must be flexible, durable and resistant to sunlight, chemicals, oil, and fatigue produced by twisting and vibration.

Suction hoses must be air tight, noncollapsible, relatively short, and as large as the pump intake. If it is difficult to maintain proper pressure, check the suction hose to make sure it has not collapsed or become stopped with scale or debris. Restricted flow may cause permanent damage to the pump. Other hoses especially those between the pressure gauge and the nozzles should be as straight as possible, with a mininmum of restrictions and fittings. Select the proper hose size for the flow rates at which you are spraying.

Boom stability is important in achieving uniform spray application. The boom should be rigid in all directions. Gauge wheels mounted near the end of the boom will help maintain uniform boom height over uneven terrain. The boom height should be adjustable to accommodate different nozzle spacings. Consult the nozzle manufacturer's publication for proper nozzle height and nozzle spacing for specific nozzles.

Nozzles:

Spray nozzles are perhaps the most important part of the spray system. They function to break the liquid into droplets of proper size and propel the droplets in the proper direction. The size of the nozzle opening determines the rate of pesticide distribution at a particular pressure, traveling speed, and nozzle spacing. Drift can be minimized by selecting nozzles that produce the largest droplet size that will provide adequate coverage at the intended application rate and pressure.

Nozzles are made from various types of materials. The most common are brass, plastic, nylon, stainless steel, hardened stainless steel, and ceramic. Brass, plastic, and nylon are the least expensive but wear rapidly. Worn nozzles distort the spray pattern and result in improper applicaton rates. Nylon nozzles resist corrosion but some chemicals cause nylon to swell. Nozzles made of harder material are more expensive but last longer.

Replace nozzles frequently. The cost of nozzles is negligable compared to the cost of pesticides. Spraying 50 acres of fairway with a pesticide costing $50.00/acre with worn nozzles which increase spray volume by 10% at a given pressure will result in an increased pesticide cost of $250.00. Replacing nozzles is only a fraction of this amount.

Each nozzle on the boom must apply the same volume of liquid, within limits. Collect the output from each nozzle at a given spraying pressure and measure it. If the discharge of a nozzle varies more than 10% from the average, replace that nozzle. Do not mix nozzles of different material, types, discharge angles, or spray capacity on the same boom. All nozzles must be spaced the same distance apart in the boom. Any mixing of nozzles will cause uneven spray patterns.

Care must be taken in cleaning nozzles which have become clogged. The nozzle should be remomved from the boom and cleaned by blowing with compressed air. **Do not put the nozzle to your mouth and blow.** Pesticide residue on the nozzle may be hazardous. A brush with soft bristles, such as a toothbrush, can also be used to clean nozzles. **Do not use a wire, jackknife point, or other hard materials** as the nozzle opening may be damaged and cause improper spray application.

The correct nozzle spray pattern must be used. For most turfgrass applications, the flat-fan type nozzle is used. Flat-fan nozzles produce a flat spray pattern in which less material is applied along the edges of the patterns. Adjoining nozzles must therefore be overlapped to give uniform coverage. For maximum uniformity the overlap should be about 30% of the nozzle spacing. Normal operating pressures for flat-fan nozzles is 30 to 40 psi. Consult the nozzle manufacturer's publications for correct operating pressure for specific nozzles. Use of "antidrip" nozzles may require an increase in pressure. "Low pressure" (LP) flat-fan nozzles are available. This type of nozzle develops proper distribution and spray pattern at pressures form 10 to 20 psi. Lower operating pressures are desirable as they produce less drift.

Nozzles must always be placed in the boom at the correct spacing and the boom adjusted to the proper height. Flat-fan nozzles should always be offset 1 to 5 degrees from parallel with the boom. If adjacent nozzles are placed parallel with the boom, the overlapping spray form adjacent nozzles will contact each other and cause distortion of the spray pattern. Consult the nozzle manufacturer's publications for information about correct boom set-up for each specific nozzle.

Other types of applicators:

Wiper applicators:

Several types of wiper applicators are available. They are usually used only in herbicide application. Basically, wiper applicators consist of a hollow tube (usually PVC or other plastic material) filled with a herbicide solution and a series of short ropes or a wetted pad on the tube which is in contact with the herbicide solution and becomes saturated by wicking action. The herbicide is then placed directly in contact with the foliage of the plants to be controlled by wiping the applicator over them. Thickeners may be used in the herbicide solution to reduce dripping. These applicators may be either tractor-mounted or small, hand operated units. They are most effective for controlling weeds which have a taller growth habit than the turf. Non-selective herbicides may be placed in contact with the foliage of tall weeds without contacting the turf. In such cases, weeds which are resistant to selective herbicides may be controlled through selective placement. This type of pesticide applicator also reduces the possibility for drift of pesticides to non-target organisms.

Granular applicators:

Various types of equipment are available for applying granular formulations of pesticides. There are two basic types, gravity (or drop-type applicators) and centrifugal-type applicators. Granular applicators may be the same ones used for applying fertilizers to turf. Drop-type granular applicators consist of a hopper to hold the material with a series of outlets at the bottom of the hopper, the size of which can be adjusted to control the rate of application. There is also an agitator at the bottom of the hopper to keep the granular material uniformly spread over the width of the hopper. Material drops straight down by gravitational force. The width of the hopper is the width of the application band. They are usually mounted on wheels and can be hand-pushed or pulled behind a tractor. Precise patterns of operation must be followed to assure uniform distribution of granules. Overlapping will result in double application.

Centrifugal-type applicators consist of a hopper with a hole in the bottom which is adjustable and a spinning plate with baffles beneath the hole. There is also an agitator at the bottom of the hopper to keep the granules uniformly distributed in the hopper. Granular material drops from the hopper to the spinning plate and is slung away by centrifugal force. The application band is lighter on the edges than in the center, requiring some application. The exact amount of overlap will depend upon the specific applicator and the speed at which it is operated. Consult manufacturer's specifications for operating speeds and amount of overlap.

Calibration of pesticide applicators:

Calibrating sprayers:

There are two basic steps in application of pesticides at the proper rate: 1. determining the amount of spray solution being applied. This is usually expressed in terms of gallons of spray solution per acre (GPA) and 2. determining how much of a given pesticide formulation to place in the spray tank to give the proper rate.

The spray rate (GPA) will depend upon such things as the spraying pressure, the output of the nozzles [gallons per minute [GPM]), the rate of travel of the sprayer, the width of the spray boom, etc. The amount of a pesticide to place in the tank depends upon such things as the concentration of the pesticide in the formulated material, the desired rate of application [usually expressed as pounds active ingredient per acre (lb. a.i./acre) and the spray rate (GPA).

There are several methods of calibrating sprayers, some of these are discussed below. Consult with the Cooperative Extension Service Pesticide Office, DOA, chemical manufacturer's representative or other sources on methods of application.

Spray monitors:

Perhaps the simplest and most fool proof method of sprayer calibration is the use of a spray monitor or spray controller. Monitors are sophisticated electronic equipment which monitor the operating conditions of the complete sprayer such as travel speed, pressure and flow rate. These data are fed into a microcomputor which displays the application rate (GPA). Other useful information may also be displayed, such as pressure, travel speed, field capacity (acres/hour), gallons applied, gallons remaining in the tank, acres covered etc. Spray controllers are monitors with the added capability of sensing the actual application rate, comparing it with the desired rate and adjusting the rate of application (usually by adjusting the spray pressure). Use of monitors and controllers will often result in improved pest control, less waste of pesticide, and reduced probability of negative environmental impact.

Methods of sprayer calibration and calculating amount of pesticide to place in the tank are discussed in the attached Extension Bulletin (Murdoch, 1986).

Nozzle output method:

In this, and all other methods of sprayer calibration, nozzles must be properly spaced and at the proper height. They must be checked at the desired spraying pressure to determine if all nozzles are applying the same volume of liquid (within 10% tolerance) before calibrating.

Fill the tank with water and operate the sprayer briefly on a paved surface, such as a road or driveway, to check for correct overlap or band pattern, skips or uneven patterns caused by worn or plugged nozzles, and uniform coverage.

The follwing steps will give a simplified method of calibrating boom sprayers.

1.Using the table below (Table 17), select the appropriate linear distance and mark it off in the area to sprayed.

2. If the vehicle on which the sprayer is mounted has a speedometer, choose the speed at which spraying will be done. If the vehicle has no speedometer, choose the throttle setting and gear which gives the desired operating speed. With the sprayer not operating, drive the measured distance and note the time (in seconds) it takes.

3. With the equipment parked, operate the sprayer at the pressure at which spraying will be done. Collect the spray from one nozzle for the same amount of time

taken to drive the measured distance.

4. The discharge from one nozzle (in ounces) is equal to gallons per acre (GPA) applied.

Table 17. Linear distances required for the nozzle volume method of calibrating sprayer at different nozzle spacings.

Nozzle spacing (inches)	Calibration distance (feet)
40	102
38	107
36	113
34	120
32	127
30	136
28	146
26	157
24	170
22	185
20	204
18	227
16	255
14	291
12	340
10	408

Calibrating granular applicators:

Granular applicators are calibrated by adding a known amount of pesticide into the hopper, spreading it at a constant speed over a measured area, weighing the amount of material remaining in the hopper, adjusting the setting of the opening through which the granules drop and repeating until the desired amount of material is applied. This is essentially a trial and error method.Different brands of granular pesticides will have different particle size, concentration, etc., therefore it is not possible to have one setting for different brands of the same basic chemical.

The following method can be used to determine the rate of application of granular spreaders.

1. Fill the hopper with a known amount of the pesticide to be applied and choose a hopper opening setting which is judged to give the desired application rate.

2. Operate the spreader over a measured linear distance at the speed at which granules will be spread. For motorized equipment, the speedometer or gear and throttle setting can be used. For hand pushed equipment, measure a linear distance and repeatedly time the spreader operator over this distance until the operator can constantly operate the spreader at the same speed (±10%).

3. Weigh the pesticide remaining in the hopper.

4. Calculate the amount of pesticide applied by the formulas given below.

5. Adjust the hopper opening setting and repeat until the desired rate of application is obtained.

Formulas for calibrating granular spreaders:

A. Area (in acres or fraction of an acre) in the test run = $\frac{\text{Swath width (feet) X linear distance in test run}}{\text{43,560 (number of sq. ft. in an acre)}}$

B. Application rate (pounds/acre) = $\frac{\text{Pounds used in test run}}{\text{Area (acres) in test run}}$

APPENDICES

APPENDIX A

SELECTED PESTICIDE LABELS

1. FUNGICIDES
2. HERBICIDES
3. INSECTICIDES

(AVAILABLE UPON REQUEST)

APPENDIX B

SELECTED REFERENCES

SELECTED REFERENCES

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APPENDIX C

BIODATA ON AUTHORS

BIOGRAPHICAL SKETCH

Oliver V. Holtzmann

Oliver V. Holtzmann was born in North Dakota. He received his B. S. and M. S. degrees from Colorado State University and Ph. D. in Plant Pathology (1955) from Washington State University. In 1956 he came to the University as Assistant Professor of Plant Pathology where he worked for 30 years before retiring in 1986. He served as Department Chairman for 15 years and taught general plant pathology for 25 years. He also taught a graduate course in plant nematology He is currently Emeritus Professor and continues to conduct research on turfgrass diseases and teach short courses on tropical plant quarantine.

Dr. Holtzmann's major contributions have been in research and instruction in plant pathology and in administration of the Department of Plant Pathology, University of Hawaii. His research interests have been in the biology and control of plant parasitic nematodes in tropical crops. He has also conducted research on turfgrass diseases and their control and continues these efforts in his retirement. He has serves as an Advisor to the Board of Directors, Hawaii Turfgrass Association and assists them with conduction of their educational programs. He has served as a consultant to turfgrass growers on numerous occasions.

BIOGRAPHICAL SKETCH

Charles L. Murdoch

Charles L. Murdoch was born in Atkins Arkansas in 1932. He completed his BS in Agriculture (1959) and MS (1960) in Agronomy, at the University of Arkansas; and Ph. D. (1966) in Agronomy at the University of Illinois. In 1966 he joined the Agronomy Department, University of Arkansas as Research Associate in Agronomy a position he held until 1970 when he joined the University of Hawaii at Manoa in 1970 as Assistant Professor of Horticulture and Assistant Turfgrass Specialist. In 1974 he was made Associate Professor and Associate Specialist, and in 1979, he was named Professor of Horticulture and Turfgrass Specialist, positions he currently holds. He has also served as Chairman of the Horticulture Graduate Faculty from 1986 to present He has held positions as Visiting Fellow, Department of Entomology, Cornell University, Geneva Experiment Station (1976-77); Visiting Fellow, University of Illinois, Department of Plant Pathology, 1980; Adjunct Professor, Department of Horticulture, University of Florida (1990-91); and Acting Chairman and Professor of Horticulture, University of Hawaii (1981).

Dr. Murdoch's major contributions have been in research, instruction and extension in Turfgrass Management and the Graduate Program of the Horticulture Department, University of Hawaii. He has served as an Advisor to the Board of Directors, Hawaii Turfgrass Association, since 1970. He works very closely with that industry organization in their educational programs. He has conducted research on turfgrass insects, weed control in turfgrass, turfgrass diseases, turfgrass soil amendments, methods of construction of athletic fields, salinity effects on turfgrasses and turfgrass fertilizer practices. His cooperative research with Weed Scientists, Entomologists, and Plant Pathologists has led to the development of new pest control technology which are commonly used by turfgrass managers throughout Hawaii. In instruction, he has taught courses in Principles of Horticulture and Turfgrass Management; he has served as major advisor of numerous MS and PhD graduates and on the Graduate Committees of numerous graduate students in the departments of Horticulture, Agronomy and Soil Science, and Entomology. He has consulted, cooperatively with a Soil Scientist, on environmental impacts of fertilizer and pesticide use for more than 25 proposed golf courses in Hawaii. In October, 1990 he was retained by the Moral, Welfare and Recreation Division, U. S. Air Force, Pacific, to advise their Golf Course personnel in the Pacific on turfgrass management programs. He advised golf course managers in Korea (Osan and Kunsan), Japan (Yokoto and Misawa), Okinawa (Kadena), Philippines (Clark AB) and Guam (Anderson AB).

BIOGRAPHICAL SKETCH
ROY K. NISHIMOTO

Roy K. Nishimoto, born in Hawaii in 1944, completed his BS (1966) and MS (1967) in Agronomy, at Oregon State University; and PhD (1970) in Horticulture with a specialization in Weed Science at Purdue University. He joined the University of Hawaii at Manoa in 1970 as Assistant Professor of Horticulture; in 1974 he was made Associate Professor, and in 1979, he was named Professor of Horticulture, a position he currently holds. He has held positions as Visiting Fellow, Department of Vegetable Crops, Cornell University (1976-77); Senior Research Fellow, Ministry of Agriculture and Fisheries, New Zealand (1983-84); Chairman and Professor of Horticulture, University of Hawaii (1980-81 and 1982-88); Vice President, Agricultural Loan Administration, Bank of Hawaii (1988-89); Acting Assistant Dean for Academic Affairs and Acting Assistant Director for Cooperative Extension, College of Tropical Agriculture and Human Resources, University of Hawaii (1989); and Acting Director, Hawaii Institute of Tropical Agriculture and Human Resources (1990).

Dr. Nishimoto's major contributions have been in research and instruction in weed science of horticultural crops. His research program has centered on establishing herbicide selectivity for many of Hawaii's important crops, such as banana, cabbage, coffee, guava, macadamia, papaya, protea, ornamental nursery crops, and turfgrass. He has conducted research on the biology of purple nutsedge, as well as the translocation of glyphosate in purple nutsedge. His research led to the development of new herbicide technology and its integration into horticultural crop production practices; these new technologies are commonly used in horticultural crop production in Hawaii. In instruction, he has taught courses in Principles of Horticulture and Weed Science; he has served as major advisor of numerous MS and PhD graduates; and he has been invited to present numerous lectures/courses in many countries in Asia and in the Pacific region.

BIOGRAPHICAL SKETCH

Wallace C. Mitchell

Wallace C. Mitchell was born in Ames, Iowa in 1920. He received his B. S. (1947), M. S. (1949) and Ph. D. (1955) degrees in Entomology from Iowa State University. Upon completion of the MS degree he came to the University of Hawaii at Manoa as an Instructor and Jr. Entomologist. He advanced through the ranks to full professor and retired as Professor Emeritus in 1985. During his many years service with UHM he taught General Entomology and conducted research and published papers in tropical economic entomology, specializing in turfgrass insects, macadamia insects, fruit flies and integrated pest management. He has participated in the administration of the College of Tropical Agriculture and Human Resources (CTAHR) as Chairman, Department of Entomology (9 years), Acting Dean of CTAHR, Director of the Hawaii Institute of Tropical Agriculture and Human Resources and Director of Cooperative Extension (1.5 years), and Associate Dean of Academic Affairs (CTAHR) (5 years). Following retirement, he has participated as a consultant on IPM and entomological problems in international programs with U. S. Agency for International Development (USAID), Gesellschaft fur Technische Zusammenarbeit/German Agency for Technical Cooperation (GTZ) and the Consortium for International Crop Protection (CICP). He is also an advisor to the Board of Directors of the Hawaii Turfgrass Association.

APPENDIX D

GLOSSARY OF TURFGRASS TERMS

GLOSSARY OF TURFGRASS TERMS

abiotic -- Non-living substance, at one time may have been living.

aerification -- A mechanical process used to facilitate soil air/water relationships of the turf without destroying the integrity of the sod.

a. i. -- Active ingredient. Chemical agent in the product primarily responsible for the pesticidal effects. Percentage of a. i. is shown on the pesticide label.

annual -- Plant that completes its life cycle from seed in one year or season.

ascervuli -- Plural of ascervulus, a microscopic, black structure, embedded in plant tissue, on which fungal spores are produced.

apron -- Fairway area immediately surrounding the collar of the green. Second cut. (see collar).

bacteria -- Microscopic, single celled organisms having a cell wall but lacking an organized nucleus and incapable of making their own food. All plant pathogenic bacteria can live saprophytically.

biennial -- Plant that completes its life cycle from seed in two years or seasons. First year it produces a vegetative plant and stores food; the second year or season it produces flowers and seed.

biotic -- Living substances.

blight -- Affecting a large portion of the leaves or the whole plant.

broadcast application -- Application over the whole area.

broadleaf weed -- Common term for plants in the dicotyledon group (dandelion, plantain, spurge, etc.).

broad spectrum pesticide -- Pesticide which is effective against several pests (in contrast with a specific pesticide which controls primarily one pest).

brushing -- A mechanical process to aid in grain control whereby horizontal stems are lifted so that they may be cut by the mower.

causal agent -- A substance which is involved in causing plant damage.

chlorophyll -- Green pigment found in structures called chloroplasts in plant leaves. Chlorophyll is the material which enables plants to carry out photosynthesis.

chlorosis -- A process by which plant tissue looses its normal green color and gradually becomes yellowed.

clippings -- Leaves, stems and stolons cut off by mowing.

collar -- Area between the putting area and the apron.

colorant -- Dye used to color turf.

combing -- See "brushing".

compaction -- Compression of soil particles into a denser mass.

compatible -- Ability to mix two or more chemicals or pesticides together without affecting each others performance.

contact herbicide -- Herbicide which kills only the plant tissue contacted with little or no translocation.

culm-- Erect stem of grasses.

cultivar-- Variety of a plant which originates and persists under cultivation.

cool season turfgrass -- Species of turfgrass normally grown in cooler climates, such as bentgrasses, bluegrasses, fescues, and ryegrasses. May also be used in the transition area or used to overseed in tropical and subtropical areas in the wintertime. A member of the subfamily Festucoideae.

coring -- Method of aerification by which soil cores are removed by hollow spoons or tines.

cutting height -- Distance from soil surface to where the turf is cut by the mower.

damage -- Any permanent or semi-permanent abnormality of a plant due to the loss of function or structure.

dicotyledoneae (dicot) -- Botanical taxonomic group in which dicotyledonous plants are placed. Having two cotyledons (seedling leaves). Leaves are generally broader than long. Leaf veins are netted rather than parallel.

disease -- Any damage in a plant due to the continuous irritation of a primary living causal agent and its intensity is measurable.

disinfection -- Killing an organism after it has entered the plant.

disinfestation -- Killing an organism on the surface of a plant or its surrounding environment.

disorder -- Damage in a plant due to a causal agent which is continuous or non-continuous which may be permanent or ameliorated.

dormant turf -- Turf which has stopped its growth process and turns brown because of unfavorable environment. Growth will resume when environmental conditions again become favorable.

emulsion -- Suspension of one liquid in another, as distinguished from a solution where two materials combine together to become one. May require an emulsifying agent. Pesticides may be dissolved in a liquid which is then combined with water for spraying.

epidemiology -- Study of the factors which are responsible for the spread or intensity of the disease.

exosmosis -- Reverse osmosis. Process by which water moves out of the root into the soil solution which has a higher salt content.

fairway -- Close mown area between the tee and green.

fertigation -- Application of fertilizer through the irrigation system.

fertilizer -- Dry or liquid material which contains one or more plant nutrients.

formulation -- Manufactured blend of a pesticide and other ingredients. Formulations may be available in liquid (flowable) concentrates, wettable powders, dusts and/or granules.

fumigation -- Use of chemicals applied into soils as gases or a form which changes into gas to kill weeds (including seed), insects, nematodes, and/or disease pathogens. Highly volatile chemicals are injected under a gas-tight tarpaulin.

foliar burn -- Injury to leaves of a plant caused by improper application of a chemical.

foot printing -- Impression left by foot traffic when the turf is in a wilted condition.

french drain -- Mechanism for drainage where a hole or trench is backfilled with coarse sand, gravel or crushed rock.

fungicide -- Any chemical used for the management of fungal diseases.

fungus -- A microscopic plant, incapable of making its own food because it lacks chlorophyll. The body of a fungus is usually filamentous (mycelium). Most fungi reproduce by various types of spores, its vegetative growth is by mycelium. Most plant pathogenic fungi are capable of surviving and reproducing saprophytically, However, some called obligate parasites are only capable of reproducing on a living host.

grain -- Undesirable horizontally oriented growth of leaves and stolons.

graminicolous -- Members of the grass family, Gramineae.

green -- Dense, smooth, closely mowed area for putting.

grooving -- See vertical mowing.

herbicide -- Chemical used in the management of weeds.

hydroseeding -- Method of seeding by mixing seed with water and spraying the suspension onto a seedbed.

inert -- Inactive ingredients such as a liquid carrier, dust or any ingredient material on or in which the active ingredient is impregnated.

infectious -- Capable of being disseminated, enter a plant and cause disease.

injury -- Damage to a plant, usually permanent, caused by the short term association with a causal agent.

irrigation -- Applying water to turf.

insecticide -- Any chemical used to manage (control) insects.

internode -- Part of a stem which lies between two successive nodes.

landing area -- Part of the fairway where tee shots usually land.

lapping, mower -- Part of the process of sharpening a reel mower.

layering, soil -- Undesirable stratification of different textured material in the soil.

localized dry spot -- Area of the soil which resists wetting.

mat -- See thatch.

monocotyledonae -- Botanical group in which monocotolyledons (one cotyledon or seed leaf) plants are placed. Leaves are usually longer than broad. Leaf veins are parallel.

mycelium (a) -- Thread-like body of the fungus generally invisible except during periods of luxuriant growth.

narrow leaf -- Common term for plants in the monocot group (all grasses, sedges, etc.)

necrosis -- Irreversible decline, death of the tissue. Usually yellow to tan or gray, then brown or black.

nematode -- Microscopic round worm which mainly infects the roots of plants. Most plant parasitic nematodes need to feed on a plant in order to get food required for reproduction.

node -- A stem joint capable of producing buds, leaves and/or roots.

noninfectious -- Incapable of entering a living plant and causing disease.

nonselective -- Herbicide which kills plants irrespective of species. Not selective for controlling weeds without injury to turf.

nursery, turf -- Place where replacement sod or vegetative planting material is grown for planting elsewhere.

obligate parasite -- An organism incapable of completing its life cycle outside a specific host plant.

osmosis -- The process by which liquid passes through a semipermeable membrane from a lower concentration to a higher concentration.

overseeding -- Seeding a semidormant turf with a cool season grass so that a playable turf is available in the wintertime.

panicle -- Many branched flower head with flowers at the end of each branch. Common in grasses such as annual bluegrass.

parasite -- Any living organism which is capable of deriving its nutrition from another living organism but may not necessarily cause disease in the host organism.

pathogen -- Any parasite capable of causing a disease.

perennial -- Plant that lives more than two years.

pesticide -- A generic name given to a chemical capable of controlling insects, pathogens and/or weeds.

photosynthesis -- Process by which plants containing chlorophyll are capable of producing their own food (carbohydrates) from carbon dioxide and water in the presence of light.

physiological -- The functioning of plant processes dependent on biochemical actions.

plugging -- Establishing turf using plugs of sod.

poling -- Using a limber pole to remove the dew from leaves of grass.

postemergence -- After germination and emergence from the soil.

preemergence -- Before germination and emergence from the soil.

prostrate -- growth habit of tendency to lie flat on the ground.

reel mower -- Mower that cuts turfgrass by means of a series of curved, rotating blades which pull the grass into a stationary bedknife and cut the grass in a manner similar to a scissor.

renovation -- Improving a turf without completely destroying the turf characteristics. May or may not include planting new seed or vegetative material into an existing sod.

residue -- That which remains.

rhizome -- Below ground stem with nodes and internodes capable of producing a new plant at each of the stem nodes.

rosette -- A tuft or cluster of closely crowded leaves arising from a very short stem. Caused by the dwarfing or compaction of the internodes.

rotary mower -- A mower that cuts the grass by means of a single blade, mounted parallel to the surface of the turf and sharpened on each end. The blade revolves at a high rate of speed in a horizontal plane and cuts the leaves of the grass by impact action.

rough -- Part of the golf course which borders the tee, fairway and greens. Usually mowed at a higher level and maintained less intensively than other parts of the golf course. Does not usually come into play.

scald -- Injury to turf caused by standing water.

scalping -- Excessive removal of the green portion of the turf plant, leaving brown stubble exposed.

sclerotia -- Propagules composed of hardened masses of mycellium which aid the fungus in surviving periods of adversity. Golden brown to black in color and spherical to irregular in shape. Can be the size of a cabbage seed to microscopic.

selective -- Type of herbicide which will control one plant species without injury to another. Usually indicates that herbicide will kill weeds without injuring certain species of turfgrasses. Excessive rates of application may reduce or eliminate the selectivity.

semidormant -- Turf which is in a quiescent stage because temperatures are below the optimum for normal growth.

senescent -- Plant tissue declining after reaching maturity. Old age.

slicing -- Method of cultivation or aerification in which a blade cuts through the turf intermittently, perpendicular to the surface.

sod -- Plug, squares or strips of turf which has some adhering soil. Usually produced in a large controlled area.

soil applied pesticide -- Pesticide which is applied to the soil where it has its activity. Some may be taken up by roots and translocated to other parts of the plants.

spiking -- Method of cultivation in which a solid tine or pointed blade penetrates the turf and soil.

sporulate -- Process by which a fungus produces spores.

spot spraying -- Application of a pesticide to small areas. Contrasted to broadcast application.

sprig -- a generic term for a vegetative planting material. May include stems, leaves, roots, stolons, rhizomes, etc.

sprigging -- Establishing turf by means of planting sprigs or stolons.

stolon -- Above ground stem which spreads laterally at the soil surface producing new plants at the nodes.

suboxidation -- A condition in which soil oxygen is severely limited.

surfactant -- Material which reduces the surface tension of a liquid (such as water) and improves the spreading of the liquid on a surface. Usually used with pesticides applied to the foliage to improve coverage.

syringing -- Applying a small amount of water, usually in the form of fine droplets, to cool the plant, prevent wilt, or remove dew.

systemic -- Pesticide which is absorbed into a plant through the leaves and/or roots and translocated throughout the plant.

thatch -- A layer consisting partially of undecomposed organic matter, between the crown of the plant and the soil surface and/or below the soil surface.

topdressing -- A thin layer of soil, organic matter and/or sand applied to a turf to smooth the surface and assist in decomposition of thatch (see above).

transition zone -- An irregular east-west zone consistent with isothermal lines between Northern and Southern sections of the United States where neither cool season or warm season grasses are well adapted. Both may be grown in this zone.

translocation -- Movement of materials within the plant from point of entry to other areas, such as leaves to roots or roots to leaves.

vascular system -- Conducting or transport avenues in plant tissue, such as veins in leaves.

vertical mowing -- Use of a mechanical device with vertical cutting blades to manage grain and thatch.

verticutting -- Using a vertical mower.

viruses -- Submicroscopic entities consisting of a nucleic acid and a protein sheath. All viruses are obligate parasites as they can only multiply in living plant cells.

warm season turfgrasses -- Species of turfgrass which are adapted to the warmer subtropical and tropical regions of the world. Members of the subfamilies Panicoideae and Eragrostideae. On golf courses in warm regions of the world, primarily bermudagrasses (Cynodon spp.).

weak pathogen -- Organism not capable of infecting vigorously growing tissue. It generally attacks tissue under a biological stress from abiotic or biotic causes. Often referred to as a "secondary pathogen'. as it usually attacks tissue previously infected by a primary pathogen.

wetting agent -- see surfactant.

wilt -- Drooping of turfgrass leaves due to loss of turgor under moisture stress. Wilt may be due to acute and/or chronic lack of soil moisture, a dysfunction of the root system such as from a root rot, excessive salts in the soil water, or from suboxidation which limits the uptake of water as oxygen is essential for the process of water uptake.

APPENDIX E

SPRAY SYSTEMS FOR TURFGRASSES: CALIBRATING SPRAYERS AND MIXING PESTICIDES

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CONTENTS

SPRAY SYSTEMS FOR TURFGRASSES: CALIBRATING SPRAYERS AND MIXING PESTICIDES

C. L. Murdoch

COMPONENTS OF THE SPRAY SYSTEM

The purpose of the sprayer is to accurately meter and distribute pesticides. Pesticides are packaged in concentrated form to facilitate handling. In order to uniformly distribute the active ingredient of the pesticide over the area sprayed, it must be diluted with a suitable carrier (in this case, water). The diluted pesticide must then be uniformly distributed in a manner that gives optimum coverage with minimal drift potential.

The basic parts of a sprayer are presented in Figure 1.

The Tank

The most common materials for construction of tanks are fiberglass, mild steel, and stainless steel. Mild steel is susceptible to corrosion damage and must be cleaned thoroughly after each use. Factory-applied interior paint is usually available for mild steel tanks. Fiberglass and stainless steel tanks are not affected by most common agricultural pesticides.

Cylindrical or rounded-bottom tanks are preferred to rectangular ones because they eliminate dead spots during mixing and agitation. Tanks should also have a large opening for access in cleaning and rinsing.

Mixing and agitation of spray solutions is essential to insure uniform distribution of the active ingredient. Only mild agitation is required for pesticides formulated as solutions or emulsifiable concentrates. Pesticides formulated as wettable powders require more vigorous and continuous agitation. Mechanical agitators should be a part of sprayers used for wettable powder pesticides. The agitation system should be kept operating at all times when wettable powders are in the spray tank to prevent them from settling out.

The Pump

The basic types of pumps used for sprayers are rotary, centrifugal, piston, and diaphragm. Rotary and centrifugal pumps are perhaps the most commonly used on agricultural sprayers. Consult your

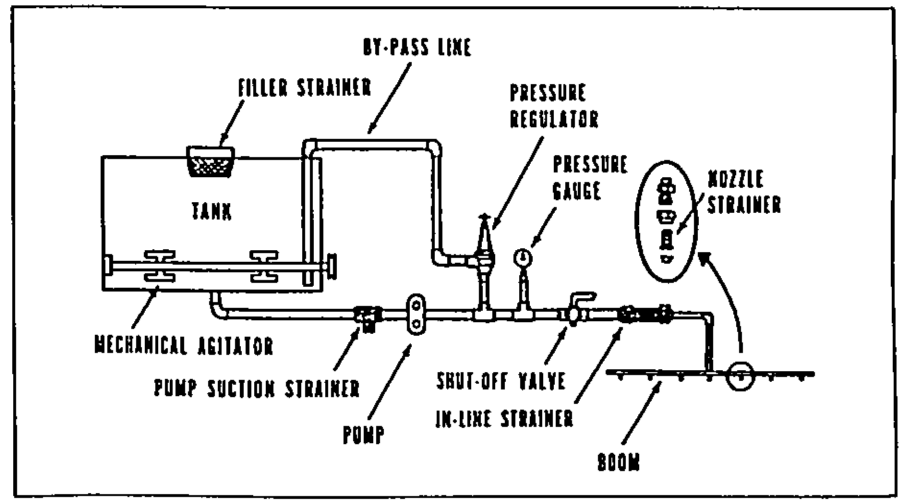

Figure 1. Components of a typical spray system. (From Robert G. Curley and Wesley E. Yates. 1974. Proceedings of the California Golf Course Superintendents Institute. Pp. 37–41.)

equipment supplier for pump specifications. Make sure the pump will supply sufficient capacity (gallons per minute) and proper pressure for the job required. Other considerations are longevity, ability to handle corrosive materials, cost, and serviceability.

Strainers and Screens

Screening is necessary to keep foreign materials out of the spray nozzles and to reduce wear on the pump. All materials poured into the tank should be screened with a coarse (10- to 20-mesh) screen at the opening of the tank. A 25- to 50-mesh screen should be placed between the tank and the suction side of the pump to prevent foreign material from entering the pump. A 50- to 100-mesh screen should be placed in the line between the pump and the spray boom and, additionally, 50- to 100-mesh screens should be placed in each nozzle. Fifty-mesh screens are the smallest size recommended when spraying wettable powders.

The Pressure Regulator

A pressure regulator is required to adjust the pressure for spraying. Most agricultural pesticides should be sprayed at the lowest pressure compatible with the particular spray nozzles in use; this will prevent excessive atomization of the spray droplets. Pressures of 25 to 40 pounds per square inch (psi) are adequate for most materials and most spray nozzles.

The Pressure Gauge

A pressure gauge is essential to measure the pressure at which the spray solution is being applied. Calibration methods covered later in this publication depend on the operator's knowing the spray pressure. The pressure gauge should be located as near as possible to the spray boom to prevent erroneous readings due to friction loss. Keep in mind that pressure may drop in nozzles near the end of the boom when several nozzles are operating at once. When calibrating sprayers, it is desirable to catch the liquid from several nozzles (or even each nozzle) on the boom for a given length of time to determine if nozzle output is uniform.

The By-pass Line

The by-pass line diverts liquid from the pressure regulator valve to the tank in order to reduce the pressure on the line. It also helps agitate spray solutions. The by-pass line should not be considered

sufficient for agitation of wettable powders, however. If the spray tank does not have mechanical agitation, it should have a separate line with holes in it from the pressure side of the pump (before the pressure regulator valve), extending into the tank to provide movement of the liquid.

Spray Nozzles

Spray nozzles are perhaps the most important part of the spray rig. They perform the vital functions of breaking up the spray stream into properly sized droplets, metering the spray, and distributing it evenly over the area.

There are three common types of spray nozzles used on agricultural sprayers: the flat fan, the hollow cone, and the solid cone. For broadcast pesticide application, the flat-fan type is most commonly used.

Nozzles may be constructed of brass, stainless steel, ceramics, or nylon. Advantages and disadvantages of each type are related to corrosion resistance, wear resistance, and cost. Consult your spray equipment supplier for specifications of the various nozzle types.

Abrasive materials, such as wettable powders, may cause rapid wear of spray nozzles made of soft metals or nylon. This may change the nozzle delivery rate or the spray pattern drastically. These should be checked periodically. If the sprayer is used often, a systematic schedule of nozzle tip replacement is good insurance for correct spray rate and pattern. Remember that in relation to the cost of pesticides, the cost of replacing worn nozzle tips is insignificant. Nozzle screens are also a vital part of a spray system. They perform the important task of screening out foreign materials that might clog the nozzles and large abrasive materials that might cause excessive wear. As mentioned previously, nozzle screens should be 50 to 100 mesh, with 50 mesh being the smallest size for wettable powders.

Nozzle screens have to be cleaned often to prevent loss of spray pressure. Since pressure gauges are located ahead of the spray nozzles, the gauge will not warn the operator of pressure loss due to a clogged spray screen. Wash the screen thoroughly in soapy water. Do not use a wire brush to clean the screen; a soft toothbrush may be used. Nozzle screens should be replaced if they are damaged or clogged so badly they cannot be cleaned.

No-drip nozzle screens are available and will prevent dripping of pesticides when the shut-off valve is closed. These screens have a spring-loaded mechanism to stop the flow of liquid when pressure to the nozzle is stopped. They cause a slight reduction in nozzle delivery rate at a given pressure. Consult the manufacturer's specifications for the delivery rate of nozzles with no-drip screens.

Nozzle tips may become clogged occasionally, even though screens are being used. Wire, knife blades, and other hard objects should not be used to unstop nozzle tips because they will enlarge or change the shape of the opening and alter the spray rate or spray pattern. A soft-bristled toothbrush or a small copper wire will remove objects without damage to the tips.

The relationship between nozzle size, spray pressure, and spray delivery rate is discussed later.

SPRAYER CALIBRATION AND PESTICIDE CALCULATIONS

Accurate sprayer calibration and calculation of amounts of pesticides to add to the spray tank are essential for proper use of pesticides. Too little pesticide will fail to control the pest. Too much pesticide is wasteful and may result in excessive damage to desirable plants or adverse effects on the environment. Sprayer calibration and pesticide calculations are simple. A few basic pieces of information are needed. The following discussion of the principles of sprayer calibration and the formulas, tables, and figures provided should enable one to quickly and accurately calibrate a sprayer and calculate amounts of pesticides to apply. Practice with these methods will help develop confidence in their use.

Calibration of Sprayers

Only three pieces of information are needed to accurately calibrate a sprayer. These are (1) the discharge rate of each spray nozzle, (2) the spacing of the nozzles on the boom, and (3) the ground speed of the sprayer. This information is easily obtained. Two parts of the information are fixed: the discharge rate of the nozzles and the spacing of the spray nozzles on the boom. The third part, the ground speed, is easily determined.

Nozzle discharge rate. Flat-fan spray nozzles are the type most commonly used in herbicide application. They are identified by a four-digit number that supplies important information. The first two digits (or three, if the angle is in excess of 100°) designate the angle of spray discharge from the nozzle at a designated spraying pressure of 40 psi. This, as we will see later, is important in determining the spacing of the nozzles on the boom. The second two digits designate the nozzle output in gallons (or parts of a gallon) per minute, also at the designated spray pressure of 40 psi. Thus an 8002 nozzle produces a spray pattern of 80° and delivers 0.2 gallons per minute.

Tables 1 and 2 illustrate the effect that spray pressure has on spray angle and nozzle discharge rate. Forty psi should be the maximum spraying pressure. If a pressure lower than 40 psi is used, note the effect this has on spray angle and nozzle output, and adjust the nozzle spacing and travel speed accordingly. Excessively high spraying pressures will result in a large proportion of small spray particles, increasing the drift hazard.

Table 1. Spray angle of flat-fan spray tips at 20 and 40 psi

Nozzle tip number	Spray pressure 20 psi	40 psi
8005	71°	80°
8008	72°	80°
9506	86°	95°
6506	54°	65°

Table 2. Spray delivery rate of flat-fan spray tips at 20, 30, and 40 psi

Nozzle tip number	Spray pressure 20 psi	30 psi	40 psi
	Nozzle delivery rate (gal/min)		
8005	0.35	0.43	0.50
8008	0.56	0.69	0.80
9506	0.42	0.52	0.60
6506	0.42	0.52	0.60

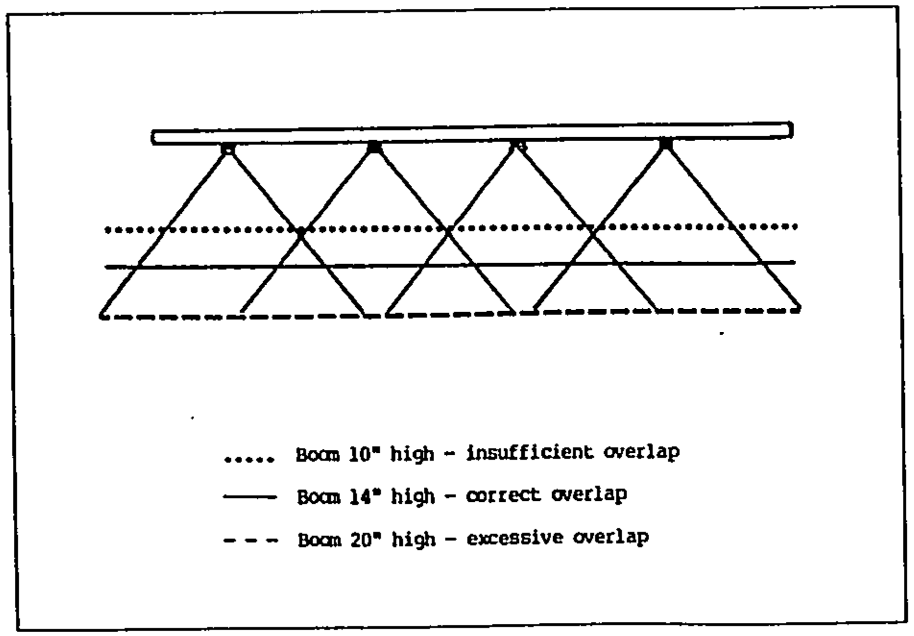

Figure 2. Effect of boom height on spray pattern. Nozzles are 80° angle flat-fan type spaced 18 inches apart on the boom.

Nozzle spacing. Another important factor to consider in setting up a spray boom is the relationship between nozzle spray angle, nozzle spacing on the spray boom, and the proper operating height of the boom. A simple illustration will help to clarify this relationship (Figure 2).

As Figure 2 shows, it is critical that the proper spacing and height for nozzles be used. Perfect calibration of nozzle output will not give proper pesticide distribution if the nozzles are not spaced properly or the boom is not adjusted to the proper height. Excessive boom height will also increase the potential for drift hazard.

Table 3 gives the proper boom height for different nozzles at different spacings on the boom.

Ground speed of sprayer. The ground speed of the sprayer is the third bit of information needed to calibrate a sprayer. If the tractor is not equipped with a speedometer, the speed can easily be determined by measuring the time required to travel a measured distance. Since 88 feet = 1/60 of a mile, this is a convenient distance to use for the sake of simplifying calculations.

First measure 88 linear feet and mark it with stakes or other convenient markers. Then determine a satisfactory gear and throttle setting for spraying. Mark the throttle setting for future reference, or if the tractor is equipped with a tachometer, note the revolutions per minute (rpm). Next determine the time, in seconds, required to travel the 88 feet. Since 60 miles per hour = 88 feet in one second, 60 divided by the measured time in seconds required to travel 88 feet = speed in miles per hour (mph). Table 4 covers the range of speeds normally used in spraying and will eliminate the need for calculations.

Determining Sprayer Output

Once the needed information is obtained, the sprayer output in gallons per acre may be calculated by the following formulas:

1. Acres covered in one hour by one nozzle = (GS × 5280 × NS)/43,560

Where:
GS = ground speed in mph
5280 = feet in one mile
NS = nozzle spacing *in feet*
43,560 = square feet in one acre

2. Sprayer output in gal/acre = (GPM × 60)/A

Where:
GPM = nozzle output in gal/min
60 = minutes in one hour
A = acres covered in one hour by one nozzle

For example, if you are spraying at 3 mph with 8004 nozzles spaced 18 inches (1.5 feet) apart, at 40 psi, the spray rate is:

1. (3 mph × 5280 × 1.5 ft)/43,560 = 0.55 acre/hr/nozzle

2. (0.4 GPM × 60)/0.55 acre/hr/nozzle = 43.6 gal/acre

Table 5 gives sprayer output when the nozzle output and ground speed are known.

Preparation of Spray Mixtures

Once the spray rate in gallons per acre is determined, it is a simple matter to determine the amount of pesticide to place in the spray tank. Since pesticide label recommendations are usually made in terms of formulated materials per acre, all calculations are made on this basis.

Mixing dry pesticide formulations. Many pesticides are formulated in a dry form (wettable powder, soluble powder, and so on) that is mixed with water and sprayed. To calculate the amount of dry formulation to place in the spray tank, use the following formula:

Wt = R(V/GPA)

Where:
Wt = weight of material for spray tank
R = desired rate of pesticide per acre
V = volume of spray solution in gallons
GPA = spray rate in gal/acre
(Wt and R must be in same units)

For example, you wish to mix 100 gallons of spray mixture with a 50 percent wettable powder and spray at the rate of 2 pounds formulated material per acre. If the spray rate is 40 gallons per acre, then 2(100/40) = 5 pounds of wettable powder per 100 gallons of spray solution.

Table 6 explains how much powder to use per gallon of solution when spraying at different rates. For example, if you wish to mix 75 gallons of spray solution to apply at the rate of 2 pounds formulated material per acre, and the spray rate is 40 gallons per

Table 3. Relationship between nozzle spacing, nozzle spray angle, and nozzle height

Nozzle spacing (inches)	Nozzle spray angle 65°	80°
	Nozzle height (inches)	
12	13	10
16	17	13
18	19	14
20	21	16
24	25	19

Source: C. R. Kaupke and R. G. Curley. 1964. Sprayer calibrations and calculations. Univ. of California, Davis.

Table 4. Speed required to travel 88 linear feet in different lengths of time

Time elapsed (seconds)	Speed (mph)
30	2.0
24	2.5
20	3.0
17	3.5
15	4.0
12	5.0

Table 5. Relationship between ground speed, nozzle discharge rate, and spray rate in gallons per acre for nozzles spaced 18 inches (1.5 feet) apart [a]

Nozzle discharge rate (gal/min)	Ground speed (mph) 2.0	2.5	3.0	3.5	4.0	4.5	5.0
	Spray rate (gal/acre)						
0.2	33.0	26.4	22.0	18.9	16.5	14.7	13.2
0.3	49.5	39.6	33.0	28.3	24.8	22.0	19.8
0.4	66.0	52.8	44.0	37.7	33.0	29.3	26.4
0.5	82.5	66.0	55.0	47.1	41.3	36.7	33.0
0.6	99.0	79.2	66.0	56.6	49.5	44.0	39.6
0.7	115.5	92.4	77.0	66.0	57.8	51.3	46.2
0.8	132.0	105.6	88.0	75.4	66.0	58.7	52.8
0.9	148.5	118.8	99.0	84.9	74.3	66.0	59.4
1.0	165.0	132.0	110.0	94.3	82.5	73.3	66.0
1.1	181.5	145.2	121.0	103.7	90.8	80.7	72.6
1.2	198.0	158.4	132.0	113.1	99.0	88.0	79.2
1.3	214.5	171.6	143.0	122.6	107.3	95.3	85.8
1.4	231.0	184.8	154.0	132.0	115.5	102.7	92.4
1.5	247.5	198.0	165.0	141.4	123.8	110.0	99.0
1.6	264.0	211.1	176.0	150.9	132.0	117.3	105.6

[a] For other nozzle spacings, spray rate $\times \frac{18}{\text{nozzle spacing}}$ = correct spray rate.

Table 6. Amount of dry formulation pesticide to use per gallon of spray solution when spraying at different rates

Desired rate	Spray rate (gal/acre)			
	40	50	60	70
(lb formulation/acre)	oz formulation/gal spray solution			
1	0.4	0.3	0.3	0.2
2	0.8	0.6	0.5	0.5
3	1.2	1.0	0.8	0.7
4	1.6	1.3	1.1	0.9
5	2.0	1.6	1.3	1.1
6	2.4	1.9	1.6	1.4
7	2.8	2.2	1.9	1.6
8	3.2	2.6	2.1	1.8
9	3.6	2.9	2.4	2.1
10	4.0	3.2	2.7	2.3

acre, then 75 gallons of spray solution = 0.8 ounce per gallon = 60 ounces (or 3 pounds, 12 ounces).

Mixing liquid formulations. Pesticides may be formulated in liquid form (soluble concentrates, emulsifiable concentrates, and flowables). To calculate the amount of liquid formulation to add to the spray tank, use the following formula:

Fl oz = R(V/GPA)

Where:
- Fl oz = fluid ounces of material for spray tank
- R = desired rate in fluid ounces of pesticide per acre
- V = volume of spray in gallons
- GPA = spray rate in gal/acre

For example, if you wish to mix 75 gallons of a spray mixture to be sprayed at 32 ounces per acre, the pesticide is a liquid formulation, and the spray rate is 50 gallons per acre, then 32(75 gallons/50 gallons per acre) = 48 ounces (or 3 pints) of formulation per 75 gallons of mixture.

Table 7 explains how much liquid to use per gallon of solution when spraying at different rates. For example, if you wish to mix 150 gallons of spray solution to apply at the rate of 3 pints formulated material per acre, and the spray rate is 60 gallons per acre, then 150 gallons of spray solution = 1.1 ounces per gallon of spray solution = 165 ounces (or 1 gallon, 1 quart, and 5 fluid ounces).

Table 7. Amount of liquid formulation pesticide to use per gallon of spray solution when spraying at different rates

Desired rate (fl oz formulation/acre)	Spray rate (gal/acre)			
	40	50	60	70
	fl oz formulation/gal spray solution			
16 (1 pt)	0.4	0.3	0.5	0.2
32 (1 qt)	0.8	0.6	0.8	0.5
48 (3 pt)	1.2	1.0	1.1	0.7
64 (½ gal)	1.6	1.3	1.3	0.9
80 (5 pt)	2.0	1.6	1.6	1.1
96 (6 pt)	2.4	1.9	1.9	1.4
112 (7 pt)	2.8	2.2	2.1	1.6
128 (1 gal)	3.2	2.6	2.4	1.8

Conversion Factors for Mixing Pesticides

Liquid measure:
- 3 teaspoons = 1 tablespoon
- 2 tablespoons = 1 fluid ounce
- 16 tablespoons = 8 fluid ounces = 1 cup
- 1 pint = 16 fluid ounces
- 2 cups = 1 pint
- 4 quarts = 1 gallon
- 1 gallon = 128 fluid ounces
- 1 gallon = 8 pints

Dry measure:
- 1 pound = 16 ounces

Linear distance:
- 1 mile = 5280 feet

Area:
- 1 acre = 43,560 square feet

Speed:
- 1 mph = 88 feet/minute
- 60 mph = 88 feet/second

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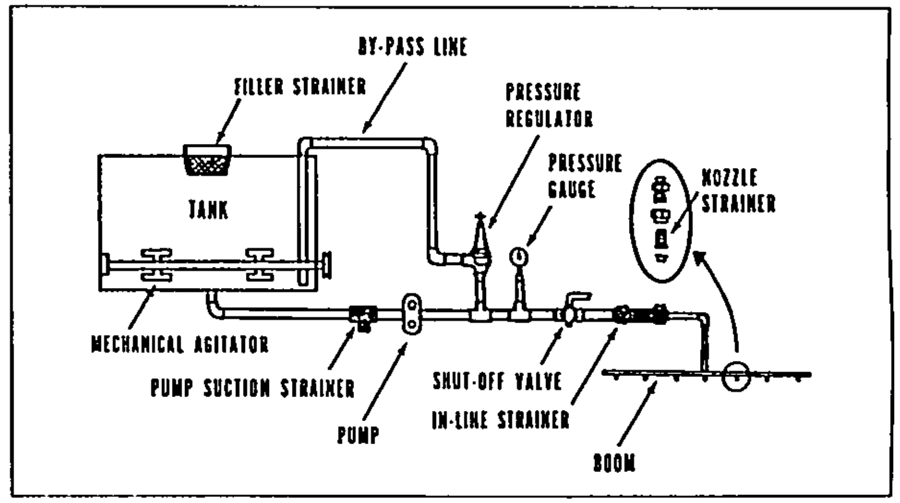

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Accurate sprayer calibration and calculation of amounts of pesticides to add to the spray tank are essential for proper use of pesticides. Too little pesticide will fail to control the pest. Too much pesticide is wasteful and may result in excessive damage to desirable plants or adverse effects on the environment. Sprayer calibration and pesticide calculations are simple. A few basic pieces of information are needed. The following discussion of the principles of sprayer calibration and the formulas, tables, and figures provided should enable one to quickly and accurately calibrate a sprayer and calculate amounts of pesticides to apply. Practice with these methods will help develop confidence in their use.

Calibration of Sprayers

Only three pieces of information are needed to accurately calibrate a sprayer. These are (1) the discharge rate of each spray nozzle, (2) the spacing of the nozzles on the boom, and (3) the ground speed of the sprayer. This information is easily obtained. Two parts of the information are fixed: the discharge rate of the nozzles and the spacing of the spray nozzles on the boom. The third part, the ground speed, is easily determined.

Nozzle discharge rate. Flat-fan spray nozzles are the type most commonly used in herbicide application. They are identified by a four-digit number that supplies important information. The first two digits (or three, if the angle is in excess of 100°) designate the angle of spray discharge from the nozzle at a designated spraying pressure of 40 psi. This, as we will see later, is important in determining the spacing of the nozzles on the boom. The second two digits designate the nozzle output in gallons (or parts of a gallon) per minute, also at the designated spray pressure of 40 psi. Thus an 8002 nozzle produces a spray pattern of 80° and delivers 0.2 gallons per minute.

Tables 1 and 2 illustrate the effect that spray pressure has on spray angle and nozzle discharge rate. Forty psi should be the maximum spraying pressure. If a pressure lower than 40 psi is used, note the effect this has on spray angle and nozzle output, and adjust the nozzle spacing and travel speed accordingly. Excessively high spraying pressures will result in a large proportion of small spray particles, increasing the drift hazard.

Table 1. Spray angle of flat-fan spray tips at 20 and 40 psi

Nozzle tip number	Spray pressure 20 psi	40 psi
8005	71°	80°
8008	72°	80°
9506	86°	95°
6506	54°	65°

Table 2. Spray delivery rate of flat-fan spray tips at 20, 30, and 40 psi

Nozzle tip number	Spray pressure 20 psi	30 psi	40 psi
	Nozzle delivery rate (gal/min)		
8005	0.35	0.43	0.50
8008	0.56	0.69	0.80
9506	0.42	0.52	0.60
6506	0.42	0.52	0.60

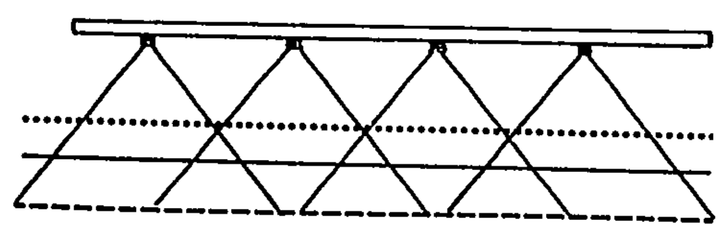

Figure 2. Effect of boom height on spray pattern. Nozzles are 80° angle flat-fan type spaced 18 inches apart on the boom.

Nozzle spacing. Another important factor to consider in setting up a spray boom is the relationship between nozzle spray angle, nozzle spacing on the spray boom, and the proper operating height of the boom. A simple illustration will help to clarify this relationship (Figure 2).

As Figure 2 shows, it is critical that the proper spacing and height for nozzles be used. Perfect calibration of nozzle output will not give proper pesticide distribution if the nozzles are not spaced properly or the boom is not adjusted to the proper height. Excessive boom height will also increase the potential for drift hazard.

Table 3 gives the proper boom height for different nozzles at different spacings on the boom.

Ground speed of sprayer. The ground speed of the sprayer is the third bit of information needed to calibrate a sprayer. If the tractor is not equipped with a speedometer, the speed can easily be determined by measuring the time required to travel a measured distance. Since 88 feet = 1/60 of a mile, this is a convenient distance to use for the sake of simplifying calculations.

First measure 88 linear feet and mark it with stakes or other convenient markers. Then determine a satisfactory gear and throttle setting for spraying. Mark the throttle setting for future reference, or if the tractor is equipped with a tachometer, note the revolutions per minute (rpm). Next determine the time, in seconds, required to travel the 88 feet. Since 60 miles per hour = 88 feet in one second, 60 divided by the measured time in seconds required to travel 88 feet = speed in miles per hour (mph). Table 4 covers the range of speeds normally used in spraying and will eliminate the need for calculations.

Determining Sprayer Output

Once the needed information is obtained, the sprayer output in gallons per acre may be calculated by the following formulas:

1. Acres covered in one hour by one nozzle = (GS × 5280 × NS)/43,560

Where:
GS = ground speed in mph
5280 = feet in one mile
NS = nozzle spacing *in feet*
43,560 = square feet in one acre

2. Sprayer output in gal/acre = (GPM × 60)/A

Where:
GPM = nozzle output in gal/min
60 = minutes in one hour
A = acres covered in one hour by one nozzle

For example, if you are spraying at 3 mph with 8004 nozzles spaced 18 inches (1.5 feet) apart, at 40 psi, the spray rate is:

1. (3 mph × 5280 × 1.5 ft)/43,560 = 0.55 acre/hr/nozzle

2. (0.4 GPM × 60)/0.55 acre/hr/nozzle = 43.6 gal/acre

Table 5 gives sprayer output when the nozzle output and ground speed are known.

Preparation of Spray Mixtures

Once the spray rate in gallons per acre is determined, it is a simple matter to determine the amount of pesticide to place in the spray tank. Since pesticide label recommendations are usually made in terms of formulated materials per acre, all calculations are made on this basis.

Mixing dry pesticide formulations. Many pesticides are formulated in a dry form (wettable powder, soluble powder, and so on) that is mixed with water and sprayed. To calculate the amount of dry formulation to place in the spray tank, use the following formula:

Wt = R(V/GPA)

Where:
Wt = weight of material for spray tank
R = desired rate of pesticide per acre
V = volume of spray solution in gallons
GPA = spray rate in gal/acre
(Wt and R must be in same units)

For example, you wish to mix 100 gallons of spray mixture with a 50 percent wettable powder and spray at the rate of 2 pounds formulated material per acre. If the spray rate is 40 gallons per acre, then 2(100/40) = 5 pounds of wettable powder per 100 gallons of spray solution.

Table 6 explains how much powder to use per gallon of solution when spraying at different rates. For example, if you wish to mix 75 gallons of spray solution to apply at the rate of 2 pounds formulated material per acre, and the spray rate is 40 gallons per

Table 3. Relationship between nozzle spacing, nozzle spray angle, and nozzle height

Nozzle spacing (inches)	Nozzle spray angle 65°	80°
	Nozzle height (inches)	
12	13	10
16	17	13
18	19	14
20	21	16
24	25	19

Source: C. R. Kaupke and R. G. Curley. 1964. Sprayer calibrations and calculations. Univ. of California, Davis.

Table 4. Speed required to travel 88 linear feet in different lengths of time

Time elapsed (seconds)	Speed (mph)
30	2.0
24	2.5
20	3.0
17	3.5
15	4.0
12	5.0

Table 5. Relationship between ground speed, nozzle discharge rate, and spray rate in gallons per acre for nozzles spaced 18 inches (1.5 feet) apart [a]

Nozzle discharge rate (gal/min)	Ground speed (mph) 2.0	2.5	3.0	3.5	4.0	4.5	5.0
	Spray rate (gal/acre)						
0.2	33.0	26.4	22.0	18.9	16.5	14.7	13.2
0.3	49.5	39.6	33.0	28.3	24.8	22.0	19.8
0.4	66.0	52.8	44.0	37.7	33.0	29.3	26.4
0.5	82.5	66.0	55.0	47.1	41.3	36.7	33.0
0.6	99.0	79.2	66.0	56.6	49.5	44.0	39.6
0.7	115.5	92.4	77.0	66.0	57.8	51.3	46.2
0.8	132.0	105.6	88.0	75.4	66.0	58.7	52.8
0.9	148.5	118.8	99.0	84.9	74.3	66.0	59.4
1.0	165.0	132.0	110.0	94.3	82.5	73.3	66.0
1.1	181.5	145.2	121.0	103.7	90.8	80.7	72.6
1.2	198.0	158.4	132.0	113.1	99.0	88.0	79.2
1.3	214.5	171.6	143.0	122.6	107.3	95.3	85.8
1.4	231.0	184.8	154.0	132.0	115.5	102.7	92.4
1.5	247.5	198.0	165.0	141.4	123.8	110.0	99.0
1.6	264.0	211.1	176.0	150.9	132.0	117.3	105.6

[a] For other nozzle spacings, spray rate $\times \frac{18}{\text{nozzle spacing}}$ = correct spray rate.

Table 6. Amount of dry formulation pesticide to use per gallon of spray solution when spraying at different rates

Desired rate	Spray rate (gal/acre)			
	40	50	60	70
(lb formulation/acre)	oz formulation/gal spray solution			
1	0.4	0.3	0.3	0.2
2	0.8	0.6	0.5	0.5
3	1.2	1.0	0.8	0.7
4	1.6	1.3	1.1	0.9
5	2.0	1.6	1.3	1.1
6	2.4	1.9	1.6	1.4
7	2.8	2.2	1.9	1.6
8	3.2	2.6	2.1	1.8
9	3.6	2.9	2.4	2.1
10	4.0	3.2	2.7	2.3

acre, then 75 gallons of spray solution × 0.8 ounce per gallon = 60 ounces (or 3 pounds, 12 ounces).

Mixing liquid formulations. Pesticides may be formulated in liquid form (soluble concentrates, emulsifiable concentrates, and flowables). To calculate the amount of liquid formulation to add to the spray tank, use the following formula:

Fl oz = R(V/GPA)

Where:
- Fl oz = fluid ounces of material for spray tank
- R = desired rate in fluid ounces of pesticide per acre
- V = volume of spray in gallons
- GPA = spray rate in gal/acre

For example, if you wish to mix 75 gallons of a spray mixture to be sprayed at 32 ounces per acre, the pesticide is a liquid formulation, and the spray rate is 50 gallons per acre, then 32(75 gallons/50 gallons per acre) = 48 ounces (or 3 pints) of formulation per 75 gallons of mixture.

Table 7 explains how much liquid to use per gallon of solution when spraying at different rates. For example, if you wish to mix 150 gallons of spray solution to apply at the rate of 3 pints formulated material per acre, and the spray rate is 60 gallons per acre, then 150 gallons of spray solution × 1.1 ounces per gallon of spray solution = 165 ounces (or 1 gallon, 1 quart, and 5 fluid ounces).

Table 7. Amount of liquid formulation pesticide to use per gallon of spray solution when spraying at different rates

Desired rate	Spray rate (gal/acre)			
	40	50	60	70
(fl oz formulation/acre)	fl oz formulation/gal spray solution			
16 (1 pt)	0.4	0.3	0.5	0.2
32 (1 qt)	0.8	0.6	0.8	0.5
48 (3 pt)	1.2	1.0	1.1	0.7
64 (½ gal)	1.6	1.3	1.3	0.9
80 (5 pt)	2.0	1.6	1.6	1.1
96 (6 pt)	2.4	1.9	1.9	1.4
112 (7 pt)	2.8	2.2	2.1	1.6
128 (1 gal)	3.2	2.6	2.4	1.8

Conversion Factors for Mixing Pesticides

Liquid measure:
- 3 teaspoons = 1 tablespoon
- 2 tablespoons = 1 fluid ounce
- 16 tablespoons = 8 fluid ounces = 1 cup
- 1 pint = 16 fluid ounces
- 2 cups = 1 pint
- 4 quarts = 1 gallon
- 1 gallon = 128 fluid ounces
- 1 gallon = 8 pints

Dry measure:
- 1 pound = 16 ounces

Linear distance:
- 1 mile = 5280 feet

Area:
- 1 acre = 43,560 square feet

Speed:
- 1 mph = 88 feet/minute
- 60 mph = 88 feet/second

APPENDIX K

BOTANICAL SURVEY

SUNSET BEACH - PAUMALU, PUPUKEA, OAHU

Prepared for: Group 70 (Obayashi Hawaii Corporation)

By: Kenneth M. Nagata

Date: 11 January 1988

INTRODUCTION

The project site, located on the north shore of Oahu in the Koolauloa District, consists of two large plateaus separated by a large gulch and bordered on either side by large gulches. The elevational range is approximately 20 feet near Kamehameha Hwy to nearly 850 feet in the uplands behind the plateau region. The vegetation of the region has been characterized by Ripperton and Hosaka (1942) as Xerophytic Shrub (Zone B) along the coast, Mixed Open Forest and Shrub in mesic portions of the uplands (Zone C, Low Phase) and Shrub and Closed Forest in wet portions of the uplands (Zone D, Low Phase). The natural vegetation in the Xerophytic Shrub Zone consists of lantana (Lantana camara), koa-haole (Leucaena leucocephala), klu (Acacia farnesiana), cactus (Opuntia megacantha), and 'ilima (Sida fallax). Above this in the Mixed Open Forest and Shrub Zone, koa-haole and lantana are still dominant but guava (Psidium guajava) and various grasses become increasingly important. In moist areas of the uplands (Zone D, Low Phase) guava becomes the dominant shrub. Species characteristic of this zone include sensitive plant (Mimosa pudica var. unijuga), Hilo grass (Paspalum conjugatum), ricegrass (P. orbiculare) and basketgrass (Oplismenus hirtellus). According to their surveys, pasturing is the major land use in low phases of zones C and D.

Aerial photographs taken in 1969 reveal that eighteen years ago pastures dominated much of the project site. These were concentrated on the plateaus but also could be found along the gulch slopes. Shrubs, probably Christmas berry (Schinus terebinthifolius) and/or strawberry guava (Psidium cattleianum) or guava (Psidium guajava), were generally confined to the gulch floors and trees which are easily identified as ironwood (Casuarina equisetifolia) were found along the top of the cliffs on the makai edges of the plateaus and in the upper elevations. Large groves of ironwood formed a broad band across the center of the eastern plateau.

METHODS

In December 1987, walk-through field surveys were conducted to determine the floristic composition of the project site. The area was first divided into several convenient topographic units then with the aid of the most recent available aerial photographs (12/69) each unit was individually surveyed. Total coverage was approximately 75%. Areas potentially containing remnant native vegetation were more intensively surveyed.

RESULTS

The general vegetation of the project site was found to be a complex of secondary forests consisting of ironwood and eucalyptus (Eucalyptus robusta, E. camaldulensis, E. sp.), grasslands, herblands and weedy brushlands. Ironwood forests which have spread considerably in the past 18 years now dominate most of the plateaus and upper slopes of the gulches. The existing pastures today consist of herbland and grassland community types. Nine broad vegetational communities were identified. These are presented in the accompanying vegetation map with distinct boundaries but it must be understood that in nature no sharp boundaries exist. Rather, vegetation exists as a continuum with one type grading into another.

Casuarina Forest (CF)

The most prevalent vegetation type in the site is the Casuarina Forest which is dominated by ironwood trees 20 to 50 feet tall. Typically the trees provide 100% canopy cover; the shrub and herb layers are almost non-existant due in part to the deep shade and the thick accumulation of litter (ie. the "needles"). Huehue-haole (Passiflora suberosa) and the native huehue (Cocculus ferrandianus) are among the very few species to be found in this shady situation.

In several areas, strawberry guava forms a dense secondary canopy. Individuals and groves of swamp mahogany (Eucalyptus robusta) too small to warrant mapping are scattered throughout the Casuarina Forest.

Erosional scars and other exposed sites are found in this community type. In these areas such common weedy species as sensitive plant, three-flowerd beggarweed (Desmodium triflorum), Spanish clover (D. canum), Jamaica vervain (Stachytarpheta jamaicensis), thatching grass (Hyparrhenia rufa) and Stylosanthes fruticosa are locally common. Small but dense colonies of guava and Christmas berry are also found in sunny sites.

Because of the abundance of micro-habitats included within the Casuarina Forest, many species are associated with this community but in small numbers. Among these are nearly two dozen native species. The most abundant native plant, huehue, is common throughout the forest. 'Ākia (Wikstroemia oahuensis) and pūkiawe (Styphelia tameiameiae) were recorded as "occasional" throughout this community type and 'ūlei (Osteomeles anthyllidifolia) and 'uhaloa (Waltheria americana) were also "occasional" but only in sunny sites. More than 12 others were regarded as "uncommon" or "rare".

Eucalyptus Forest (EuF)

Several large groves of swamp mahogany, a smaller grove of an unidentified species (Eucalyptus sp.) and a single extensive grove of Murray red gum (E. camaldulensis) are found in the project site. Typically this forest consists of planted eucalyptus trees 40 to 100 feet tall with a canopy cover of 75-100%. In some areas the sparse understory consists of occasional Koster's curse (Clidemia hirta), lantana, Christmas berry, huehue-haole and the native huehue and 'ākia; in other areas strawberry guava or Christmas berry form a dense understory 10 to 15 feet tall. Silk oak (Grevillea robusta) and ironwood are widely scattered through the forest. Several native species are also associated with the Eucalyptus Forest but with the exception of huehue and

'ākia they were all considered "rare".

Waltheria herbland (WH)

A considerable portion of the plateau areas presently being utilized as pasture consists of Waltheria herbland dominated by the indigenous 'uhaloa. Typically, 'uhaloa provides 50-75% of the vegetational cover. In some sections it provides nearly 100% of the cover and in others, Jamaica vervain is co-dominant. Common in this community are such weedy herbaceous species as sensitive plant, thatching grass, an unidentified Paspalum, perennial foxtail (Setaria geniculata), partridge pea (Cassia leschenaultiana) and Stylosanthes. Small groves and individuals of ironwood, strawberry guava, guava, Christmas berry, silk oak and Java plum (Eugenia cumini) are also found in this community. In addition to the ubiquitous 'uhaloa the only other native species recorded in this community was 'ūlei. Conspicuous in its absence is the native 'ilima which is commonly found in similar habitats elsewhere.

Intensively grazed areas are characterized by a larger grass component consisting largely of golden beardgrass (Chrysopogon aciculatus), West Indian dropseed (Sporobolus indicus) and Hilo grass. Three-flowered beggarweed is also common in such areas.

Grassland (G)

Grassland communities are found on the plateaus often adjacent to the Waltheria herbland communities and on the upper slopes of gulches. These are characterized by broomsedge (Andropogon virginicus) or thatching grass, with emergent individuals or small groves of ironwood, strawberry guava, Java plum and Formosan koa (Acacia confusa). Common in the Grassland are such herbaceous species as Jamaica vervain, partridge pea, Spanish clover, and Asiatic pennywort (Centella asiatica). The native sword fern (Nephrolepis exaltata) is also common. Several other native species including pala'a (Sphenomeris chusana), alahe'e (Canthium odoratum), 'ulaloa, huehue, 'ūlei and 'ākia are also found but in small numbers. Most of the Grassland community appear ungrazed, even on the plateaus, and consequently the grasses attain heights of three to five feet. In grazed areas the grasses which are cropped very short, consist mainly of kikaipua's (Digitaria pruriens), paragrass (Brachiaria mutica), perennial foxtail and golden beardgrass.

Whether they are being actively grazed today or not, the Grassland community on the plateaus together with the Waltheria Herbland are remnants of former pasture lands. They are being invaded by strawberry guava and ironwood and some have been reduced in size by more than 50%. On the other hand, Grassland communities on the gulch slopes appear to have been quite stable in the past two decades. Christmas berry becomes increasingly abundant on the lower portions of these slopes, forming a transitional zone between the Grassland community above and the Schinus Brush community below.

Psidium-Clidemia Gulch Association (PCGA)

This community type is found on the floor and lower slopes of the moist, upper reaches of the major gulches in the project site. It consists of dense stands of strawberry guava 10 to 20 feet tall with an understory dominated by koster's curse. Dominance of these two aggressive species is so complete that they often form nearly pure stands. The upper canopy tree component consists largely of kukui (Aleurites moluccana), ironwood, swamp mahogany and Murray red gum.

Numerous species are associated with this community type but only on erosional scars and on the middle slopes in what might be considered a transitional zone with the Casuarina Forest, and also in somewhat exposed sites on the gulch floor are these found in significant numbers. On erosional scars and on the middle slopes such common native species as 'ōhi'a-lehua

(Metrosideros collina subsp. polymorpha), naupaka (Scaevola gaudichaudiana), uluhe (Dicranopteris linearis), pala'a, pūkiawe, and 'ākia are found in small to moderate numbers. Nearly 20 other native species are found in this community type but in small numbers. Exposed sites on the gulch floors are occupied by common weedy species such as Jamaica vervain, Asiatic pennywort, partridge pea, Spanish clover, sensitive plant, Hilo grass, and ageratum (Ageratum conyzoides).

Schinus Brush (SB)

The middle and lower reaches of the major gulches, the lower slopes of the seaward cliffs and most of the small ravines are dominated by Schinus Brush. This vegetation type is characterized by dense stands of Christmas berry 10 to 20 feet tall with occasional emergent Formosan koa, swamp mahogany and Java plum. In some areas the Christmas berry is so dense that the understory is nearly devoid of vegetation and in other areas strawberry guava or basketgrass are dominant in the understory.

The Schinus Brush community is best developed on the floors of the ravines where moisture is more readily available. Occasionally where sunny sites are found in the stands, Jamaica vervain and koster's curse become common. Associated with these moist sites are also partridge pea, perennial foxtail, Asiatic pennywort and lantana. Where it extends up the ravine slopes the plants become shrubbier and more widely spaced. Numerous other species are found in these upper slope habitats, most notably sword fern, paragrass, broomsedge and molassesgrass (Melinis minutiflora). Species diversity is rather large in this vegetation type due in part to the varied ecological habitats which it occupies but most of the species are found in low numbers.

Psidium Gulch Association (PGA)

This community type is only found in the moist, upper half of the gulch which constitutes the south boundary of the project site. The Casuarina Forest which dominates the slopes in this region extends down to the gulch floor. Consequently the Psidium Gulch Association is confined to the very floor of the gulch. This community type is characterized by dense stands of strawberry guava 15 to 25 feet tall with occasional emergent ironwood, silk oak and rose apple (Eugenia jambos). The canopy cover provided by the strawberry guava is often 100% and the resulting deep shade and the thick carpet of ironwood litter discourages any understory development. Sunny sites within the community provide habitat for herbaceous species such as ageratum, Jamaica vervain, Hilo grass, Asiatic pennywort and comb hyptis (Hyptis pectinata).

It appears that portions of the gulch were cultivated in the past. Several very large mango (Mangifera indica), avocado (Persea americana) and breadfruit (Artocarpus altilis) trees are found in the upper reaches of the gulch. Coffee (Coffea arabica) has become naturalized in one section and several banana plants (Musa x paradisiaca) and one coconut (Cocos nucifera) were also found. In addition, one rather sizable section of the gulch floor appears to have been recently cleared. Although it is now densely overgrown by a number of weedy species, it has not yet been invaded by strawberry guava.

Mixed Gulch Association (MGA)

The vegetation in the lower portion of the south boundary gulch is a mosaic of several community types too small to be feasibly mapped. It consists of small groves of strawberry guava, Christmas berry, Java plum and ironwood, and small fields of thatching grass grasslands and Waltheria Herbland. Also included are small heterogeneous communities with no expressions of species dominance. These communities contain numerous weedy species such as 'uhaloa, Asiatic pennywort, guava, Koster's curse, molassesgrass, broomsedge, sword fern, koa-haole, Stylosanthes, and buttonweed (Borreria laevis). It is the smallest of all the community types found in the project site.

Lowland Wasteland (LW)

Another vegetational mosaic is located along Kamehameha Highway. It too, consists of a patchwork of individual units too small to be feasibly mapped. A grove of ironwood and a closed-canopied kiawe (Prosopis pallida) forest line Kamehameha Highway. Behind this are found a heterogeneous community of weedy species such as Guinea grass (Panicum maximum), kolomona (Cassia surattensis), hairy abutilon (Abutilon grandifolium), paragrass, sensitive plant and partridge pea, also an intensively grazed pasture consisting of short-cropped grasses such as Kūkaipua'a and Hilo grass, a thicket of koa-haole, a weedy pasture of Guinea grass, Jamaica vervain, Indian pluchea (Pluchea indica), pluchea (P. odorata) and klu (Acacia farnesiana), and a small forest of Ceara rubber (Manihot glaziovii). Sourgrass (Tricachne insularis) is common throughout this vegetation type.

Native Species and Native Plant Communities

Numerous common native plant species are found in the project site but these are generally few in numbers and occur mostly as widely scattered individuals. On steep, exposed slopes in the Psidium-Clidemia Gulch Association, small numbers of 'ōhi'a-lehua, naupaka, ulehe, pala'a and pūkiawe grow in close proximity to each other but these pockets are so small, degraded and widely scattered that they cannot be interpreted as viable communities. Only four native species were found in any significant numbers in the project site. Huehue and 'ākia are the most abundant native species. Both are found on all topographic situations except the gully floors and in all but two vegetation types in small to moderate numbers. 'Ūlei and pala'a, also widespread throughout much of the site, are generally restricted to sunny, exposed sites especially on the upper slopes.

Several sandalwood trees (Santalum freycinetianum) are found on steep, sunny slopes, and six halapepe (Pleomele halapepe) individuals were observed. Although these are not considered rare, it was surprising to find them still extant in such disturbed sites. Other common species that are rare in the project site include Pittosporum confertiflorum (1 plant) and 'aulu (Planchonella sandwicensis) (2 plants).

Rare and Endangered Species

Four trees of Koolau eugenia (Eugenia koolauensis) were discovered in a small, moist ravine in the upper portion of the project site. They are situated in an extensive thicket of strawberry guava with an understory of koster's curse. Nearby are a solitary halapepe and an 'ohe'ohe makai (Reynoldsia sandwicensis), both unusual finds in such a totally disturbed habitat.

Koolau eugenia was considered "localized" and "rare" by Fosberg and Herbst (1975) in the first assessment of the status of Hawaiian plants. Subsequently however, it was not included in the U.S. Fish and Wildlife Service's recommended list of candidates for Endangered Status. Nonetheless, it has not been collected in 30 years and until its re-discovery in the project site, it was considered "possibly extinct" (W. Wagner, Bishop Museum, pers. comm.). According to D. Herbst (U.S. Fish and Wildlife Service) it will be included as a Category 1 candidate in the next official listing of candidates for Endangered Species status (pers. comm.).

POTENTIAL PROBLEMS AND MITIGATING MEASURES

A portion of the field survey was conducted during a kona storm during which a considerable amount of runoff was observed on the existing erosional scars. This resulted in heavily silt-laden stream flow in many of the gullies and consequently in the major gulches. Although it is not known how much of the stream load is deposited in the headlands and how much actually enters the ocean, during the construction phase of the project when large areas will certainly be denuded steps should be taken to alleviate runoff and soil erosion.

The four trees of the Koolau eugenia are the only known specimens in the world. The gully which they inhabit is situated far from the plateau lands and thus perhaps outside the zone of construction. If construction occurs nearby, great care should be exercised to prevent not only physical damage to the gully itself but also excessive erosion and runoff from above. In addition, measures should be taken to prevent any fertilizer runoff which will stimulate more vigorous growth of the aggressive strawberry guava and koster's curse already present. It is also recommended that a select portion of the strawberry guava surrounding the eugenia trees be cut down to alleviate the present crowded condition. This is not an intent to restore a native habitat because there really is no native habitat. Rather, this may afford more optimal growing conditions for these trees and thus insure their survival. More active management of this unique resource may include monitoring for flowers and fruits and propagation experiments with a long term goal of increasing the population. Extensive clearing of the strawberry guava at this time is not recommended as this may only serve to stimulate the growth of koster's curse and cause erosion.

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Wagner, W.H., Jr., & F.S. Wagner. Revised Checklist of Hawaiian Pteridophytes. (unpublished)

SPECIES CHECKLIST

Plant families are arranged alphabetically in three groups - Pteridophytes, Gymnosperms and Angiosperms. The Angiosperms are subdivided into Monocotyledones and Dicotyledones. Genera and species are arranged alphabetically within each family. Taxonomy of the Pteridophytes follows that of Wagner's unpublished list and common names for the ferns are those which are commonly accepted. Taxonomy, common names and the status of the Gymnosperms and Angiosperms generally follow that of St. John (1973).

EXPLANATION OF SYMBOLS

Species Status:

- E - Endemic to the Hawaiian Islands, ie. occuring naturally nowhere else in the world.
- I - Indigenous, ie. native to the Hawaiian Islands but also occuring naturally elsewhere.
- X - Exotic (alien), ie. plants introduced after the Western discovery of the islands.
- P - Polynesian introduction, plants introduced before the Western discovery of the islands.
- N - Native, endemic or indigenous (for Pteridophytes only)

FR - Federal Register status; official listing by U.S. Fish & Wildlife Service (if applicable)

FH - Endangered status listing by Fosberg & Herbst (1975) (if applicable)

CHECK LIST OF PLANTS

SCIENTIFIC NAME	COMMON NAME	STATUS	FR	FB	CF	EIT	LT	C	PCG	SR	PGA	MGA	IU
PTERIDOPHYTES													
ADIANTACEAE													
Doryopteris decipiens (Smith) Hook.		N								P			
Pellaea viridis (Forsk.) Prantl		X								P			
Pityrogramma austroamericana Domin	Gold fern	X						U					
P. calomelanos (L.) Link	Silver fern	X					R	U	R			O	
Pteris vittata		X			R								
BLECHNACEAE													
Blechnum occidentale L.		E							C		R		
Doodia kunthiana Gaud.		E							U				
DAVALLIACEAE													
Nephrolepis exaltata (L.) Schott	Sword fern	N			U	R		C	U	C		O	
DENNSTAEDTIACEAE													
Pteridium aquilinum var. decompositum (Gaud.) R. Tryon	Bracken fern	N			R				C	R			
DICKSONIACEAE													
Cibotium splendens (Gaud.) Krajina ex Skottsb.	Hapu'u	E							U				
GLEICHENIACEAE													
Dicranopteris linearis (Burm.) Underw.	Uluhe	N			U			U	C				
LINDSAEACEAE													
Sphenomeris chusana (L.) Copel.	Pala'a	N			C	R		O	O	U		O	
POLYPODIACEAE													
Microsorium scolopendrium (Burm.) Copel.	Lauae	N				R			R	U			
Phlebodium aureum (L.) J. Smith		X				R							
Pleopeltis thunbergiana Kaulf.		N							U	U			
PSILOTACEAE													
Psilotum nudum (L.) Beauv.	Moa	N			U	R			U	R			
SELAGINELLACEAE													
Selaginella arbuscula Kaulf.		E							U				
THELYPTERIDACEAE													
Christella dentata (Forssk.) Brownsey & Jermy		X			U	R		O	C	O	C	C	
C. parasitica (L.) Leveille		X				R			C		C		
GYMNOSPERMS													
CUPRESSACEAE													
Cupressus sp.		X			R								

CHECK LIST OF PLANTS

SCIENTIFIC NAME	COMMON NAME	STATUS	FR	FB	CF	EIT	LT	C	PCGA	SR	PGA	MGA	IU
ANGIOSPERMS - MONOCOTYLEDONS													
AMARYLLIDACEAE													
Furcraea foetida (L.) Haw.	Mauritius hemp	X											U
ARACEAE													
Xanthosoma sagittifolium (L.) Schott		X									R		
COMMELINACEAE													
Commelina diffusa Burm. f.	Honohono	X								R			
CYPERACEAE													
Carex meyenii Nees		E							U				
C. wahuensis C.A. Mey.		E			U	A			U	U			
Cyperus gracilis R. Br.	McCoy Grass	X											
C. kyllinga Endl.	Kyllinga	X											O
Fimbristylis dichotoma (L.) Vahl	Tall fringe rush	X							R		A	U	
Gahnia beecheyi H. Mann	'Uki	E			R				U			U	
GRAMINEAE													
Andropogon virginicus L.	Broomsedge	X			U			A	U				A
A. pertusus (L.) Willd.		X			R								A
Brachiaria mutica (Forsk.) Stapf	Paragrass	X			U		O	O		R		U	C
Cenchrus echinatus L.	Common sandbur	X											O
Chloris inflata Link	Swollen fingergrass	X											U
Chrysopogon aciculatus (Retz.) Trin.	Golden beardgrass	X			A		O	O		U		U	
Cynodon dactylon (L.) Pers.	Bermuda grass	X					U					R	C
Digitaria pruriens (Fisch. ex Trin.) Buse	Kukaipua'a	X					O	O		U		U	O
Eleusine indica (L.) Gaertn.	Goosegrass	X											U
Hyparrhenia rufa (Nees.) Stapf	Thatching grass	X				R	C	A	U	U		O	
Oplismenus hirtellus (L.) Beauv.	Basketgrass	X			U	O			U	C	C		
Melinis minutiflora Beauv.	Molassesgrass	X			R			O		O		O	R
Panicum maximum Jacq.	Guinea grass	X			R		R	U		R	O		C
Paspalum conjugatum Berg.	Hilo grass	X			R			O	O		O	U	O
P. sp.		X			U	O	C	O	U	O		O	
Pennisetum purpureum Schumach	Elephantgrass	X						R					
P. setosum (Sw.) L.C. Rich	Feathery pennisetum	X								U			
Sacciolepis indica (L.) Chase	Glenwoodgrass	X			R			O					
Schizachyrium sp.		X			O								
Setaria geniculata (Poir.) Beauv.	Perennial foxtail	X			O	R	C	O	O	O	R	U	R
S. verticillata (L.) Beauv.	Bristly foxtail	X											U
Sporobolus indicus (L.) R. Br.	West Indian dropseed	X					U	R					
Tricachne insularis (L.) Nees	Sourgrass	X										R	A
LILIACEAE													
Cordyline terminalis (L.) Kunth	Ti	P			U	O			U	U	R		
Dianella sandwicensis H. & A.	'Uki	E			R				R				
Pleomele halapepe St. John	Halapepe	E			R				R	R			

Vegetation Types:

CF - Casuarina Forest

ECF - Eucalyptus Forest

WH - Waltheria Herbland

G - Grassland

PCGA - Psidium-Clidemia Gulch Association

SB - Schinus Brush

PGA - Psidium Gulch Association

MGA - Mixed Gulch Association

LW - Lowland Wasteland

Relative Abundance Rating:

A - Abundant, generally the major or dominant element in an area.

C - Common, generally distributed throughout a given area in large numbers.

O - Occasional, generally distributed throughout a given area in small numbers

U - Uncommon, observed uncommonly but more than 10 times in a given area.

R - Rare, observed 2-10 times in a given area.

CHECK LIST OF PLANTS

SCIENTIFIC NAME	COMMON NAME	STATUS	FR	FH	RELATIVE ABUNDANCE								
					CF	ECF	WH	G	PCGA	SB	PGA	MGA	LW
MUSACEAE													
Musa x paradisiaca L.	Banana	P									R	R	
ORCHIDACEAE													
Epidendrum x obrienianum Rolfe		X			R								
Spathoglottis plicata Bl.		X			O	R		U		U		U	
PALMAE													
Cocos nucifera L.	Coconut	P			R						R		
Phoenix sylvestris (L.) Roxb.	Wild date palm	X				R	R	R		R	R	R	
ZINGIBERACEAE													
Zingiber zerumbet (L.) Roscoe	Awapuhi kuahiwi	P							O		A		
ANGIOSPERMS - DICOTYLEDONES													
ACANTHACEAE													
Asystasia gangetica (L.) T. Anders.	Asystasia	X											A
AMARANTHACEAE													
Achyranthes indica (L.) Mill.		X											O
Alternanthera repens (L.) Ktze.	Khaki weed	X											A
Amaranthus spinosus L.	Spiny amaranth	X											O
ANACARDIACEAE													
Mangifera indica L.	Mango	X						C	R			R	
Schinus terebinthifolius Raddi	Christmas berry	X			O	A	O		C		A	A	C
APOCYNACEAE													
Alyxia oliviformis Gaud.	Maile	E			R				R				
Thevetia peruviana (Pers.) K. Schum.	Be-still tree	X			R								R
ARALIACEAE													
Brassaia actinophylla Endl.	Umbrella tree	X								A		C	
Reynoldsia sandwicensis Gray	'Ohe'ohe makai	E							R				
BEGONIACEAE													
Begonia hirtella Link		X			R								
BIGNONIACEAE													
Spathodea campanulata Beauv.	African tulip tree	X			U			U	U			U	R
CACTACEAE													
Opuntia megacantha Salm-Dyck	Prickly pear	X						R					
CARICACEAE													
Carica papaya L.	Papaya	X											R
CASUARINACEAE													
Casuarina equisetifolia Stickm.	Ironwood	X			A	O	O		C	C		O	C

CHECK LIST OF PLANTS

SCIENTIFIC NAME	COMMON NAME	STATUS	FR	FH	CF	CUF	UH	G	PCGA	SB	PCA	MCA	LU
COMPOSITAE													
Acanthospermum australe (Loefl.) Ktze.	Spiny-bur	X			O			U					
Ageratum conyzoides L.	Ageratum	X			R				U		O	U	
Bidens alba var. radiata (Schz. bip.) Ballard ex Melchert		X										R	R
B. torta Sherff	Corkscrew bidens	X						R					
B. pilosa L.	Spanish needle	X											R
Calyptocarpus vialis Less.		X			R								O
Crassocephalum crepidioides (Benth.) Sp. Moore		X									R		
Elephantopus mollis HBK.	Elephant's-foot	X			O			R	R	U		C	
Emilia fosbergii Nicolson		X					C	O		U		C	
E. sonchifolia (L.) DC.	Lilac pualele	X						O		U		U	
Erigeron bonariensis L.	Hairy horseweed	X			U		O	U		U	R	R	O
Pluchea x fosbergii Cooperrider & Galang		X											R
P. indica (L.) Less.	Indian pluchea	X								R			R
P. odorata (L.) Cass.	Pluchea	X			O		C	U	R	U	O	O	C
Sonchus oleraceus L.	Sow thistle	X							R				O
Verbesina encelioides (Cav.) B. & H. ex Gray	Golden crown-beard	X											R
Vernonia cinerea (L.) Less.	Ironweed	X					C	O		U		O	
Wedelia trilobata (L.) Hitchc.	Wedelia	X					R				U		R
Youngia japonica (L.) DC.	Oriental hawksbeard	X			R					R		R	
CONVOLVULACEAE													
Ipomoea ochracea (Lindl.) G. Don		X								R			
CRASSULACEAE													
Kalanchoe pinnata (Lam.) Pers.	Air plant	X								R			R
CRUCIFERAE													
Lepidium virginicum L.	Wild peppergrass	X											R
CUCURBITACEAE													
Cucurbita pepo L.	Field pumpkin	X										•	R
Momordica charantia var. pavel Crantz	Peria	X										U	C
EBENACEAE													
Diospyros ferrea (Willd.) Bakh.	Lama	E							U				
EPACRIDACEAE													
Styphelia tameiameiae (Cham.) F. Muell.	Pukiawe	I			O	R		R	O				
EUPHORBIACEAE													
Aleurites moluccana (L.) Willd.	Kukui	P			R	R			O		R	R	
Euphorbia hirta L.	Garden spurge	X					U						
Manihot glaziovii Muell.-Arg.	Ceara rubber	X											C
Phyllanthus debilis Klein ex Willd.	Phyllanthus weed	X					U			R	R	R	
GOODENIACEAE													
Scaevola gaudichaudiana Cham.	Naupaka-kuahiwi	E			C	P		R	O			U	

CHECK LIST OF PLANTS

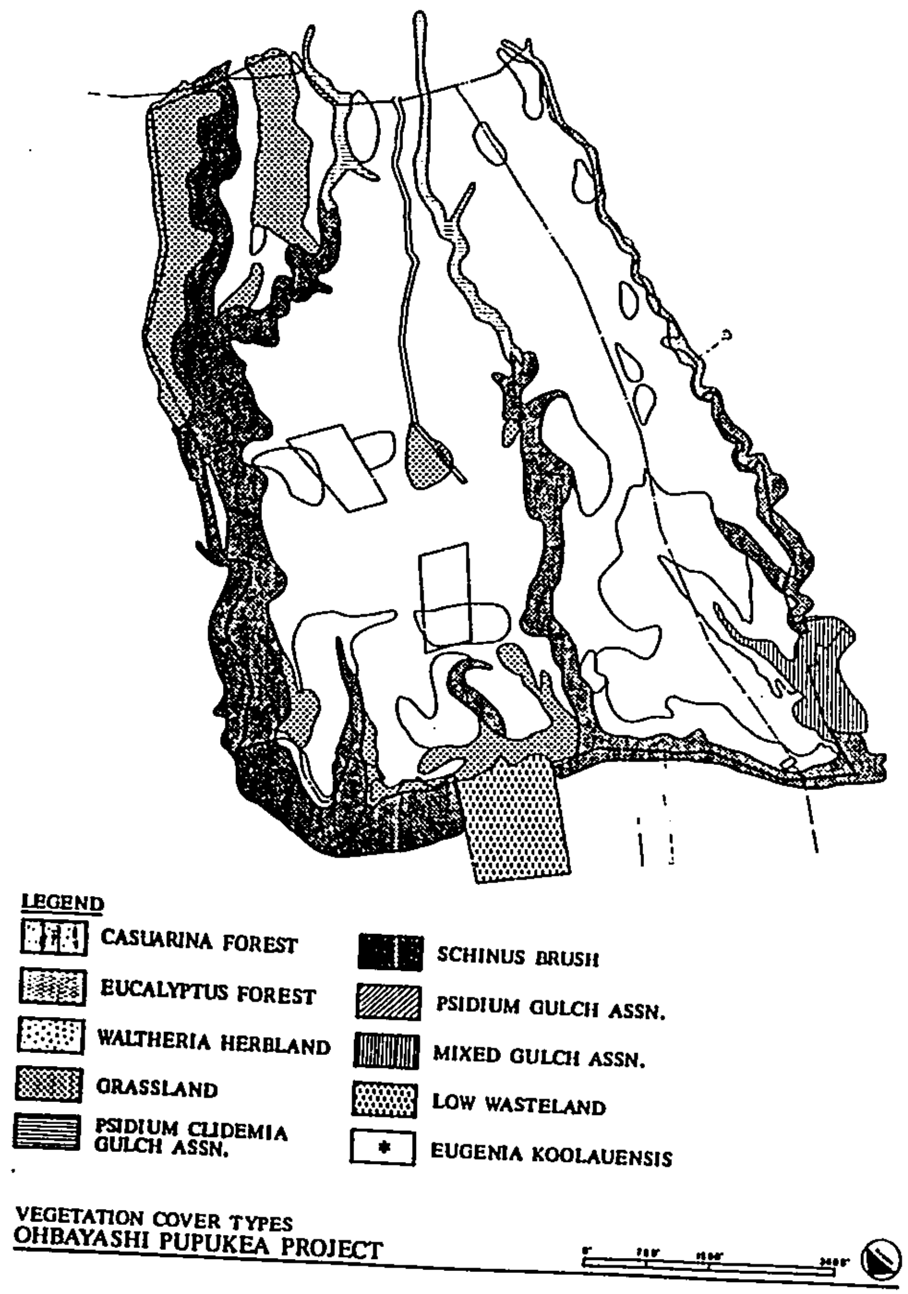
SCIENTIFIC NAME	COMMON NAME	STATUS	FR	FH	CF	CUF	UH	G	PCGA	SB	PCA	MCA	LU
GUTTIFERAE													
Calophyllum inophyllum L.	Kamani	P									R		
LABIATAE													
Hyptis pectinata (L.) Poit.	Comb hyptis	X							R	R	U	C	C
Leonotis nepetaefolia (L.) Ait. f.	Lions-ear	X											R
LAURACEAE													
Cassytha filiformis L.	Kauna'oa-pehu	X								R			
Persea americana Mill	Avocado	X									R	R	
LEGUMINOSAE													
Acacia confusa Merr.	Formosan koa	X			R		R	O	C	O		U	
A. farnesiana (L.) Willd.	Klu	X				R							U
A. koa Gray	Koa	E			R			R	R			R	
Canavalia cathartica Thouars	Mauna-loa	X									R		
Cassia leschenaultiana DC.	Partridge pea	X			U		C	C	R	O	R	C	O
C. occidentalis L.	Coffee senna	X											R
C. surattensis Burm. f.	Kolomona	X					R						O
Crotalaria pallida Aiton		X							R	R		C	
Desmanthus virgatus (L.) Willd.	Virgate mimosa	X					R				O		C
Desmodium canum (Gmel.) Schinz & Thell.	Spanish clover	X			O		O	C	C	C		C	U
D. triflorum (L.) DC.	Three-flowered beggarweed	X			C		O					U	R
Glycine wightii (Wight & Arnold) Verdc.		X										R	
Indigofera suffruticosa Mill.	Indigo	X						R					
Leucaena leucocephala (Lam.) de Wit	Koa-haole	X			C	R	R			C	R	O	C
Mimosa pudica var. unijuga (Duchass. & Walp.) Griseb.	Sensitive plant	X			C		C	R	C	U		O	O
Peltophorum africanum Sond.		X			R			R				A	
Prosopis pallida (Humb. & Bonpl. ex Willd.) HBK.	Kiawe	X								R			C
Stylosanthes fruticosa (Retz.) Alston		X			O		C	O				O	
LOGANIACEAE													
Buddleja asiatica Lour.	Dogtail	X								R			
MALVACEAE													
Abutilon grandifolium (Willd.) Sweet	Hairy abutilon	X								R		R	O
Hibiscus tiliaceus L.	Hau	X											A
Malva parviflora L.	Little mallow	X											R
Malvastrum coromandelianum (L.) Garcke	False mallow	X			R							R	O
Sida rhombifolia L.	Cuba jute	X										U	O
MELASTOMATACEAE													
Clidemia hirta (L.) D. Don	Koster's curse	X			C	C		O	A	C	R	O	
MELIACEAE													
Melia azedarach L.	Pride of India	X			R		R				R	R	
MENISPERMACEAE													
Cocculus ferrandianus Gaud.	Huehue	I			C	C	R	O	R	C		O	

CHECK LIST OF PLANTS

SCIENTIFIC NAME	COMMON NAME	STATUS	FR	FH	CF	CCF	VR	C	PCGA	SB	PGA	MGA	LV
MORACEAE													
Artocarpus altilis (Parkins. ex Z) Fosb.	Breadfruit	P									R		
Cecropia obtusifolia Bertol.	Guarumo	X							R				
Ficus microcarpa L. f.	Chinese banyan	X			R		R	R		R		R	R
MYRTACEAE													
Eucalyptus camaldulensis Dehnh.	Murray red gum	X			O	A			O				R
E. robusta Sm.	Swamp mahogany	X			C	A			C	O			
E. sp.		X				O							
Eugenia cumini (L.) Druce	Java plum	X			C		C	O	O	O	O	O	
E. jambos L.	Rose apple	X									O		
E. koolauensis Deg.	Koolau eugenia	E		Local, rare					R				
Melaleuca leucadendra (Stickm.) L.	Paper bark	X			R	R							
Metrosideros collina subsp. polymorpha (Gaud.) Rock	'Ohi'a-lehua	E			C			R	O	C			
Psidium cattleianum Sabine	Strawberry guava	X			C	C	O	O	A	C	A	C	
P. guajava L.	Guava	X			O		C	C	C	O	A	C	O
NYCTAGINACEAE													
Boerhavia coccinea Mill.		X											R
OLEACEAE													
Osmanthus sandwicensis (Gray) Knobl.	Olopua	E							R				
OXALIDACEAE													
Oxalis corniculata L.	Yellow wood sorrel	X ?								R		C	C
O. martiana Zucc.	Pink wood sorrel	X									R		
PASSIFLORACEAE													
Passiflora edulis f. flavicarpa Deg.	Yellow lilikoi	X			R	O	R	C	O	C	O	O	R
P. foetida L.	Scarlet-fruited passion flower	X						R				R	
P. suberosa L.	Huehue-haole	X			O	C			O	O	O	O	O
P. subpeltata Ortega	White passion flower	X										R	
PIPERACEAE													
Peperomia leptostachya H. & A.		I								O			
PITTOSPORACEAE													
Pittosporum confertiflorum Gray		E							A				
PLANTAGINACEAE													
Plantago lanceolata L.	Narrow-leaved plantain	X											R
P. major L.	Common plantain	X											C
PORTULACACEAE													
Portulaca oleracea L.	Common purslane	X									[illegible]		R
PROTEACEAE													
Grevillea robusta A. Cunn.	Silk oak	X			C	C	C	C	R	C	O	O	

CHECK LIST OF PLANTS

SCIENTIFIC NAME	COMMON NAME	STATUS	FR	FH	CF	CCF	VR	C	PCGA	SB	PGA	MGA	LV
ROSACEAE													
Osteomeles anthyllidifolia Lindl.	'Ulei	E			O		R			C		C	
Rubus rosaefolius Sm.	Roseleaf raspberry	X							R				
RUBIACEAE													
Borreria laevis (Lam.) Griseb.	Buttonweed	X			C		C	R	R			O	
Canthium odoratum (Forst. f.) Seem.	Alahe'e	I			R	R		C	C				
Coffea arabica L.	Arabian coffee	X									O		
Morinda citrifolia L.	Noni	P							R	[illegible]	R		C
RUTACEAE													
Citrus sp.		X									R		
Murraya paniculata (L.) Jack	Mock orange	X											R
SANTALACEAE													
Santalum freycinetianum Gaud.		E							R	R			
SAPOTACEAE													
Chrysophyllum oliviforme L.	Satin leaf	X							R				
Planchonella sandwicensis (Gray) Pierre	Alaa	E			R				R				
SOLANACEAE													
Capsicum annuum L.	Red pepper	X											C
Solanum nigrum L.	Black nightshade	X ?								R		C	O
S. sodomeum L.	Apple of Sodom	X								R			C
STERCULIACEAE													
Waltheria americana L.	'Uhaloa	I			O		A		O			O	R
THYMELIACEAE													
Wikstroemia oahuensis (Gray) Rock	'Akia	E			O	O		O	O	O			
TILIACEAE													
Triumfetta semitriloba (L.) Jacq.	Burbush	X							R	C	R		O
ULMACEAE													
Trema orientalis (L.) Bl.	Gunpowder tree	X							R		R		
UMBELLIFERAE													
Centella asiatica (L.) Urban	Asiatic pennywort	X			R	R	R	C	R	O	O	O	
VERBENACEAE													
Duranta repens L.	Golden dewdrop	X							R				
Lantana camara L.	Lantana	X			O	O	O	C	C	O	R	C	C
Stachytarpheta jamaicensis (L.) Vahl	Jamaica vervain	X			O	C	A	C	C	C	C	O	C
S. urticifolia (Salisb.) Sims		X			R		R						
Verbena litoralis HBK.	Weed verbena	X									R		



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PHASE I: PAUMALU - KALELEIKI STREAMS WETLANDS SURVEY LIHI LANI RECREATIONAL COMMUNITY

INTRODUCTION

The proposed Lihi Lani Recreational Community consists of approximately 1,143 acres of land located makai of Kamehameha Highway and Sunset Beach. Elevation ranges from 20 ft. near the highway to nearly 850 ft. on the plateau area where it abuts the Pupukea-Paumalu Forest Reserve. Four streams cross the project site. To the north are Paumalu Stream and its tributary, Keleleiki Stream; to the south are Kalunawaika'ala Stream and Pakulena Stream.

Field studies to search for wetlands along the Paumalu and Keleleiki streams were conductted on 29 March 1991. Three botanists were used for the survey work. A similar survey will be conducted for the streams on the southern portion of the property at a later date.

DESCRIPTION OF THE STREAMSIDE VEGETATION

The vegetation on the entire project site has been described and mapped in detail in the report prepared by Nagata (1988) for Group 70. For consistency and cross reference, the scientific names used in the Nagata report, which is based on St. John's 1973 checklist, are followed although a more recent taxonomic treatment is available.

Vegetation along the banks of the lower one-half of Paumalu Stream consists of Christmas berry scrub (*Schinus terebinthifolius*), 10 to 20 ft. tall, with emergent Java plum trees (*Eugenia cumuni*). Scattered trees and shrubs of Formosan koa (*Acacia confusa*) and guava (*Psidium guajava*) are occasional along the streamside. Along the upper one-half of Paumalu Stream, Java plum and Formosan koa quickly drop out and the scrub becomes a dense Christmas berry tangle. A few blocks of forestry plantings of swamp mahogany (*Eucalyptus robusta*) and a large banyan species (*Ficus* sp.) with pale green leaves and pink fruit are found on the banks bordering the stream and extend upslope for some distance.

Because of the moisture growing conditions along the streamside, the Christmas berry shrubs and associated tree species form a dense cover. The ground below tends to be heavily shaded and supports very sparse vegetation consisting of scattered clumps of more shade-tolerant species as Hilo grass (*Paspalum conjugatum*), basket grass (*Oplismenus hirtellus*), downy wood fern (*Christella parasitica*), and laua'e (*Microsorium scolopendrium*). Seedlings of Java plum are numerous. Barren, red clay hard-pan, rounded boulders, and piles of debris (branches and leaves) typify the streamside on this portion of the property. Also during heavy rains, the streamsides are periodically swept clean of vegetation.

Along most of Kaleleiki Stream, the vegetation is a dense tangle of Christmas berry scrub. On its upper reaches, stands of strawberry guava (*Psidium cattleianum*), 10 to 20 ft. tall, with an understory of Koster's curse (*Clidemia hirta*) become the dominant components. Again ground cover along the streamsides is sparse with bare soil, rocks, and litter characteristic.

DISCUSSION

The vegetation is typical of most lower elevation, disturbed

streams in the Hawaiian Islands. Both Paumalu and Kaleleiki streams are dominated with Christmas berry, along with scattered plants of Java plum and guava, along most of their length. The upper portion of Kaleleiki Stream supports a dense strawberry guava/*Clidemia* scrub.

Three criteria must be met for an area to be identified as a wetland. It must have hydrophytic vegetation, hydric soils, and wetland hydrology; all three condtions must be present. We did not encounter any areas dominated by hydrophytic vegetation nor did we find any areas with anaerobic soil conditions. Nagata (1988) also did not note any wetlands during his survey of the entire property.

Physically, the Paumalu and Kaleleiki streams do not broaden out on the property, thus providing areas where soil and organic matter may be unloaded, accumulate, and wetland species take root.

Rferences

Nagata, K. H. 1988. Botanical survey, Sunset Beach - Paumalu, Pupukea, Oahu. Prepared for Group 70, Honolulu. January 1988.

St. John, H. 1973. List and summary of the flowering plants in the Hawaiian Islands. Pacific Tropical Botanical Garden Memoir No. 1, Lawai, Kauai.

APPENDIX L

Terrestrial Vertebrates of the Ohbayashi Project, Pupukea, Oahu

By Andrew J. Berger

This study was prepared on instructions received from Ralph Portmore of Group 70, Honolulu, Hawaii. For our initial site visit, I met Mr. Portmore at Sunset Beach on December 22, 1987. In a 4-wheel drive vehicle, he then drove Gordon Dugan, Ron Darby, Frank Scott, and me throughout the proposed project area. Additional observations were made on foot at a later date.

This study presents information on the terrestrial vertebrates (amphibians, reptiles, birds, and mammals) of the project area and adjacent lands.

The Habitat

As in most regions of Oahu, the vegetation in the project area has been disturbed for more than 100 years. The vast majority of the vegetation in the area is introduced or alien to the Hawaiian Islands. The dominant vegetation in all of the numerous gulches was Common ironwood (_Casuarina equisetifolia_). Other introduced tree species are Christmas berry (_Schinus terebinthfolius_), eucalyptus (_Eucalyptus_ sp.), and guava (_Psidium guajava_). The vegetation also contains numerous shrubs, vines, and grasses that are foreign to the islands. There is no semblance of an endemic or native ecosystem anywhere near the proposed project site. Therefore, there are no endangered Hawaiian forest birds in the project area.

Amphibians and Reptiles

There are no endemic amphibians or land reptiles in the Hawaiian Islands. All, therefore, have been introduced by man.

I. _Amphibians_

1.Giant Neotropical Toad (_Bufo marinus_). This toad was first introduced to the Hawaiian Ialnds in 1932 "when Dr. C. E. Pemberton brought 148 adult toads from Puerto Rico. Eighty of these were liberated in a taro patch near Waipio, Oahu, and 68 were released in a swampy part of Manoa Valley" (Oliver and Shaw, 1953:77). The toads were very successful, and "in a little over two years more than 100,000 descendents of the original stock were distributed through Dr. Pemberton's activities throughout the islands." Hunsaker and Breese (1967) wrote that _Bufo marinus_ was the "commonest species of amphibian in Hawaii." I did not see any live toads, but saw one that had been smashed on the road.

2. American Bullfrog (_Rana catesbeiana_). "This was probably one of the first species of amphibians to be introduced into the Hawaiian Islands and may have been one of the frogs that was imported prior to 1867" (Oliver and Shaw, 1953). The frogs were abundant enough to be harvested commercially by 1900. Tinker (1941) wrote that "the University of Hawaii has organized 'frog clubs' to encourage the production of frogs for food." The species is not nearly so common now, presumably because of the drainage of so many wetland areas and, perhaps also, because of the widespread use of pesticides

during recent decades. I did not see or hear any bullfrogs during my daytime field studies, but they are very common in the Waimea valley stream nearby.

II. Reptiles

1. Blind Snake (Typhlops braminus). "This small, secretive snake was apparently introduced from the Philippines in the dirt surrounding plants that were brought in for landscaping the campus of the Kamehameha Boys School in Honolulu. It was first found there in January of 1930" (Oliver and Shaw, 1953). By 1967, Hunsaker and Breese wrote that "it now appears to occupy the lowland area over the entire island." These blind, worm-like snakes are rarely seen until they are flooded from their underground burrows by heavy rain or unless one looks for them under branches and other debris on the ground. I did not search for these snakes because they are of no significance for an impact statement.

2. Skinks and Geckos. Eleven species of skinks (Family Scincidae) and geckos (Family Gekkonidae) occur on Oahu. Some of the more common are the mourning gecko (Lepidodactylus lugubris), fox gecko (Hemidactylus garnoti), and the metallic skink (Lygosoma metallicus). All are foreign to the islands, all are insect eaters, and all adapt well to both urban and rural areas (McKeown, 1978). Their presence is irrelevant to an impact assessment.

The Birds

Three groups of birds are found in the Hawaiian Islands: 1. introduced or alien, 2. indigenous, and 3. endemic. The vast majority of the birds to be found in the project area are introduced species.

I. Introduced Birds.

More than 170 species of alien birds have been intentionally introduced to the Hawaiian Islands (Berger, 1981). The following have been reported in the Pupukea region.

A. Order Ciconiiformes

a. Family Ardeidae, herons and egrets

1. Cattle Egret (Bulbucus ibis). This species was imported to Hawaii from Florida to aid "in the battle to control house flies, horn flies, and other flies that damage hides and cause lower weight gains in cattle" (Breese, 1959). A number of birds were released on Oahu in 1959 and 22 additional birds were released during July 1961. Thistle (1962) reported that the population of Cattle Egrets on Oahu exceeded 150 birds by July 1962. The population has increased greatly since that time. Personnel of the State Division of Forestry and Wildlife counted 621 egrets on Oahu during their January 1986 census (Walker et al., 1986); 988 egrets were reported on the Honolulu Christmas count of the Hawaii Audubon Society (Pyle, 1987); 386 egrets were reported in the Waipio sector alone during the same period (Bremer, 1987). Cattle Egrets are common throughout the project region.

B. Order Columbiformes

a. Family Columbidae, pigeons and doves

2. Rock Dove or feral Pigeon (Columba livia). The pigeon probably was the first exotic bird to be introduced to the Hawaiian Islands; their importation has been traced back to 1796. Schwartz and Schwartz (1949) found heavy parasitism of feral pigeons by tapeworms, and they stated that the tapeworm infestation retards proper nutrition and "occludes the intestine, produces undesirable toxins, and hinders breeding." Navvab Gojrati (1970) reported infection by bird malaria, Haemoproteus, and Leucocytozoon in birds at the Honolulu Zoo. Kishimoto and Baker (1969) reported finding the fungus Cryptococcus neoformans in 13 out of 17 samples of pigeon droppings collected on Oahu. The full significance of their findings has not been determined, but in man this fungus causes a chronic cerebrospinal meningitis; Hull (1963:468) remarked that "in all but the cutaneous forms the prognosis is very grave." At least one flock of pigeons inhabits the project area.

3. Spotted or Lace-necked Dove (Streptopelia chinensis). Also called the Chinese Dove, this Asian species was released in the Hawaiian Islands at an early date; the exact date is unknown, but the birds are said to have been very common on Oahu by 1879. Although this species does occur where the rainfall exceeds 100 inches per year, the highest densities are found in drier areas, especially where the introduced kiawe or mesquite is one of the dominant plants. Schwartz and

Schwartz (1949), for example, reported densities as great as 100 birds per square mile in dry areas on Molokai. This dove is common throughout the Pupukea region.

4. Barred or Zebra Dove (Geopelia striata). This dove is native to Australia and the Orient. The species is said to have been introduced to Hawaii sometime after 1922 (Bryan, 1958). It now is abundant on all of the islands. This dove also prefers the drier areas. Schwartz and Schwartz (1949) reported densities as high as 400 to 800 birds per square mile in some areas on Oahu: for example, Barber's Point to Makaha. This dove is very common throughout the project site and the Pupukea region.

The Barred Dove also is classified as a game bird in Hawaii. One study of the food habits in Hawaii revealed that the diet consists of 97 percent seeds and other plant materials the 3 percent animal matter included several species of beetles, weevils, and wireworm larvae.

C. Order Strigiformes

a. Family Tytonidae, Barn Owls

5. Barn Owl (Tyto alba pratincola). The first Barn Owls were imported from California and released on Hawaii island during April 1958. Barn Owls were released at Hauula, Oahu, on two different occasions. Seven birds were imported from the San Diego Zoo and released during September 1959; 11 additional birds were imported from the San Antonio Zoo, Texas, and released at Hauula during October 1959 (Tomich, 1962).

As with the mongoose during the last century, the Barn Owl was introduced in the hope that it would prey on the abundant rats that were damaging sugarcane. No food habits study has been conducted on Oahu, but on Hawaii Tomich (1971) found that almost 90 percent of Barn Owl pellets contained only the remains of house mice. Tomich commented that, although the Barn Owl sometimes feeds on rats, it is not likely a significant factor in the economic control of rats in Hawaii. Moreover, Byrd and Telfer (1980) reported that Barn Owls had killed more than 100 seabirds and their chicks on Kauai and Kaula Rock.

No study of the spread of the Barn Owl from the Hauula region since 1960 has been conducted, but the birds have been seen or found dead or injured in both the windward and leeward sections of Oahu. This owl is nocturnal in habits, and I did not see any during my daytime field studies. The birds are known to inhabit the Waimea Valley just over the ridge from Pupukea, and they undoubtedly occur in the project area.

D. Order Passeriformes

a. Family Timaliidae, babblers

6. Melodious Laughing-thrush (Garrulax canorus) Long called the Chinese Thrush or Hwa-mei in Hawaii, this species is not a thrush (family Turdidae) but is a babbler. It was introduced to the islands from China or Formosa as a cage bird many years ago. "A number obtained their freedom at the time of the great fire in the Oriental quarter of Honolulu in 1900, and took to the hills behind the city" (Caum, 1933). This

babbler is found in both the Koolau and the Waianae mountains. In general, it prefers the wetter areas where there are thickets and clumps of dense vegetation. The birds have a loud, attractive song, and they more often are heard than seen. This species is a resident of the project area.

b. Family Pycnonotidae, Bulbuls

7. Red-vented Bulbul (Pycnonotus cafer). Although all members of this family are listed as "prohibited entry" by the State Quarantine Division of the Department of Agriculture, two species of bulbuls are now well established on Oahu. The history of the spread of the Red-vented Bulbul since the mid-1960s has been discussed by Berger (1975, 1981) and Williams (1987); the status of the Red-whiskered Bulbul (P. jocusus) has been discussed by van Riper, van Riper, and Berger (1979). The Red-vented Bulbul now inhabits the Pupukea region. The birds are a scourge to fruit and flower growers. The birds eat buds, flowers, and ripe fruits of many kinds.

c. Family Turdidae, Thrushes and Bluebirds

8. White-rumped Shama (Copysychus malabaricus). Shama is the Indian name for this very attractive thrush, which is native to India, Nepal, Burma, Malaysia, and throughout Indochina. The Hui Manu imported Shamas in 1940 and released them in Nuuanu Valley "and at some homes in the 2400 block on Makiki Heights road" (Harpham, 1953). The Shama is now common on both the windward and leeward sides of Oahu. The birds prefer lush vegetation, and I heard several birds singing during my December field studies.

d. Family Zosteropidae, White-eyes and Silver-eyes.

9. Japanese White-eye (<u>Zosterops japonicus</u>). Long a favorite cage bird in the Orient, this species was first introduced by the Territorial Board of Agriculture and Forestry in 1929 (Caum, 1933). Later importations were made by the Hui Manu and by individuals. The Japanese name is Mejiro, and Mejiro clubs held singing competitions with these birds. The White-eye has been a remarkably successful introduction and this species undoubtedly is now the most abundant song bird in the Hawaiian Islands. These birds occur from sea level to 10,000 feet elevation on Maui and Hawaii. They inhabit near desert conditions (e.g., Kawaihae, Hawaii) and those with an annual rainfall exceeding 300 inches. The White-eye is very common throughout the project area.

e. Family Sylviidae, Old-world Warblers

10. Japanese Bush Warbler (<u>Cettia diphone</u>). This warbler, which is native to Japan and Formosa, was first released on Oahu in 1929 (Caum, 1933). The Japanese name is Uguisu. Berger (1975b) summarized our knowledge of the distribution of this species on Oahu. These are shy and secretive birds, typically occurring in habitats with dense underbrush. Their song period lasts from about January to mid-July. I did not see or hear any Bush Warblers during my late December field studies, but I have seen the species in this region in the past.

f. Family Sturnidae, Starlings and Mynas

11. Common Indian Myna (<u>Acridotheres tristis</u>). The Common Myna, which is native to Sri Lanka, India, Nepal, and adjacent regions, "was introduced from India in 1865 by Dr. William Hillebrand to combat the plague of army worms that was ravaging the pasture lands of the islands. It has spread and multiplied to an amazing extent; reported to be abundant in Honolulu in 1879, it now is extremely common throughout the Territory" (Caum, 1933). The Myna is still common to abundnat in lowland areas of all islands, being most common in residential and urban areas, as well as in the vicinity of human habitation in rural areas. It is a common bird throughout the Pupukea region.

g. Family Ploceidae, Weaverbirds and their Allies

This is a large family of Old-world birds. The best known example in Hawaii is the House Sparrow. However, since the mid-1960s more than 15 different species of this family have been intentionally or accidentally released on Oahu (<u>Elepaio</u>, 1966:79; 1973:81-82). A number of species have established wild populations in the Kuilima region and undoubtedly will spread from there.

12. Nutmeg Mannikin or Ricebird (<u>Lonchura puntulata</u>). Also called the Spotted Munia, this Asian species was released in Hawaii by Dr. William Hillebrand about 1865 (Caum, 1933). Caum wrote that the ricebird "feeds on the seeds of weeds and grasses and does considerable damage to green rice." Rice

is no longer grown in Hawaii, but the Ricebird has become a serious pest again by eating the seeds of experimental crops of sorghum (to be discussed under House Finch). The Nutmeg Mannikin is another abundant species on all of the islands, and is widespread in the Pupukea region.

13. House Sparrow (*Passer domesticus*). The House Sparrow (erroneously called the English Sparrow) was first imported to Oahu in 1871, when nine birds were brought from New Zealnad (where the species had previously been brought from England). Caum (1933) wrote that "whether or not there were further importations is not known, but the species was reported to be numerous in Honolulu in 1879." In North America, the House Sparrow (first introduced to Brooklyn, New York, in 1852) became a serious pest and tens of thousands of dollars were spent in attempting to control the population (Dearborn, 1912). This sparrow apparently never became a pest in Hawaii. It is omnivorous in diet, eating weed seeds as well as insects and their larvae. House Sparrows are common around man's buildings and in outlying areas, including the Pupukea region.

h. Family Fringillidae, Cardinals and New-world Sparrows.

14. Red-crested Cardinal (*Paroaria coronata*). Although this species traditonally has been called the Brazilian Cardinal in Hawaii, the species has a much larger native range in Uruguay, Paraguay, Brazil, and parts of Bolivia and Argentina. This cardinal was released in Hawaii on several occasions between

1929 and 1931 (Caum, 1933). The species is common on lowland areas, and is a characteristic bird of the leeward section of Oahu, finding the dry, introduced vegetation suitable habitat for its annual cycle. It is a common bird in the Pupukea region.

15. Cardinal (*Cardinalis cardinalis*). This species has been given a number of venacular names: for example, Virginia Cardinal, Kentucky Cardinal, Kentucky Redbird. Its native range is the eastern part of North America, east of the plains and northward into Ontario. The Cardinal was released several times in Hawaii between 1929 and 1931 (Caum, 1933). The species is common in lowland areas and is a characteristic bird in leeward Oahu, finding the introduced vegetation suitable for its annual cycle. The Cardinal tends to inhabit forested areas and at higher elevation than does the Red-crested Cardinal. It is common in the Pupukea region.

16. House Finch (*Carpodacus mexicanus frontalis*). Also known as the Papaya Bird in Hawaii, the House Finch was introduced from California "prior to 1870, probably from San Francisco" (Caum, 1933). The House Finch is now an abundant species on all of the islands, in both rural and urban areas, and probably is the second most common song bird species in the islands. Although the birds sometimes eat overripe papaya and other soft fruits, the House Finch is predominantly a seed-eater. House Finches and Ricebirds caused great damage to experimental sorghum crops planted on Kauai and Hawaii during 1971-1972.

"A report by the Senate Committee on Zoology, Environment, and Recreation says ricebirds and linnets [House Finch] caused a 30 to 50 percent loss in the sorghum fields at Kilauea on Kauai last year. . . . Seed-eating birds at Kohala ate about 50 tons of sorghum grain in a 30-acre experimental field that was expected to produce 60 tons" (Honolulu Advertiser, March 14, 1972, page B-2). Hence the growing of small grain crops in the islands is not a promising potential for the much talked about "diversified agriculture" in the State. Other seed-eating birds have become established on one or more of the islands during the past 15 or 20 years. The House Finch is widely distributed in the Pupukea region.

17. Gallinaceous Birds (Order Galliformes, Family Phasianidae, Family Numididae). I add this section because a number of gallinaceous species have been intentionally released at Waimea Falls Park, and it is possible that some of these birds may have strayed into the Pupukea area. These birds include the following: Red Jungle Fowl (Gallus gallus), Swinhoe's Pheasant (Lophura swinhoei), Ring-necked Pheasant (Phasianus colchicus), Silver Pheasant (Lophura n. nycthemera), Chukar Partridge (Alectoris chukar), and the Common Guineafowl (Numida meleagris).

II. Indigenous Birds

These are species that are native to the Hawaiian Islands but whose total range also includes other islands in the Pacific Basin or North America. These are the

Black-crowned Night Heron, 22 species of seabirds, and a number of migratory species that nest in North America or Siberia and which spend their winter or nonbreeding season in the islands.

A. Order Ciconiiformes

a. Family Ardeidae, Herons and Egrets

1. Black-crowned Night Heron (Nycticorax n. hoactli). This subspecies has a breeding range that includes Hawaii and the Western Hemisphere from Washington and Oregon southward to northern Chile and south-central Argentina. Because the Hawaiian birds are considered the same subspecies as the mainland birds, the species is not classified as an endangered species, even though the future of the species in Hawaii depends on the preservation of suitable wetland areas. Herons inhabit marshes, swamps, and streams. They feed on a wide variety of aquatic and terrestrial life: e.g., fish, frogs, crayfish, mice, and insects. In Hawaii, at least, this heron also eats the downy young of seabirds and probably the downy young of the endangered Hawaiian waterbirds. They also relish prawns and the State Land Board gave prawn producers a "120-day permit to destroy black-crowned herons which have been causing economic havoc at Oahu's Kahuku prawn farm as well as other aquaculture farms statewide" (Honolulu Star-Bulletin, October 26, page A-8 and October 30, 1985, front page). There is no foraging habitat for this heron in the project region, but there is a population of herons along Waimea stream.

B. Seabirds

1. White-tailed Tropicbird (<u>Phaethon lepturus dorotheae</u>)

This is the only one of the seabirds that needs to be mentioned because it does nest on the cliffs that bound Waimea Valley. There appears to be no nesting habitat for this tropicbird in the Pupukea project area, however.

C. Migratory Species.

The most conspicuous of these is the Lesser Golden Plover (<u>Pluvialis dominica fulva</u>), which occurs from sea level to elevations of nearly 10,000 feet on Maui and Hawaii during the winter season. This plover frequents lawns in residential areas, golf courses, weedy pastures, open areas in the mountains, mud flats, and cane haul roads. Plovers were common along the dirt road through the project area, and I saw one flock of nine birds.

The other migratory species are restricted to mud flats, ponds, or mountain streams. I did not see any in the project area, nor would I expect to see them there.

III. <u>Endemic Birds</u>

These are birds that are restricted to the Hawaiian Islands; they are unique to the islands. At lease 40 percent of these unique birds already are extinct, and another 40 percent are now classified as rare or endangered. Most of these endangered species are forest birds and very few are left on Oahu. There are none in the project area or near it.

Three species of endangered Hawaiian waterbirds occur in Waimea Valley: Koloa or Hawaiian Duck (<u>Anas wyvilliana</u>),

Hawaiian Gallinule or 'Alae 'Ula (<u>Gallinula chloropus sandvicensis</u>), and Hawaiia Coot or 'Alae Ke'oke'O (<u>Fulica americana alai</u>). There is, however, no suitable habitat for these waterbirds in the project area.

Pueo or Hawaiian Owl (<u>Asio flammeus sandwichensis</u>). This is a permanent resident on all of the inhabited islands in the Hawaiian chain. The birds are tolerant of wide climatic conditions (Richardson and Bowles, 1964). The Division of Forestry and Wildlife considers the Pueo to be an endangered species on Oahu, but not on the other islands. The Pueo differs from most other owls in that it is diurnal in habit; hence, they are seen much more often than is the nocturnal Barn Owl. Scott <u>et al</u>. (1986) wrote that the Pueo "was most often seen in grasslands, shrublands, and montane-parklands." This owl, indeed appears to be rare on Oahu. None were seen on the 1986 Christmas Count of the Hawaii Audubon Society (Pyle, 1987), although two birds were seen in Waipio area and one bird along Palehua Road on December 22, 1986 (Bremer, 1987). I did not see any Pueo during my field studies. However, one bird was found dead in Waimea Valley several years ago.

The Mammals

I. <u>Endemic Mammals</u>

The only endemic land mammal in the Hawaiian Islands is the Hawaiian bat (<u>Lasiurus cinereus semotus</u>), a subspecies of the North American hoary bat. The Hawaiian bat occurs primarily on the islands of Kauai and Hawaii (Tomich, 1969;

Kramer, 1971; Ten Bruggencate, 1983). I know of no evidence that there is a resident population of the bat on the island of Oahu.

II. Introduced Mammals

All of these introduced species of mammals in Hawaii have proven to be highly destructive to man, his buildings, products, or agricultural crops and/or to the native forests and their animal life. None is an endangered species and none is of any concern as far as detrimental effects resulting from this, or any other, proposed project. It would, in fact, be a great boon to the islands if it were possible to exterminate all of them.

With the possible exception of the house mouse (*Mus musculus*), all of the smaller alien mammals prey on birds, their eggs, and young. These small mammals include the roof rat (*Rattus rattus*), Polynesian rat (*Rattus exulans*), Norway rat (*Rattus norvegicus*), and the small Indian mongoose (*Herpestes auropunctatus*), as well as feral cats (*Felis catus*) and feral dogs (*Canis familiaris*).

The mongoose is diurnal in habits, and I saw several during my field surveys. Because the rodents are serious pests, I did not set night traplines in order to sample the population. It is reasonable to assume that all of them occur in the project area (Tomich, 1969; Kramer, 1971).

The Polynesian ancestors of the Hawaiians brought with them pigs (*Sus scrofa*), and Captain James Cook and later ship captains released English pigs on the islands. In 1925, the central forest of Oahu was "riddled with wild pigs which

were destroying the undergrowth." In writing about the Kilauea Forest on the island of Hawaii, Mueller-Dombois, *et al*. (1981) noted that this was "the best intact example of this forest type remaining in the state" and that "the effect of feral pig is very noticeable, and there is little doubt that the widespread pig digging in the Kilauea forest has been a major factor in reducing the native ground vegetation." I did not happen to see any pigs during my daytime field studies but pigs are common in the upper part of Waimea Valley and probably occur in the upper stretches of the Pupukea forests.

Summary and Conclusions

1. Because of the destruction of the native vegetation in the mountains on Oahu by cattle, goats, and pigs, the Hawaiian Government appropriated $12,000 for tree planting in 1882. The first forest reserve was established in 1903. L. W. Bryan (1947) said that 1,057 different species of exotic plants were tested in arboreta on the island of Hawaii during the period of 1921-1946. And, St. John (1973) lists 4,643 different species of exotic flowering plants (trees and shrubs) that have been introduced to the Hawaiian Islands. This explains the numbers of exotic trees, shrubs, ferns, and grasses that now grow in the Pupukea project area. This introduced vegetation does not provide suitable habitat for any of the endemic forest birds. Any disturbance to any of this vegetation would be irrelevant.

2. All of the amphibian and land reptiles that occur

in the project area are introduced animals, none is a rare or endangered species, and all are irrelevant to any environmental impact statement.

3. None of the 16 species of introduced birds found in the proposed project area is an endangered species and a number of them have proven to be serious pests in Hawaii. The destruction of sorghum crops by the Ricebird and the House Finch already has been discussed. The doves and the Myna have been implicated in spreading the seeds of such noxious weed plants as Lantana camara. The Red-vented Bulbul and the Japanese White-eye cause considerable damage to ornamental flowers and to fruit crops (Keffer, et al., 1976). The Barn Owl is known to eat birds and their young on Kauai and Kaula Rock, and probably on the other islands. To be sure, some of the introduced species apparently cause no damage to crops or to the endemic forest birds, and they do provide pleasure for many people. However, development, including landscaping, would still provide habitat for many of the introduced species that occur in rural and urban areas.

4. Although the White-tailed Tropicbird and the Black-crowned Night Heron are found in Waimea Valley, there is no habitat for them in the Pupukea project area. In fact, if ponds are constructed in the golf courses, the heron might well adapt to them for feeding and resting.

5. The Lesser Golden Plover now occupies the nonforested

portion of the Pupukea project area. It would continue to spend winters on the golf courses that are proposed for this development.

6. There is no habitat for the endangered waterbirds that are found along the stream in Waimea Valley.

7. I know of no recent observations of the Pueo or Hawaiian Owl in the project region. The habitat there is not suitable for this diurnal owl. In fact, construction of two golf courses might provide foraging habitat for this owl.

8. All of the mammals that occur in the project region are introduced or alien mammals. Many of them are predators on birds, their eggs or young, and most of them are destructive to agriculture and to forest lands and/or to man, his buildings and products. None of these mammals is of any significance for an environmental impact statement.

9. In conclusion, therefore, one can assert strongly that the proposed project would have absolutely no adverse effects on any native ecosystem and on the endemic animals that inhabit such ecosystems. There is no native ecosystem anywhere near the proposed project. With respect to such native ecosystems, therefore, one can readily classify the entire area as a "waste land."

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Preliminary Survey of four streams: Paumalu, Kaleleiki, Pukulena, and Kalunawaikaala, located in the Pupukea Paumalu area of Oahu's North Shore.

by

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Introduction

A preliminary survey of four streams: Paumalu, Kaleleiki, Pukulena, and Kalunawaikaala, located in the Pupukea Paumalu area of Oahu's North Shore, was conducted from 27 March to 30 March, 1991. (See Figure 1.) These streams are reported to be intermittent (Hawaii Stream Assessment, 1980), flowing primarily during heavy rainfall. This survey was conducted following more than a week of heavy rainfall. Flows had decreased considerably by the time we began our survey. On Kaleleiki Stream (Site I), flow was merely a trickle (less than 0.5 meters across) but evidence of recent flow 8.5 meters across could be seen; and on Pakulena Stream (Site P) all that remained of the flow (estimated to be 7.11 meters wide) were small puddles in the mud.

Methods

A total of 20 sites, each chosen to reflect typical habitat in that region of the stream, were selected for sampling (See Figure 2). Substrate type, riparian cover, and width and depth of water were recorded at each site. Dip nets and a surber sampler were used to collect benthic invertebrates. Samples were collected both from the water and the substrate below the water. Post-larval gobies were noted through visual observations and collected from three sampling sites for confirmation of species identification.

Flow Characteristics

Of the streams surveyed, Paumalu Stream was the only one with water flowing continuously throughout the survey area (See Figure 3). The upper limit of our survey on Paumalu Stream (Site K) was determined by dense forest and tree roots that prevented further movement upstream. Several human made rock walls were observed along the lower stream channel. The two tributaries to Paumalu Stream, Aimuu Gulch and Kaleleiki Stream consisted primarily of mud with small pools of water. Kaleleiki Stream was completely dry from below Site J to where it joins Paumalu Stream (and is nearly impassable due to thick vegetation).

The lower portion of Pakulena Stream was mostly mud and small pools while the upper portion flowed continuously. A large landslide had recently occurred between Sites A and B and the stream was full of debris, although water still flowed through. Kalunawaikaala Stream was essentially dry during this survey, with some mud and pools in the upper and lower reaches.

Sampling Results

Nine sampling sites were chosen on Paumalu Stream and one (Site Q) on its tributary, Aimuu Gulch. Gobies were collected at Site P, Site R, and Site S (See Figure 4). Benthic samples for invertebrates were collected at the remaining sites. Four samples were taken from Kaleleiki Stream, also a tributary to Paumalu Stream. On Paukulena Stream five sampling sites were chosen. No samples were taken on Kalunawaikaala Stream as there was insufficient water.

Site Q, Aimuu Gulch. This site is as far upstream as we were

able to survey on Aimuu Gulch because of dense vegetation. The area was very overgrown, with riparian cover 85%. Water in this area consisted of shallow pools and some trickle flow. In the pools the water was barely moving, was cloudy in color, and appeared stagnant. The substrate of the channel was large boulders and rocks. At our sampling site the pool was 1.92m wide and 10cm deep. A large toad was observed just downstream of Site Q, but no insects or other invertebrates were found in the benthic sample.

Site K, Paumalu Stream. Riparian cover was 100%, with the canopy 1 to 3 meters above the stream. The substrate was mud, roots, and fallen branches. At Site K the stream width ranged from 1.18m to 4.75m, with an average depth of 16cm. The deepest spot at this site was 68cm. Thiarid snails and amphipods were collected in the benthic sample.

Site L, Paumalu Stream. Site L is near the upper boundary of the property. Riparian cover was approximately 80% and the canopy relatively low. Water flowed over two cascades at this site. Large boulders and roots of a large tree in the middle of the flow made up the substrate. The width of the stream was 3.6m, the height of the first cascade, 0.75m and the height of the second cascade, 1.5m. Average stream depth at this site was 23cm. No organisms were found in the benthic sample.

Site M, Paumalu Stream. Riparian cover at Site M was 75%. The substrate consisted mostly of dirt with rocks, boulders, and roots interspersed. The width of the stream channel in this area was 2.2m and the water was 30cm deep. Amphipods and the introduced riparian Cynidae, Geotomus pygmaeus, were observed at Site M.

Site N. Paumalu Stream. At Site N the riparian cover was 50%, and the stream banks low and flat. The substrate was hard mud with roots and branches also on the stream bed. The water was shallow (17cm) and flowing quickly. Width of the stream in this area was 2 meters. No organisms were found in the benthic samples.

Site O. Paumalu Stream. Site O had low sloping banks, and many branches had fallen over the stream channel. Riparian cover was 75%. Stream substrate consisted of large boulders, rocks, and mud. Width of the water was 2.41m and depth was 20cm. The only organism collected at this site was the introduced riparian Cynidae, Geotomus pygmaeus.

Site P, R, and S: Paumalu Stream. Post-larval gobies were observed in the lower portion of Paumalu Stream (See Figure 4). Gobies (Sicyopterus stimpsoni) were collected at Sites P, R, and S. All gobies collected or observed were less than 2cm standard length. Site R was typical of the habitat in which gobies were observed. The substrate had many large boulders which the gobies perched on (8 to 10 gobies per boulder were observed). The water was 4m wide at Site R and 1m deep. At Site P, the water was 2.5m wide and 0.75m deep.

Site T. Paumalu Stream. The jeep trail crosses Paumalu Stream at Site T. Riparian cover in this area was 60%. Substrate consisted of boulders, roots, and dirt. The width of flowing water was 2.32 meters and the depth was 17cm. No organisms were found in the benthic sample at this site.

Site F. Kaleleiki Stream. Site F is the uppermost point surveyed on Kaleleiki Stream. Riparian cover was 60% at Site F and the substrate consisted of gravel and dirt. Stream width here was 1.28 meters and depth was 17cm. The only organisms collected at this site were flatworms.

Site G. Kaleleiki Stream. At Site G there was a small cascade (1.5 meters) falling into a small deep pool (depth, 94cm; diameter, 3.1m). Riparian cover was 75% in this area and the canopy was very low. Recently fallen leaves covered the bottom of the pool. Benthic organisms found at this site included amphipods, isopods, thiarid snails, and tadpoles.

Site H. Kaleleiki Stream. This site was located just upstream of the jeep trail. Riparian cover here ranged from 25% to 50%. Water was mostly small isolated pools surrounded by mud. Substrate consisted of mud, dirt, and gravel. Width of the pool at the sampling site was 1.2m and depth of water was 5.75cm. Thiarid snails were collected at this site.

Site I and Site J. Kaleleiki Stream. Below the jeep trail which crosses Kaleleiki Stream, flow is minimal. Water was primarily small isolated pools surrounded by mud. The introduced riparian Cynidae, Geotomus pygmaeus was collected in this area. Below Site J, the stream dries completely and vegetation is very thick.

Site A. Pakulena Stream. Site A is at the headwaters of Pakulena Stream. Riparian cover here was thick (90%), with tall trees, vines and branches crossing the stream channel. Substrate of the stream channel was hard mud. A small waterfall was formed by bedrock and tree roots. The pool below the waterfall was 1.3 meters wide and 40cm deep. Water flowed out of the pool and downstream in a trickle (30cm wide, 2cm deep). Organisms collected at this site included the introduced riparian Cynidae Geotomus pygmaeus, an endemic Veliidae (Microvelia vagans), an endemic Dytiscidae (Rhantus pacificus), the introduced mayfly Caenodes nigropunctatus, flatworms, and thiarid snails.

Site B, Pakulena Stream. Upstream of Site B on Pakulena Stream is a large landslide. Downstream of Site B, flow ceases to be continuous. At Site B, riparian vegetation was very dense (100% cover) and the canopy low. The stream channel is narrow with high steep banks, and substrate is mud on bedrock. Width of the water here was 90cm and depth was 10cm. No organisms were found from the benthic sample at this site.

Site C, Pakulena Stream. Site C was a little puddle of water. Riparian cover here was minimal (0%). The substrate was grass and mud. No organisms were found in the benthic sample.

Site D and Site E, Pakulena Stream. Very little water remained in the lower reaches of Pakulena Stream. Isopods were collected from a small pool of standing water at Site D. Isopods and the endemic Dytiscidae Rhantus pacificus were found in the benthic sample at Site E.

Discussion

Hawaiian stream gobies have an amphidromous life cycle

(McDowall,1988). Eggs are laid in the stream, larvae then hatch and wash out to sea. After spending a larval phase as marine plankton, the post-larvae return to the streams where they spend the remainder of their life cycle (Kinzie, 1988). Gobies appear to base return migrations from the sea by cuing on the high flows that occur during spates (Manacop,1953; Erdman,1968; Kinzie and Ford, 1982). In order for a viable population of gobies to become established, the fish must have access between the stream and sea.

The Sicyopterus stimpsoni that we observed in Paumalu Stream during this survey may have responded to the fresh water flowing into the ocean from Paumalu Gulch. There are two probable outcomes for these post-larval gobies. One, the stream channel will dry up and the gobies will perish, or two, the gobies may reach some permanent water in the upper portion of the stream where, given that adequate food is available and other requirements are met, they could survive through adulthood.

Summary

Benthic organisms collected from the Paumalu Watershed (Paumalu and Kaleleiki Stream) included isopods, amphipods, cynids (Geotomus pygmaeus), thiarid snails, flatworms, and tadpoles, Benthic organisms collected from the Pakulena Watershed included the organisms listed above, plus waterstriders (Microvelia vagans), beetles (Rhantus pacificus), and mayflies (Caenodes nigropunctatus). Post-larval gobies (Sicyopterus stimpsoni) were present in the lower reaches of Paumalu Stream, the only place they were observed during this survey.

As these streams are intermittent, water will be flowing primarily during heavy rainfall. Kalunawaikaala, and the lower portions of Pukalena and Kaleleiki were mostly mud and small evaporating pools just days after more than a week of heavy rainfall. It is possible however, that in the upper reaches of these streams some water remains throughout the year.

Acknowledgements

William Barnum provided assistance during the field survey. Dan Polhemus and Arnold Suzumoto generously assisted in species identification.

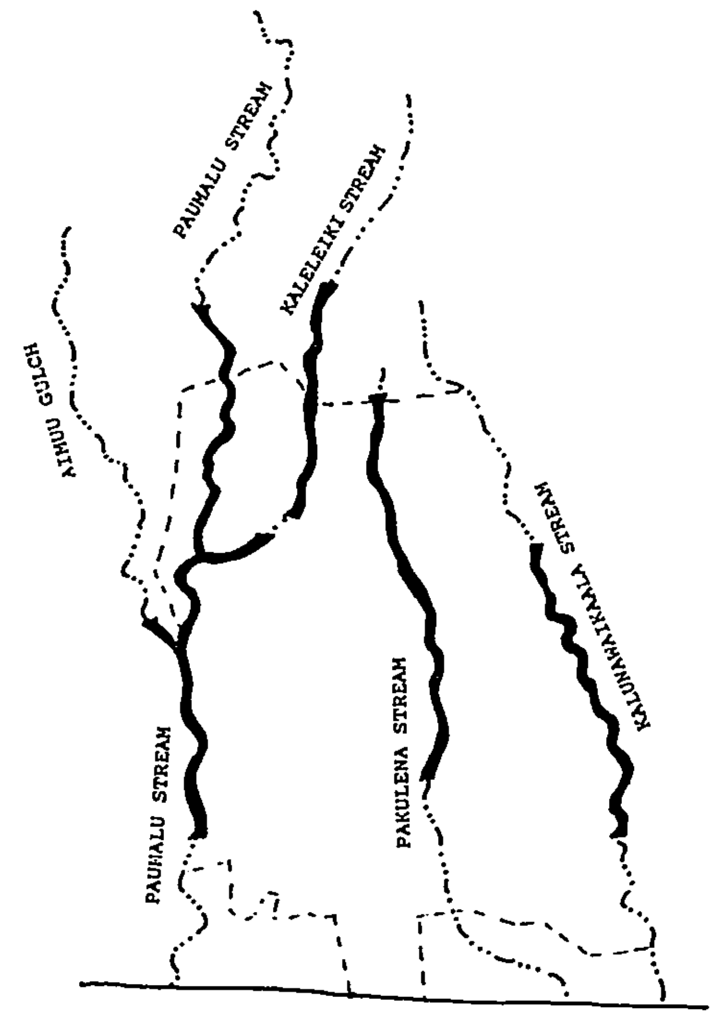

Figure 1. Area covered during survey (indicated by bold). Dashed line is property boundary.

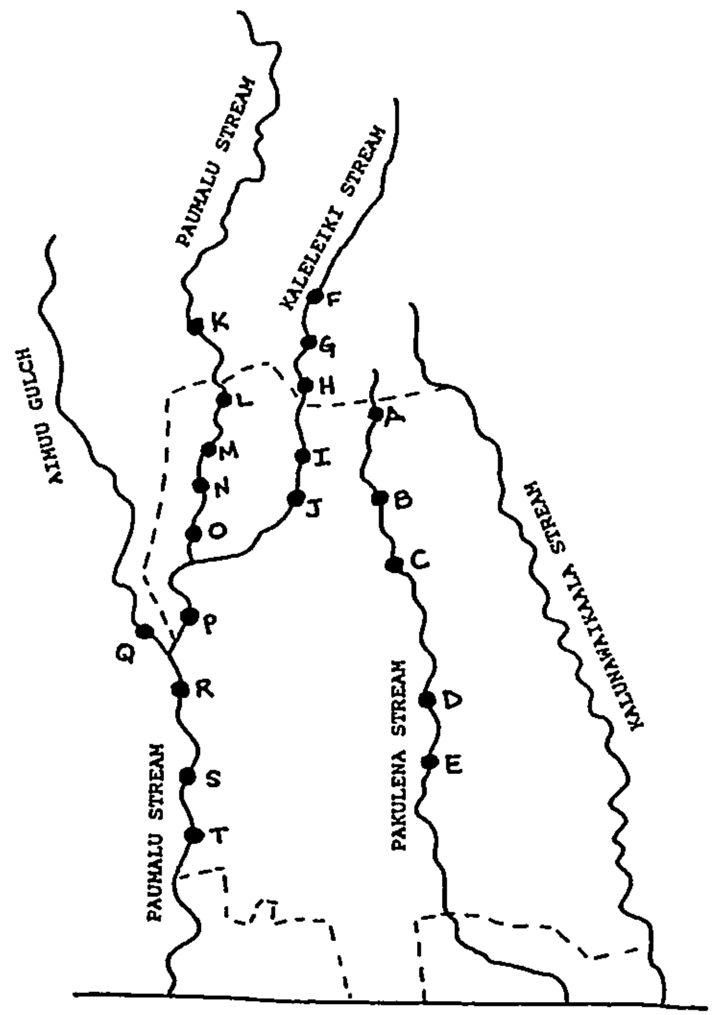

Figure 2. Sampling Sites. (Dashed line is property boundary.)

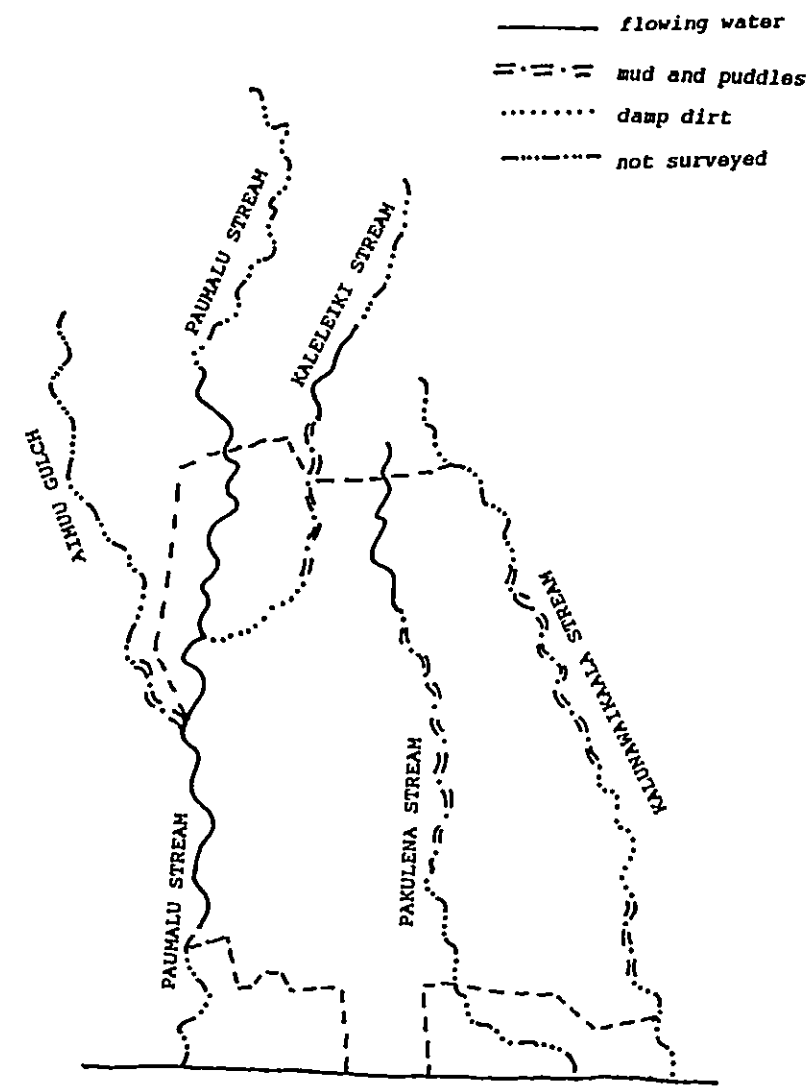

Figure 3. Flow characteristics. (Dashed line is property boundary.)

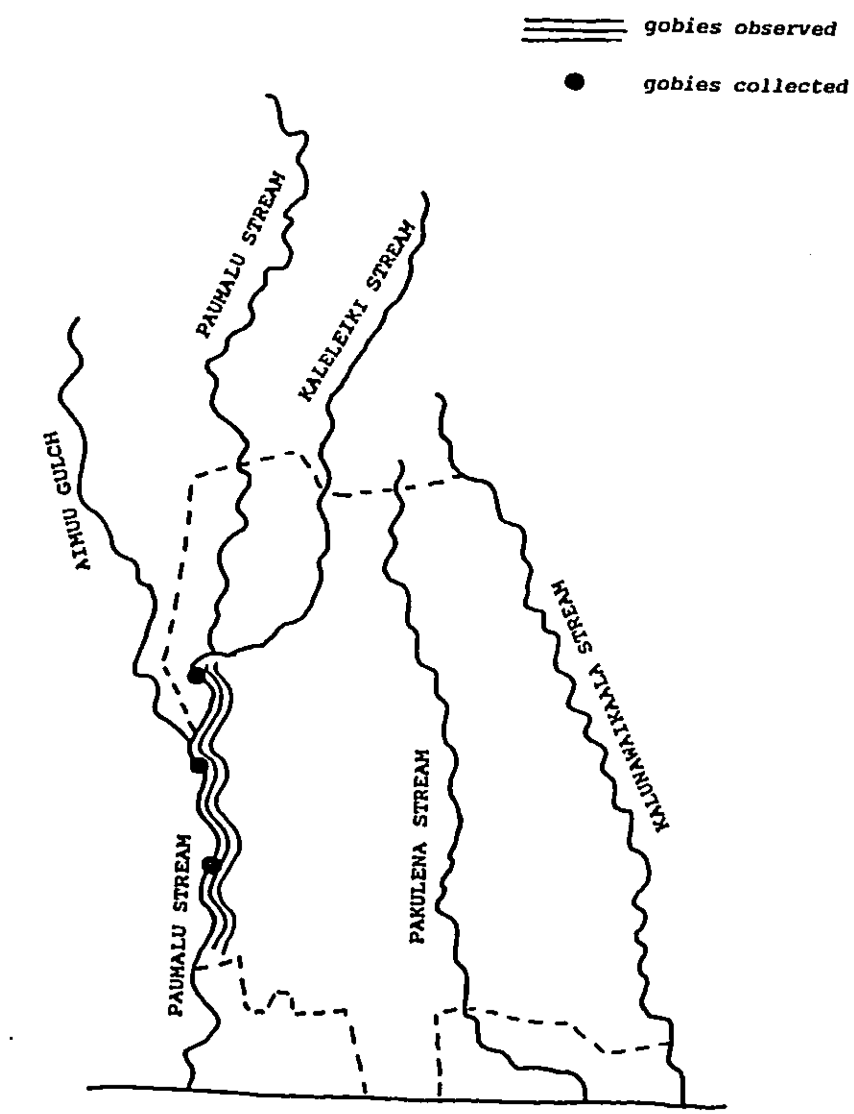

Figure 4. Location of post larval gobies. (Dashed line is property boundary.)

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Terrestrial Vertebrates of the Ohbayashi Project, Pupukea, Oahu

By Andrew J. Berger

This study was prepared on instructions received from Ralph Portmore of Group 70, Honolulu, Hawaii. For our initial site visit, I met Mr. Portmore at Sunset Beach on December 22, 1987. In a 4-wheel drive vehicle, he then drove Gordon Dugan, Ron Darby, Frank Scott, and me throughout the proposed project area. Additional observations were made on foot at a later date.

This study presents information on the terrestrial vertebrates (amphibians, reptiles, birds, and mammals) of the project area and adjacent lands.

The Habitat

As in most regions of Oahu, the vegetation in the project area has been disturbed for more than 100 years. The vast majority of the vegetation in the area is introduced or alien to the Hawaiian Islands. The dominant vegetation in all of the numerous gulches was Common ironwood (Casuarina equisetifolia). Other introduced tree species are Christmas berry (Schinus terebinthfolius), eucalyptus (Eucelyptus sp,), and guava (Psidium guajava). The vegetation also contains numerous shrubs, vines, and grasses that are foreign to the islands. There is no semblance of an endemic or native ecosystem anywhere near the proposed project site. Therefore, there are no endangered Hawaiian forest birds in the project area.

Amphibians and Reptiles

There are no endemic amphibians or land reptiles in the Hawaiian Islands. All, therefore, have been introduced by man.

I. Amphibians

1.Giant Neotropical Toad (Bufo marinus). This toad was first introduced to the Hawaiian Ialnds in 1932 "when Dr. C. E. Pemberton brought 148 adult toads from Puerto Rico. Eighty of these were liberated in a taro patch near Waipio, Oahu, and 68 were released in a swampy part of Manoa Valley" (Oliver and Shaw, 1953:77). The toads were very successful, and "in a little over two years more than 100,000 descendents of the original stock were distributed through Dr. Pemberton's activities throughout the islands." Hunsaker and Breese (1967) wrote that Bufo marinus was the "commonest species of amphibian in Hawaii." I did not see any live toads, but saw one that had been smashed on the road.

2. American Bullfrog (Rana catesbeiana). "This was probably one of the first species of amphibians to be introduced into the Hawaiian Islands and may have been one of the frogs that was imported prior to 1867" (Oliver and Shaw, 1953). The frogs were abundant enough to be harvested commercially by 1900. Tinker (1941) wrote that "the University of Hawaii has organized 'frog clubs' to encourage the production of frogs for food." The species is not nearly so common now, presumably because of the drainage of so many wetland areas and, perhaps also, because of the widespread use of pesticides

during recent decades. I did not see or hear any bullfrogs during my daytime field studies, but they are very common in the Waimea valley stream nearby.

II. Reptiles

1. Blind Snake (Typhlops braminus). "This small, secretive snake was apparently introduced from the Philippines in the dirt surrounding plants that were brought in for landscaping the campus of the Kamehameha Boys School in Honolulu. It was first found there in January of 1930" (Oliver and Shaw, 1953). By 1967, Hunsaker and Breese wrote that "it now appears to occupy the lowland area over the entire island." These blind, worm-like snakes are rarely seen until they are flooded from their underground burrows by heavy rain or unless one looks for them under branches and other debris on the ground. I did not search for these snakes because they are of no significance for an impact statement.

2. Skinks and Geckos. Eleven species of skinks (Family Scincidae) and geckos (Family Gekkonidae) occur on Oahu. Some of the more common are the mourning gecko (Lepidodactylus lugubris), fox gecko (Hemidactylus garnoti), and the metallic skink (Lygosoma metallicus). All are foreign to the islands, all are insect eaters, and all adapt well to both urban and rural areas (McKeown, 1978). Their presence is irrelevant to an impact assessment.

The Birds

Three groups of birds are found in the Hawaiian Islands: 1. introduced or alien, 2. indigenous, and 3. endemic. The vast majority of the birds to be found in the project area are introduced species.

I. Introduced Birds.

More than 170 species of alien birds have been intentionally introduced to the Hawaiian Islands (Berger, 1981). The following have been reported in the Pupukea region.

A. Order Ciconiiformes

a. Family Ardeidae, herons and egrets

1. Cattle Egret (Bulbucus ibis). This species was imported to Hawaii from Florida to aid "in the battle to control house flies, horn flies, and other flies that damage hides and cause lower weight gains in cattle" (Breese, 1959). A number of birds were released on Oahu in 1959 and 22 additional birds were released during July 1961. Thistle (1962) reported that the population of Cattle Egrets on Oahu exceeded 150 birds by July 1962. The population has increased greatly since that time. Personnel of the State Division of Forestry and Wildlife counted 621 egrets on Oahu during their January 1986 census (Walker et al., 1986); 988 egrets were reported on the Honolulu Christmas count of the Hawaii Audubon Society (Pyle, 1987); 386 egrets were reported in the Waipio sector alone during the same period (Bremer, 1987). Cattle Egrets are common throughout the project region.

B. Order Columbiformes

a. Family Columbidae, pigeons and doves

2. Rock Dove or feral Pigeon (Columba livia). The pigeon probably was the first exotic bird to be introduced to the Hawaiian Islands; their importation has been traced back to 1796. Schwartz and Schwartz (1949) found heavy parasitism of feral pigeons by tapeworms, and they stated that the tapeworm infestation retards proper nutrition and "occludes the intestine, produces undesirable toxins, and hinders breeding." Navvab Gojrati (1970) reported infection by bird malaria, Haemoproteus, and Leucocytozoon in birds at the Honolulu Zoo. Kishimoto and Baker (1969) reported finding the fungus Cryptococcus neoformans in 13 out of 17 samples of pigeon droppings collected on Oahu. The full significance of their findings has not been determined, but in man this fungus causes a chronic cerebrospinal meningitis; Hull (1963:468) remarked that "in all but the cutaneous forms the prognosis is very grave." At least one flock of pigeons inhabits the project area.

3. Spotted or Lace-necked Dove (Streptopelia chinensis). Also called the Chinese Dove, this Asian species was released in the Hawaiian Islands at an early date; the exact date is unknown, but the birds are said to have been very common on Oahu by 1879. Although this species does occur where the rainfall exceeds 100 inches per year, the highest densities are found in drier areas, especially where the introduced kiawe or mesquite is one of the dominant plants. Schwartz and

Schwartz (1949), for example, reported densities as great as 100 birds per square mile in dry areas on Molokai. This dove is common throughout the Pupukea region.

4. Barred or Zebra Dove (Geopelia striata). This dove is native to Australia and the Orient. The species is said to have been introduced to Hawaii sometime after 1922 (Bryan, 1958). It now is abundant on all of the islands. This dove also prefers the drier areas. Schwartz and Schwartz (1949) reported densities as high as 400 to 800 birds per square mile in some areas on Oahu: for example, Barber's Point to Makaha. This dove is very common throughout the project site and the Pupukea region.

The Barred Dove also is classified as a game bird in Hawaii. One study of the food habits in Hawaii revealed that the diet consists of 97 percent seeds and other plant materials the 3 percent animal matter included several species of beetles, weevils, and wireworm larvae.

C. Order Strigiformes

a. Family Tytonidae, Barn Owls

5. Barn Owl (Tyto alba pratincola). The first Barn Owls were imported from California and released on Hawaii island during April 1958. Barn Owls were released at Hauula, Oahu, on two different occasions. Seven birds were imported from the San Diego Zoo and released during September 1959; 11 additional birds were imported from the San Antonio Zoo, Texas, and released at Hauula during October 1959 (Tomich, 1962).

As with the mongoose during the last century, the Barn Owl was introduced in the hope that it would prey on the abundant rats that were damaging sugarcane. No food habits study has been conducted on Oahu, but on Hawaii Tomich (1971) found that almost 90 percent of Barn Owl pellets contained only the remains of house mice. Tomich commented that, although the Barn Owl sometimes feeds on rats, it is not likely a significant factor in the economic control of rats in Hawaii. Moreover, Byrd and Telfer (1980) reported that Barn Owls had killed more than 100 seabirds and their chicks on Kauai and Kaula Rock.

No study of the spread of the Barn Owl from the Hauula region since 1960 has been conducted, but the birds have been seen or found dead or injured in both the windward and leeward sections of Oahu. This owl is nocturnal in habits, and I did not see any during my daytime field studies. The birds are known to inhabit the Waimea Valley just over the ridge from Pupukea, and they undoubtedly occur in the project area.

D. Order Passeriformes

a. Family Timaliidae, babblers

6. Melodious Laughing-thrush (Garrulax canorus) Long called the Chinese Thrush or Hwa-mei in Hawaii, this species is not a thrush (family Turdidae) but is a babbler. It was introduced to the islands from China or Formosa as a cage bird many years ago. "A number obtained their freedom at the time of the great fire in the Oriental quarter of Honolulu in 1900, and took to the hills behind the city" (Caum, 1933). This

babbler is found in both the Koolau and the Waianae mountains. In general, it prefers the wetter areas where there are thickets and clumps of dense vegetation. The birds have a loud, attractive song, and they more often are heard than seen. This species is a resident of the project area.

b. Family Pycnonotidae, Bulbuls

7. Red-vented Bulbul (Pycnonotus cafer). Although all members of this family are listed as "prohibited entry" by the State Quarantine Division of the Department of Agriculture, two species of bulbuls are now well established on Oahu. The history of the spread of the Red-vented Bulbul since the mid-1960s has been discussed by Berger (1975, 1981) and Williams (1987); the status of the Red-whiskered Bulbul (P. jocusus) has been discussed by van Riper, van Riper, and Berger (1979). The Red-vented Bulbul now inhabits the Pupukea region. The birds are a scourge to fruit and flower growers. The birds eat buds, flowers, and ripe fruits of many kinds.

c. Family Turdidae, Thrushes and Bluebirds

8. White-rumped Shama (Copsychus malabaricus). Shama is the Indian name for this very attractive thrush, which is native to India, Nepal, Burma, Malaysia, and throughout Indochina. The Hui Manu imported Shamas in 1940 and released them in Nuuanu Valley "and at some homes in the 2400 block on Makiki Heights road" (Harpham, 1953). The Shama is now common on both the windward and leeward sides of Oahu. The birds prefer lush vegetation, and I heard several birds singing during my December field studies.

d. Family Zosteropidae, White-eyes and Silver-eyes.

9. Japanese White-eye (Zosterops japonicus). Long a favorite cage bird in the Orient, this species was first introduced by the Territorial Board of Agriculture and Forestry in 1929 (Caum, 1933). Later importations were made by the Hui Manu and by individuals. The Japanese name is Mejiro, and Mejiro clubs held singing competitions with these birds. The White-eye has been a remarkably successful introduction and this species undoubtedly is now the most abundant song bird in the Hawaiian Islands. These birds occur from sea level to 10,000 feet elevation on Maui and Hawaii. They inhabit near desert conditions (e.g., Kawaihae, Hawaii) and those with an annual rainfall exceeding 300 inches. The White-eye is very common throughout the project area.

e. Family Sylviidae, Old-world Warblers

10. Japanese Bush Warbler (Cettia diphone). This warbler, which is native to Japan and Formosa, was first released on Oahu in 1929 (Caum, 1933). The Japanese name is Uguisu. Berger (1975b) summarized our knowledge of the distribution of this species on Oahu. These are shy and secretive birds, typically occurring in habitats with dense underbrush. Their song period lasts from about January to mid-July. I did not see or hear any Bush Warblers during my late December field studies, but I have seen the species in this region in the past.

f. Family Sturnidae, Starlings and Mynas

11. Common Indian Myna (Acridotheres tristis). The Common Myna, which is native to Sri Lanka, India, Nepal, and adjacent regions, "was introduced from India in 1865 by Dr. William Hillebrand to combat the plague of army worms that was ravaging the pasture lands of the islands. It has spread and multiplied to an amazing extent; reported to be abundant in Honolulu in 1879, it now is extremely common throughout the Territory" (Caum, 1933). The Myna is still common to abundnat in lowland areas of all islands, being most common in residential and urban areas, as well as in the vicinity of human habitation in rural areas. It is a common bird throughout the Pupukea region.

g. Family Ploceidae, Weaverbirds and their Allies

This is a large family of Old-world birds. The best known example in Hawaii is the House Sparrow. However, since the mid-1960s more than 15 different species of this family have been intentionally or accidentally released on Oahu (Elepaio, 1966:79; 1973:81-82). A number of species have established wild populations in the Kuilima region and undoubtedly will spread from there.

12. Nutmeg Mannikin or Ricebird (Lonchura puntulata). Also called the Spotted Munia, this Asian species was released in Hawaii by Dr. William Hillebrand about 1865 (Caum, 1933). Caum wrote that the ricebird "feeds on the seeds of weeds and grasses and does considerable damage to green rice." Rice

is no longer grown in Hawaii, but the Ricebird has become a serious pest again by eating the seeds of experimental crops of sorghum (to be discussed under House Finch). The Nutmeg Mannikin is another abundant species on all of the islands, and is widespread in the Pupukea region.

13. House Sparrow (Passer domesticus). The House Sparrow (erroneously called the English Sparrow) was first imported to Oahu in 1871, when nine birds were brought from New Zealnad (where the species had previously been brought from England). Caum (1933) wrote that "whether or not there were further importations is not known, but the species was reported to be numerous in Honolulu in 1879." In North America, the House Sparrow (first introduced to Brooklyn, New York, in 1852) became a serious pest and tens of thousands of dollars were spent in attempting to control the population (Dearborn, 1912). This sparrow apparently never became a pest in Hawaii. It is omnivorous in diet, eating weed seeds as well as insects and their larvae. House Sparrows are common around man's buildings and in outlying areas, including the Pupukea region.

h. Family Fringillidae, Cardinals and New-world Sparrows.

14. Red-crested Cardinal (Paroaria coronata). Although this species traditonally has been called the Brazilian Cardinal in Hawaii, the species has a much larger native range in Uruguay, Paraguay, Brazil, and parts of Bolivia and Argentina. This cardinal was released in Hawaii on several occasions between

1929 and 1931 (Caum, 1933). The species is common on lowland areas, and is a characteristic bird of the leeward section of Oahu, finding the dry, introduced vegetation suitable habitat for its annual cycle. It is a common bird in the Pupukea region.

15. Cardinal (Cardinalis cardinalis). This species has been given a number of venacular names: for example, Virginia Cardinal, Kentucky Cardinal, Kentucky Redbird. Its native range is the eastern part of North America, east of the plains and northward into Ontario. The Cardinal was released several times in Hawaii between 1929 and 1931 (Caum, 1933). The species is common in lowland areas and is a characteristic bird in leeward Oahu, finding the introduced vegetation suitable for its annual cycle. The Cardinal tends to inhabit forested areas and at higher elevation than does the Red-crested Cardinal. It is common in the Pupukea region.

16. House Finch (Carpodacus mexicanus frontalis). Also known as the Papaya bird in Hawaii, the House Finch was introduced from California "prior to 1870, probably from San Francisco" (Caum, 1933). The House Finch is now an abundant species on all of the islands, in both rural and urban areas, and probably is the second most common song bird species in the islands. Although the birds sometimes eat overripe papaya and other soft fruits, the House Finch is predominantly a seed-eater. House Finches and Ricebirds caused great damage to experimental sorghum crops planted on Kauai and Hawaii during 1971-1972.

"A report by the Senate Committee on Zoology, Environment, and Recreation says ricebirds and linnets [House Finch] caused a 30 to 50 percent loss in the sorghum fields at Kilauea on Kauai last year. . . . Seed-eating birds at Kohala ate about 50 tons of sorghum grain in a 30-acre experimental field that was expected to produce 60 tons" (Honolulu Advertiser, March 14, 1972, page B-2). Hence the growing of small grain crops in the islands is not a promising potential for the much talked about "diversified agriculture" in the State. Other seed-eating birds have become established on one or more of the islands during the past 15 or 20 years. The House Finch is widely distributed in the Pupukea region.

17. Gallinaceous Birds (Order Galliformes, Family Phasianidae, Family Numididae). I add this section because a number of gallinaceous species have been intentionally released at Waimea Falls Park, and it is possible that some of these birds may have strayed into the Pupukea area. These birds include the following: Red Jungle Fowl (Gallus gallus), Swinhoe's Pheasant (Lophura swinhoei), Ring-necked Pheasant (Phasianus colchicus), Silver Pheasant (Lophura n. nycthemera), Chukar Partridge (Alectoris chukar), and the Common Guineafowl (Numida meleagris).

II. Indigenous Birds

These are species that are native to the Hawaiian Islands but whose total range also includes other islands in the Pacific Basin or North America. These are the

Black-crowned Night Heron, 22 species of seabirds, and a number of migratory species that nest in North America or Siberia and which spend their winter or nonbreeding season in the islands.

A. Order Ciconiiformes

a. Family Ardeidae, Herons and Egrets

1. Black-crowned Night Heron (Nycticorax n. hoactli). This subspecies has a breeding range that includes Hawaii and the Western Hemisphere from Washington and Oregon southward to northern Chile and south-central Argentina. Because the Hawaiian birds are considered the same subspecies as the mainland birds, the species is not classified as an endangered species, even though the future of the species in Hawaii depends on the preservation of suitable wetland areas. Herons inhabit marshes, swamps, and streams. They feed on a wide variety of aquatic and terrestrial life: e.g., fish, frogs, crayfish, mice, and insects. In Hawaii, at least, this heron also eats the downy young of seabirds and probably the downy young of the endangered Hawaiian waterbirds. They also relish prawns and the State Land Board gave prawn producers a "120-day permit to destroy black-crowned herons which have been causing economic havoc at Oahu's Kahuku prawn farm as well as other aquaculture farms statewide" (Honolulu Star-Bulletin, October 26, page A-8 and October 30, 1985, front page). There is no foraging habitat for this heron in the project region, but there is a population of herons along Waimea stream.

N. Seabirds

1. White-tailed Tropicbird (<u>Phaethon lepturus dorotheae</u>)

This is the only one of the seabirds that needs to be mentioned because it does nest on the cliffs that bound Waimea Valley. There appears to be no nesting habitat for this tropicbird in the Pupukea project area, however.

M. Migratory Species.

The most conspicuous of these is the Lesser Golden Plover (<u>Pluvialis dominica fulva</u>), which occurs from sea level to elevations of nearly 10,000 feet on Maui and Hawaii during the winter season. This plover frequents lawns in residential areas, golf courses, weedy pastures, open areas in the mountains, mud flats, and cane haul roads. Plovers were common along the dirt road through the project area, and I saw one flock of nine birds.

The other migratory species are restricted to mud flats, ponds, or mountain streams. I did not see any in the project area, nor would I expect to see them there.

III. <u>Endemic Birds</u>

These are birds that are restricted to the Hawaiian Islands; they are unique to the islands. At lease 40 percent of these unique birds already are extinct, and another 40 percent are now classified as rare or endangered. Most of these endangered species are forest birds and very few are left on Oahu. There are none in the project area or near it.

Three species of endangered Hawaiian waterbirds occur in Waimea Valley: Koloa or Hawaiian Duck (<u>Anas wyvilliana</u>),

Hawaiian Gallinule or 'Alae 'Ula (<u>Gallinula chloropus sandvicensis</u>), and Hawaiia Coot or 'Alae Ke'oke'O (<u>Fulica americana alai</u>). There is, however, no suitable habitat for these waterbirds in the project area.

Pueo or Hawaiian Owl (<u>Asio flammeus sandwichensis</u>). This is a permanent resident on all of the inhabited islands in the Hawaiian chain. The birds are tolerant of wide climatic conditions (Richardson and Bowles, 1964). The Division of Forestry and Wildlife considers the Pueo to be an endangered species on Oahu, but not on the other islands. The Pueo differs from most other owls in that it is diurnal in habit; hence, they are seen much more often than is the nocturnal Barn Owl. Scott <u>et al</u>. (1986) wrote that the Pueo "was most often seen in grasslands, shrublands, and montane-parklands." This owl, indeed appears to be rare on Oahu. None were seen on the 1986 Christmas Count of the Hawaii Audubon Society (Pyle, 1987), although two birds were seen in Waipio area and one bird along Palehua Road on December 22, 1986 (Bremer, 1987). I did not see any Pueo during my field studies. However, one bird was found dead in Waimea Valley several years ago.

The Mammals

I. <u>Endemic Mammals</u>

The only endemic land mammal in the Hawaiian Islands is the Hawaiian bat (<u>Lasiurus cinereus semotus</u>), a subspecies of the North American hoary bat. The Hawaiian bat occurs primarily on the islands of Kauai and Hawaii (Tomich, 1969;

Kramer, 1971; Ten Bruggencate, 1983). I know of no evidence that there is a resident population of the bat on the island of Oahu.

II. Introduced Mammals

All of these introduced species of mammals in Hawaii have proven to be highly destructive to man, his buildings, products, or agricultural crops and/or to the native forests and their animal life. None is an endangered species and none is of any concern as far as detrimental effects resulting from this, or any other, proposed project. It would, in fact, be a great boon to the islands if it were possible to exterminate all of them.

With the possible exception of the house mouse (Mus musculus), all of the smaller alien mammals prey on birds, their eggs, and young. These small mammals include the roof rat (Rattus rattus), Polynesian rat (Rattus exulans), Norway rat (Rattus norvegicus), and the small Indian mongoose (Herpestes auropunctatus), as well as feral cats (Felis catus) and feral dogs (Canis familiaris).

The mongoose is diurnal in habits, and I saw several during my field surveys. Because the rodents are serious pests, I did not set night traplines in order to sample the population. It is reasonable to assume that all of them occur in the project area (Tomich, 1969; Kramer, 1971).

The Polynesian ancestors of the Hawaiians brought with them pigs (Sus scrofa), and Captain James Cook and later ship captains released English pigs on the islands. In 1925, the central forest of Oahu was "riddled with wild pigs which

were destroying the undergrowth." In writing about the Kilauea Forest on the island of Hawaii, Mueller-Dombois, et al. (1981) noted that this was "the best intact example of this forest type remaining in the state" and that "the effect of feral pig is very noticeable, and there is little doubt that the widespread pig digging in the Kilauea forest has been a major factor in reducing the native ground vegetation." I did not happen to see any pigs during my daytime field studies but pigs are common in the upper part of Waimea Valley and probably occur in the upper stretches of the Pupukea forests.

Summary and Conclusions

1. Because of the destruction of the native vegetation in the mountains on Oahu by cattle, goats, and pigs, the Hawaiian Government appropriated $12,000 for tree planting in 1882. The first forest reserve was established in 1903. L. W. Bryan (1947) said that 1,057 different species of exotic plants were tested in arboreta on the island of Hawaii during the period of 1921-1946. And, St. John (1973) lists 4,643 different species of exotic flowering plants (trees and shrubs) that have been introduced to the Hawaiian Islands. This explains the numbers of exotic trees, shrubs, ferns, and grasses that now grow in the Pupukea project area. This introduced vegetation does not provide suitable habitat for any of the endemic forest birds. Any disturbance to any of this vegetation would be irrelevant.

2. All of the amphibian and land reptiles that occur

in the project area are introduced animals, none is a rare or endangered species, and all are irrelevant to any environmental impact statement.

3. None of the 16 species of introduced birds found in the proposed project area is an endangered species and a number of them have proven to be serious pests in Hawaii. The destruction of sorghum crops by the Ricebird and the House Finch already has been discussed. The doves and the Myna have been implicated in spreading the seeds of such noxious weed plants as Lantana camara. The Red-vented Bulbul and the Japanese White-eye cause considerable damage to ornamental flowers and to fruit crops (Keffer, et al., 1976). The Barn Owl is known to eat birds and their young on Kauai and Kaula Rock, and probably on the other islands. To be sure, some of the introduced species apparently cause no damage to crops or to the endemic forest birds, and they do provide pleasure for many people. However, development, including landscaping, would still provide habitat for many of the introduced species that occur in rural and urban areas.

4. Although the White-tailed Tropicbird and the Black-crowned Night Heron are found in Waimea Valley, there is no habitat for them in the Pupukea project area. In fact, if ponds are constructed in the golf courses, the heron might well adapt to them for feeding and resting.

5. The Lesser Golden Plover now occupies the nonforested

portion of the Pupukea project area. It would continue to spend winters on the golf courses that are proposed for this development.

6. There is no habitat for the endangered waterbirds that are found along the stream in Waimea Valley.

7. I know of no recent observations of the Pueo or Hawaiian Owl in the project region. The habitat there is not suitable for this diurnal owl. In fact, construction of two golf courses might provide foraging habitat for this owl.

8. All of the mammals that occur in the project region are introduced or alien mammals. Many of them are predators on birds, their eggs or young, and most of them are destructive to agriculture and to forest lands and/or to man, his buildings and products. None of these mammals is of any significance for an environmental impact statement.

9. In conclusion, therefore, one can assert strongly that the proposed project would have absolutely no adverse effects on any native ecosystem and on the endemic animals that inhabit such ecosystems. There is no native ecosystem anywhere near the proposed project. With respect to such native ecosystems, therefore, one can readily classify the entire area as a "waste land."

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Preliminary Survey of four streams: Paumalu, Kaleleiki, Pukulena, and Kalunawaikaala, located in the Pupukea Paumalu area of Oahu's North Shore.

by

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Prepared for Group 70, Limited

Project #8763-14

Submitted

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Introduction

A preliminary survey of four streams: Paumalu, Kaleleiki, Pukulena, and Kalunawaikaala, located in the Pupukea Paumalu area of Oahu's North Shore, was conducted from 27 March to 30 March, 1991. (See Figure 1.) These streams are reported to be intermittent (Hawaii Stream Assessment, 1980), flowing primarily during heavy rainfall. This survey was conducted following more than a week of heavy rainfall. Flows had decreased considerably by the time we began our survey. On Kaleleiki Stream (Site I), flow was merely a trickle (less than 0.5 meters across) but evidence of recent flow 8.5 meters across could be seen; and on Pakulena Stream (Site P) all that remained of the flow (estimated to be 7.11 meters wide) were small puddles in the mud.

Methods

A total of 20 sites, each chosen to reflect typical habitat in that region of the stream, were selected for sampling (See Figure 2). Substrate type, riparian cover, and width and depth of water were recorded at each site. Dip nets and a surber sampler were used to collect benthic invertebrates. Samples were collected both from the water and the substrate below the water. Post-larval gobies were noted through visual observations and collected from three sampling sites for confirmation of species identification.

Flow Characteristics

Of the streams surveyed, Paumalu Stream was the only one with water flowing continuously throughout the survey area (See Figure 3). The upper limit of our survey on Paumalu Stream (Site K) was determined by dense forest and tree roots that prevented further movement upstream. Several human made rock walls were observed along the lower stream channel. The two tributaries to Paumalu Stream, Aimuu Gulch and Kaleleiki Stream consisted primarily of mud with small pools of water. Kaleleiki Stream was completely dry from below Site J to where it joins Paumalu Stream (and is nearly impassable due to thick vegetation).

The lower portion of Pakulena Stream was mostly mud and small pools while the upper portion flowed continuously. A large landslide had recently occurred between Sites A and B and the stream was full of debris, although water still flowed through. Kalunawaikaala Stream was essentially dry during this survey, with some mud and pools in the upper and lower reaches.

Sampling Results

Nine sampling sites were chosen on Paumalu Stream and one (Site Q) on its tributary, Aimuu Gulch. Gobies were collected at Site P, Site R, and Site S (See Figure 4). Benthic samples for invertebrates were collected at the remaining sites. Four samples were taken from Kaleleiki Stream, also a tributary to Paumalu Stream. On Paukulena Stream five sampling sites were chosen. No samples were taken on Kalunawaikaala Stream as there was insufficient water.

Site Q, Aimuu Gulch. This site is as far upstream as we were

able to survey on Aimuu Gulch because of dense vegetation. The area was very overgrown, with riparian cover 85%. Water in this area consisted of shallow pools and some trickle flow. In the pools the water was barely moving, was cloudy in color, and appeared stagnant. The substrate of the channel was large boulders and rocks. At our sampling site the pool was 1.92m wide and 10cm deep. A large toad was observed just downstream of Site Q, but no insects or other invertebrates were found in the benthic sample.

Site K, Paumalu Stream. Riparian cover was 100%, with the canopy 1 to 3 meters above the stream. The substrate was mud, roots, and fallen branches. At Site K the stream width ranged from 1.18m to 4.75m, with an average depth of 16cm. The deepest spot at this site was 60cm. Thiarid snails and amphipods were collected in the benthic sample.

Site L, Paumalu Stream. Site L is near the upper boundary of the property. Riparian cover was approximately 80% and the canopy relatively low. Water flowed over two cascades at this site. Large boulders and roots of a large tree in the middle of the flow made up the substrate. The width of the stream was 3.6m, the height of the first cascade, 0.75m and the height of the second cascade, 1.5m. Average stream depth at this site was 23cm. No organisms were found in the benthic sample.

Site M, Paumalu Stream. Riparian cover at Site M was 75%. The substrate consisted mostly of dirt with rocks, boulders, and roots interspersed. The width of the stream channel in this area was 2.2m and the water was 30cm deep. Amphipods and the introduced riparian Cynidae, Geotomus pygmaeus, were observed at Site H.

Site N, Paumalu Stream. At Site N the riparian cover was 50%, and the stream banks low and flat. The substrate was hard mud with roots and branches also on the stream bed. The water was shallow (17cm) and flowing quickly. Width of the stream in this area was 2 meters. No organisms were found in the benthic samples.

Site O, Paumalu Stream. Site O had low sloping banks, and many branches had fallen over the stream channel. Riparian cover was 75%. Stream substrate consisted of large boulders, rocks, and mud. Width of the water was 2.41m and depth was 20cm. The only organism collected at this site was the introduced riparian Cynidae, Geotomus pygmaeus.

Site P, R, and S: Paumalu Stream. Post-larval gobies were observed in the lower portion of Paumalu Stream (See Figure 4). Gobies (Sicyopterus stimpsoni) were collected at Sites P, R, and S. All gobies collected or observed were less than 2cm standard length. Site R was typical of the habitat in which gobies were observed. The substrate had many large boulders which the gobies perched on (8 to 10 gobies per boulder were observed). The water was 4m wide at Site R and 1m deep. At Site P, the water was 2.5m wide and 0.75m deep.

Site T, Paumalu Stream. The jeep trail crosses Paumalu Stream at Site T. Riparian cover in this area was 60%. Substrate consisted of boulders, roots, and dirt. The width of flowing water was 2.32 meters and the depth was 17cm. No organisms were found in the benthic sample at this site.

Site F, Kaleleiki Stream. Site F is the uppermost point surveyed on Kaleleiki Stream. Riparian cover was 60% at Site F and the substrate consisted of gravel and dirt. Stream width here was 1.28 meters and depth was 17cm. The only organisms collected at this site were flatworms.

Site G, Kaleleiki Stream. At Site G there was a small cascade (1.5 meters) falling into a small deep pool (depth, 94cm; diameter, 3.1m). Riparian cover was 75% in this area and the canopy was very low. Recently fallen leaves covered the bottom of the pool. Benthic organisms found at this site included amphipods, isopods, thiarid snails, and tadpoles.

Site H, Kaleleiki Stream. This site was located just upstream of the jeep trail. Riparian cover here ranged from 25% to 50%. Water was mostly small isolated pools surrounded by mud. Substrate consisted of mud, dirt, and gravel. Width of the pool at the sampling site was 1.2m and depth of water was 5.75cm. Thiarid snails were collected at this site.

Site I and Site J, Kaleleiki Stream. Below the jeep trail which crosses Kaleleiki Stream, flow is minimal. Water was primarily small isolated pools surrounded by mud. The introduced riparian Cynidae, Geotomus pygmaeus was collected in this area. Below Site J, the stream dries completely and vegetation is very thick.

Site A, Pakulena Stream. Site A is at the headwaters of Pakulena Stream. Riparian cover here was thick (90%), with tall trees, vines and branches crossing the stream channel. Substrate of the stream channel was hard mud. A small waterfall was formed by bedrock and tree roots. The pool below the waterfall was 1.3 meters wide and 40cm deep. Water flowed out of the pool and downstream in a trickle (30cm wide, 2cm deep). Organisms collected at this site included the introduced riparian Cynidae _Geotomus pygmaeus_, an endemic Veliidae (_Microvelia vagans_), an endemic Dytiscidae (_Rhantus pacificus_), the introduced mayfly _Caenodes nigropunctatus_, flatworms, and thiarid snails.

Site B. Pakulena Stream. Upstream of Site B on Pakulena Stream is a large landslide. Downstream of Site B, flow ceases to be continuous. At Site B, riparian vegetation was very dense (100% cover) and the canopy low. The stream channel is narrow with high steep banks, and substrate is mud on bedrock. Width of the water here was 90cm and depth was 10cm. No organisms were found from the benthic sample at this site.

Site C. Pakulena Stream. Site C was a little puddle of water. Riparian cover here was minimal (0%). The substrate was grass and mud. No organisms were found in the benthic sample.

Site D and Site E. Pakulena Stream. Very little water remained in the lower reaches of Pakulena Stream. Isopods were collected from a small pool of standing water at Site D. Isopods and the endemic Dytiscidae _Rhantus pacificus_ were found in the benthic sample at Site E.

Discussion

Hawaiian stream gobies have an amphidromous life cycle

(McDowall,1988). Eggs are laid in the stream, larvae then hatch and wash out to sea. After spending a larval phase as marine plankton, the post-larvae return to the streams where they spend the remainder of their life cycle (Kinzie, 1988). Gobies appear to base return migrations from the sea by cuing on the high flows that occur during spates (Hanacop,1953; Erdman,1968; Kinzie and Ford, 1982). In order for a viable population of gobies to become established, the fish must have access between the stream and sea.

The _Sicyopterus stimpsoni_ that we observed in Paumalu Stream during this survey may have responded to the fresh water flowing into the ocean from Paumalu Gulch. There are two probable outcomes for these post-larval gobies. One, the stream channel will dry up and the gobies will perish, or two, the gobies may reach some permanent water in the upper portion of the stream where, given that adequate food is available and other requirements are met, they could survive through adulthood.

Summary

Benthic organisms collected from the Paumalu Watershed (Paumalu and Kaleleiki Stream) included isopods, amphipods, cynids (_Geotomus pygmaeus_), thiarid snails, flatworms, and tadpoles. Benthic organisms collected from the Pakulena Watershed included the organisms listed above, plus waterstriders (_Microvelia vagans_), beetles (_Rhantus pacificus_), and mayflies (_Caenodes nigropunctatus_). Post-larval gobies (_Sicyopterus stimpsoni_) were present in the lower reaches of Paumalu Stream, the only place they were observed during this survey.

As these streams are intermittent, water will be flowing primarily during heavy rainfall. Kalunawaikaala, and the lower portions of Pukalena and Kaleleiki were mostly mud and small evaporating pools just days after more than a week of heavy rainfall. It is possible however, that in the upper reaches of these streams some water remains throughout the year.

Acknowledgements

William Barnum provided assistance during the field survey. Dan Polhemus and Arnold Suzumoto generously assisted in species identification.

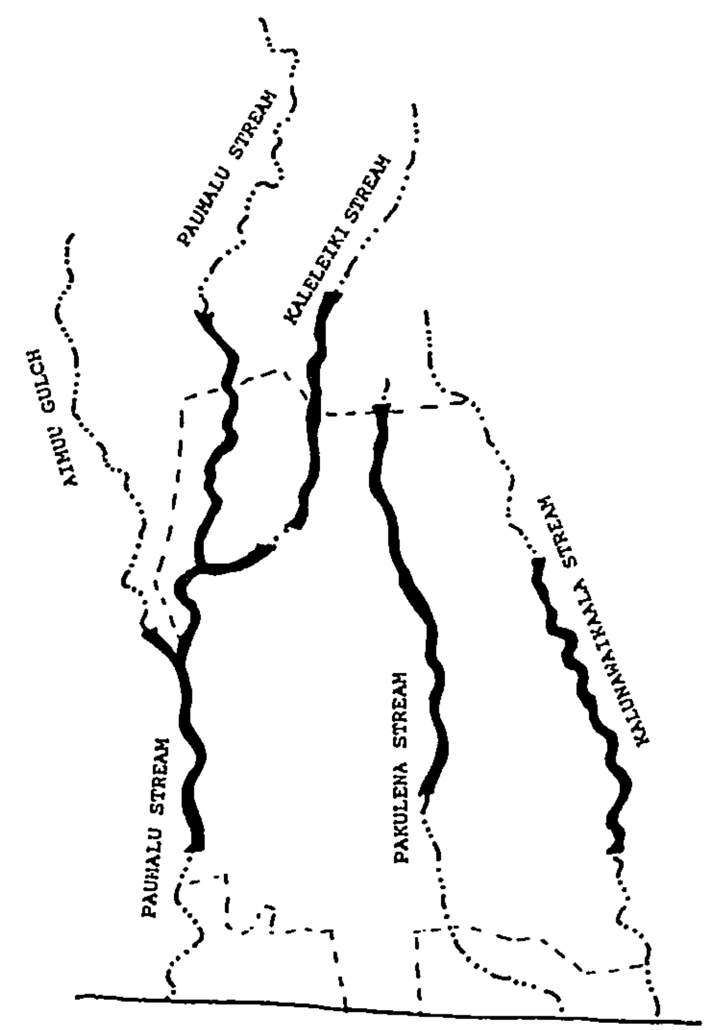

Figure 1. Area covered during survey (indicated by bold). Dashed line is property boundary.

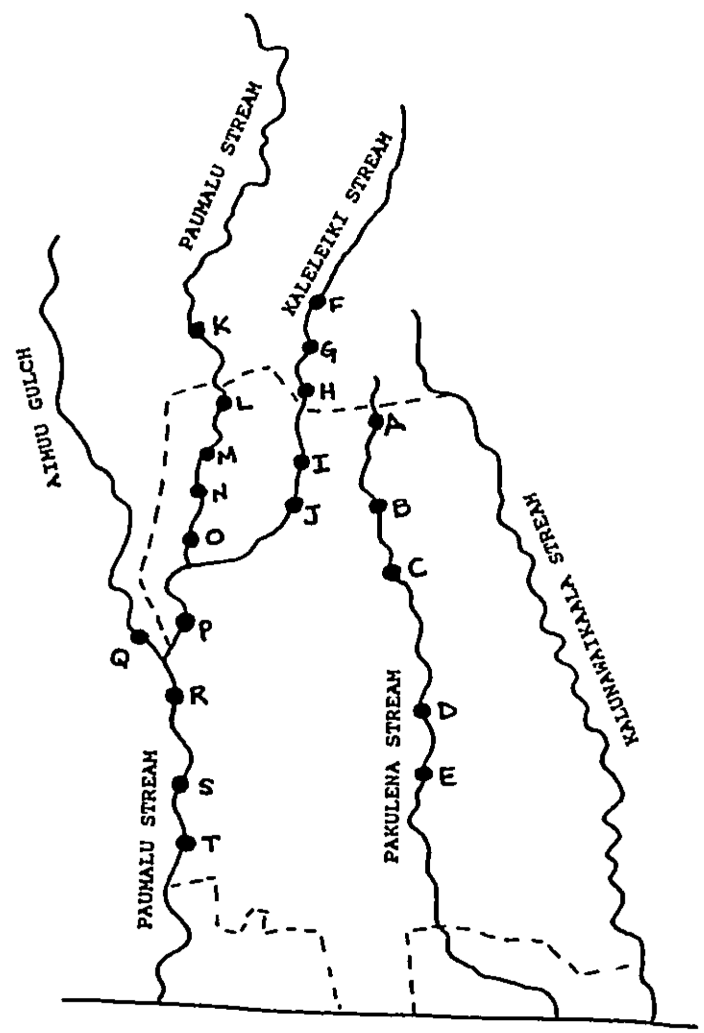

Figure 2. Sampling Sites. (Dashed line is property boundary.)

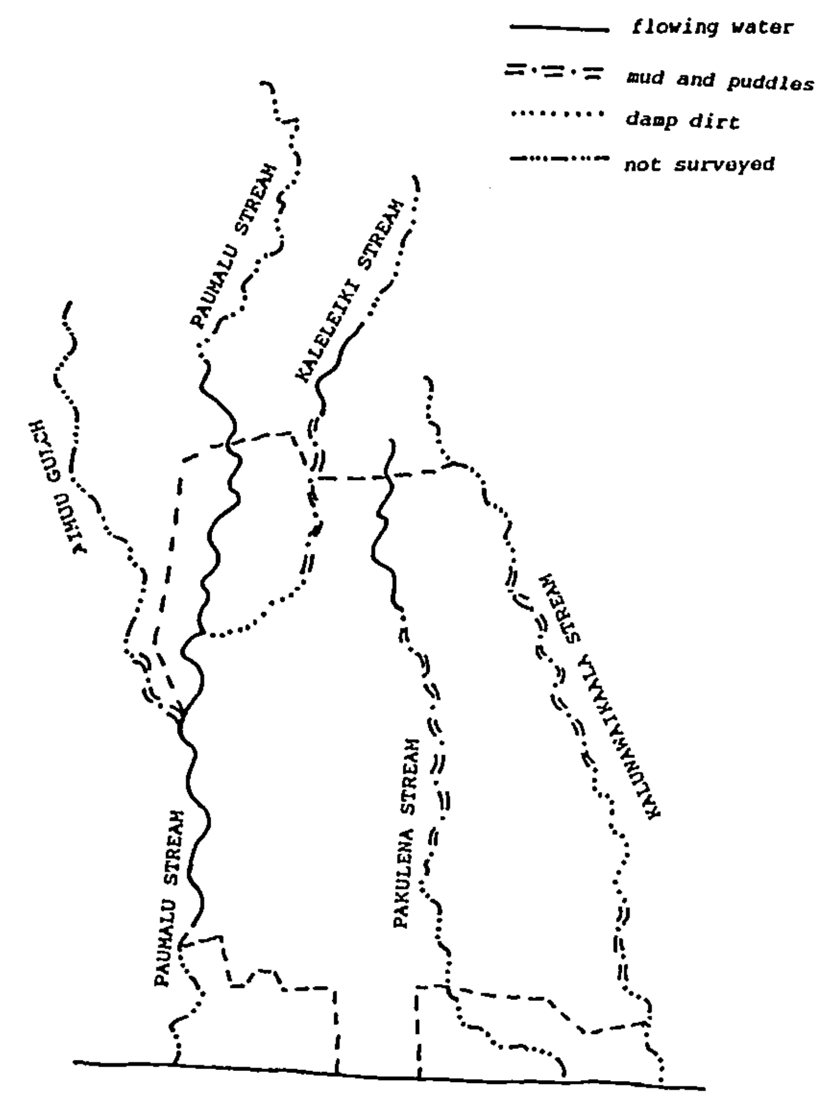

Figure 3. Flow characteristics. (Dashed line is property boundary.)

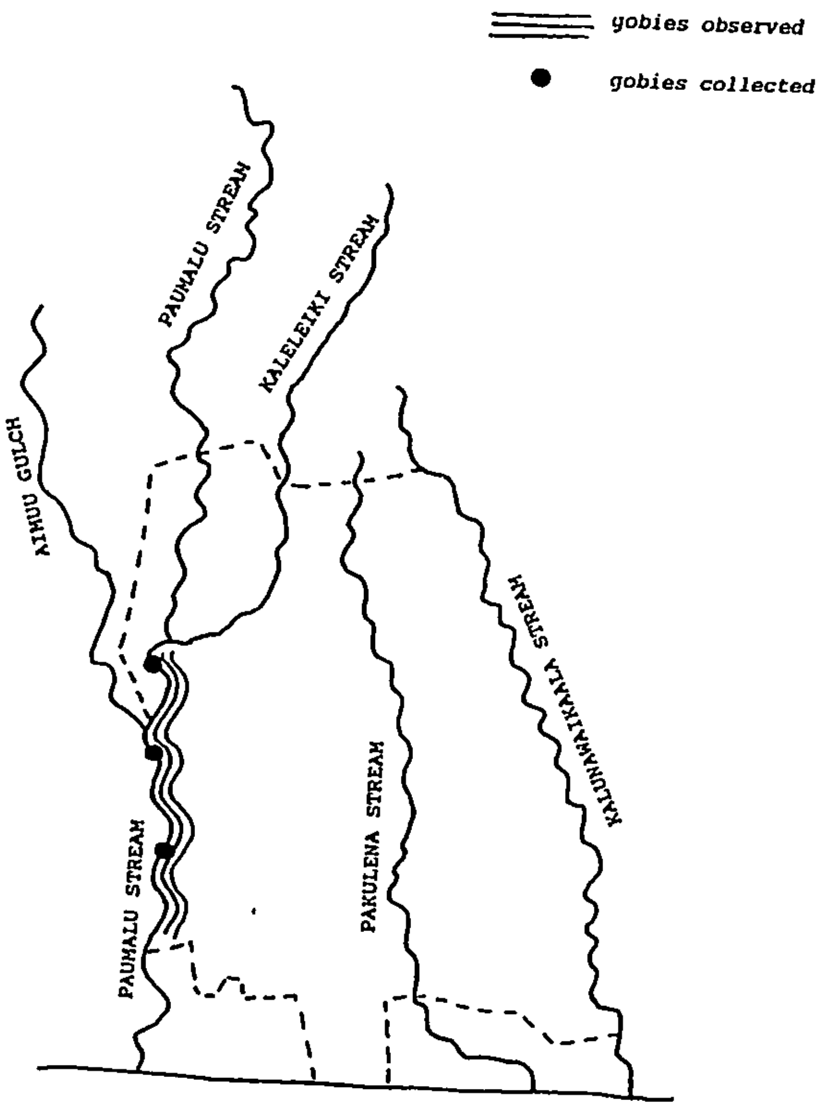

Figure 4. Location of post larval gobies: (Dashed line is property boundary.)

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APPENDIX M

BASELINE ASSESSMENT OF THE MARINE ENVIRONMENT IN THE VICINITY OF THE LIHI LANI RECREATIONAL COMMUNITY, PUPUKEA, OAHU, HAWAII

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INTRODUCTION

The proposed Lihi Lani Recreational Community Project, located at Pupukea in the Koolauloa District on the north shore of Oahu, consists of a gross area of 1,130 acres, with approximately 492 acres planned for actual development. The current planning concept includes an 18-hole golf course, a 120 lot subdivision, and 28 acres of affordable housing, as well as a tennis center and an equestrian ranch. The proposed golf course will minimize the amount of land being altered. It is estimated that only 90 acres out of the 196 acres of the golf course will actually be developed and maintained. Wastewater treatment and disposal will be handled completely on the subject site with a secondary sewage treatment plant, built and operated in accordance with State requirements. It is presently planned to use the sewage effluent that will be generated by the project for irrigation of the golf courses.

There are, however, no plans for any shoreline modification. Thus, any changes that might occur in the marine environment will originate from land-derived material input to non-point source discharges. In terms of effects from irrigants used on the golf course, such non-point source discharge will occur through material input to groundwaters that enter the ocean at the shoreline. Construction of the proposed development will also alter runoff characteristics of storm waters that enter the ocean. Such input will largely occur as sheet flow to the nearshore ocean.

Sewage disposal via irrigation/fertilization with effluent have been used at other golf courses in Hawaii without measurable negative alteration to the shoreline and the marine environment (Dollar and Smith 1988). However, each development scenario represents a unique situation. Thus, it is important to include information in the planning process that can be useful for assuring maintenance of environmental integrity with each proposed development. The basic premise for recognizing the potential for effects to the marine environment is that materials applied to the golf course for irrigation, fertilization, and pest control, may percolate into groundwater, move laterally downslope, and enter coastal waters at the shoreline. Once in the nearshore ocean, these materials may cause alteration of chemical and biological components of the marine environment.

In order to evaluate the potential magnitude of alteration, a baseline assessment of the nearshore marine environment was conducted in the vicinity of the proposed Lihi Lani Project. The primary objective of the baseline assessment is to construct a comprehensive qualitative and quantitative description of existing water chemistry parameters that can be used to evaluate the magnitude of possible changes that may result from construction and operation of the project. In addition, qualitative assessments of the nearshore biological communities inhabiting the area were conducted in order to evaluate the potential for changes to biota from alteration of water chemistry.

An additional objective of the baseline assessment was to evaluate the degree of natural stresses (e.g. wave scour, freshwater input, etc.) that influence nearshore marine communities in the vicinity of the proposed development. Typically, the composition of reef communities is intimately associated with the magnitude and frequency of these stresses, and any impacts caused by the proposed development will be superimposed on natural environmental factors. Therefore, evaluating the range of natural stress is a prerequisite for assessing the potential for additional change to the marine environment owing to the planned development.

ANALYTICAL METHODS

Water Quality

Water quality was evaluated along 2 transects oriented perpendicular to the shoreline, directly offshore of the proposed development (OP-1 and OP-2). These transects were located near the area where the subject property extends almost to the shoreline (see Figure 1). At the time of sample collection, this area was planned to contain evaporation/percolation fields for sewage disposal. Thus, the sampling sites were selected with respect to identifying effects from percolation fields. However, even with the elimination of the percolation field scenario, the sampling locations still are representative of conditions that will prevail with sewage disposal on the golf course.

At each transect water samples were collected over the widest possible salinity range to evaluate the effects of groundwater efflux. Samples were collected from the highest reaches of wave wash to a distance of approximately 500 meters (m) offshore. At all locations, except in the nearshore breaker zone, samples were collected at two depths; a surface sample was collected within approximately 10 centimeters (cm) of the surface, and a deep sample was collected approximately midway between the sea surface and the sea floor. In addition, single water samples were collected at 5 locations spaced along the entire development frontage (see Figure 1). These samples were collected as near to the shoreline as possible. Duplicate samples were also collected from the Board of Water Supply (BWS) well that supplies potable water near the development site.

Water quality parameters evaluated included the 10 specific criteria designated for open coastal waters in Chapter 11-54, Section 06 (Open Coastal waters) of the Water Quality Standards, Department of Health (DOH), State of Hawaii. These criteria include: total nitrogen, nitrate + nitrite nitrogen ($NO_3^- + NO_2^-$), ammonia nitrogen (NH_4^+), total phosphorus, Chlorophyll a (Chl a), turbidity, dissolved oxygen, temperature, pH and salinity. In addition, orthophosphate phosphorus (PO_4^{-3}) and dissolved silica (Si) were also reported because these parameters are sensitive indicators of biological activity and degree of groundwater mixing, respectively.

Water samples for nutrient analysis were collected in 1 liter (l) polyethylene bottles opened by divers at the desired location. Sub-samples for nutrient analyses were filtered through glass-fiber filters into 125 milliliter (ml) acid-washed, triple rinsed, polyethylene bottles in the field and immediately placed on ice. Analysis for NH_4^+, $NO_3^- + NO_2^-$, and PO_4^{3-} were conducted using standard techniques on a Technicon autoanalyzer. Total nitrogen and total phosphorus were analyzed in a similar fashion following persulfate digestion. All nutrient analyses were conducted by the Analytical Services Laboratory, Hawaii Institute of Marine Biology, Honolulu, Hawaii.

Water for other analyses was subsampled from 1 liter polyethylene bottles and kept chilled until analysis. Turbidity was determined on 60-ml subsamples fixed with HgCl to terminate biological activity. Fixed samples were kept refrigerated until turbidity was measured on a Turner Designs nephelometer (No. 40) and reported in nephelometric turbidity units (NTU). Chlorophyll a was measured by filtering 300 ml of water through glass fiber filters; pigments on filters were extracted and assessed fluorometrically. Salinity was determined using a AGE Model 2100 laboratory salinometer with a readability of 0.0001 $^o/oo$. Turbidity and Chl a were analyzed by AECOS, an environmental laboratory located in Kailua, Oahu.

In-situ field measurements included dissolved oxygen and water temperature (YSI Model 58 meter with a readability of 0.01 milligrams per liter (mg/l) and 0.1 oC., respectively). pH was determined in the field with a Cole-Parmer Digisense millivolt meter with a readability of 0.001 pH units.

Biological Community Structure

Qualitative reconnaissance surveys covering representative areas of the nearshore zone fronting the proposed development were conducted by divers swimming from the shoreline to a distance of approximately 500 m from shore. These reconnaissance surveys were useful in making relative comparisons between areas, identifying any unique or unusual biotic resources, and providing a general picture of the physiographic structure and biotic community assemblages occurring throughout the region of study.

During the reconnaissance surveys, divers knowledgeable of the taxonomy of resident species visually estimated the percent cover and occurrence of organisms and substrata types. Organism types included benthos (bottom dwellers) and reef fish. Only macrofaunal species greater than approximately 2 cm were noted; no attempt was made to identify and enumerate cryptic species dwelling within the reef framework.

RESULTS

Physical Setting

The physical (and to a large part chemical and biological) oceanographic setting of the area offshore of the proposed development is dominated by the effects of wave action. During the winter months, large waves that originate from storms in the north Pacific impact the north shores of the Hawaiian Islands. Within the nearshore area fronting the proposed development is the "Pipeline", a surfing area that is renown worldwide for the quality and force of waves breaking on the nearshore reefs. Because all of the property frontage consists of open coastline, there is no regions sheltered from wave energy.

The entire shoreline fronting the development is composed of a wide beach composed of coarse calcareous sand. Portions of the shoreline are composed of solid limestone (beachrock) that generally occurs in areas where there is consistent flow of low salinity groundwater into the ocean.

The nearshore region is essentially divided into two zones - a nearshore boulder/sand area and a deeper reef platform zone. Moving seaward from the beach, the most shoreward zone consists primarily of boulders and limestone extrusions interspersed on a sandy bottom. Surfaces of the rocks are essentially barren owing to frequent mechanical stress from breaking waves and scouring action of sand. The only macro-organisms occurring on the boulders are marine algae of several species. The extent of the boulder zone in terms of distance offshore varies depending on the specific location, but in general is on the order of 50 m.

At a water depth of about 5 m the seafloor grades from sand and boulders to a solid calcium carbonate reef platform. Interspersed in the solid pavement are pockets of sand, as well as shallow ledges and small undercut caves. Owing to the greater water depth and distance from shore, destructive force of waves is less in this area, allowing reef biota to occur. The major forms of benthic (bottom dwelling) organisms in this area are corals and algae; however the occurrence of corals is limited to small flat encrustations. The flat carbonate pavement continues out to the limits of investigation for this study, approximately 500 m offshore, and to water depths of about 15 m.

Water Chemistry

Tables 1 and 2 show measurements of all DOH specific and non-specific water chemistry parameters for all sampling sites located offshore of the Lihi Lani property. Table 1 also includes nutrient concentrations from groundwater samples obtained from the BWS well on land adjacent to the property.

Considering nutrient parameters (Nitrogen, Phosphorus, Silica), it can be see in Table 1 and Figure 2 that there is no distinct pattern with respect to distance from shore or surface versus deep water for total nitrogen and ammonia nitrogen. It can be seen from nutrient concentrations in the BWS well water (table 1) that almost all of the nitrogen in groundwater is in the form of $NO_3^- + NO_2^-$. In the absence of stream flow or surface runoff (as was the case during the present survey), influx of groundwater in the nearshore zone is the only source of nutrient subsidy to the receiving environment. Therefore, the lack of variation in nutrient parameters that are not abundant in groundwater (i.e. total N and NH_4^+) is expected.

$NO_3^- + NO_2^-$ and Si are nutrients that are present in high concentrations in groundwater. It can be seen in Table 1 and Figure 2 that these parameters exhibit definite patterns within the sampling scheme. These patterns are most pronounced on transect 1, but are also evident on transect 2. All samples collected within 10 m of the shoreline were substantially higher in $NO_3^- + NO_2^-$ and Si than samples collected farther offshore. The elevation in nutrient concentrations indicates a zone of mixing near the shoreline where input from groundwater extrusion is discernible owing to incomplete dilution with ocean water. The lack of a well-defined surface layer of high nutrient content relative to deep water implies that the entire water column is mixing sea water with groundwater.

The situation is slightly different for phosphorus. While essentially all phosphorus in groundwater is in

the form of orthophosphate (PO_4^{3-}), there is no indication of increased levels of PO_4^{3-} near the shoreline or in surface layers. While the concentration of PO_4^{3-} in groundwater is elevated with respect to ocean water, enrichment of P is substantially less than N. The relatively small enrichment of P appears to be obliterated by dilution and nearshore mixing.

Besides $NO_3^- + NO_2^-$ and Si, salinity is the best indicator of the degree of groundwater influence on nearshore water chemistry. In Table 2 and Figure 2 it can be seen that salinity is decreased in the nearshore zone (within 10 m from shore) of transect 1 by about 0.5 $^o/oo$. This decrease is a result of mixing of fresh groundwater with open ocean water.

Considering the remaining water quality parameters, it can be seen in table 1 that Chl a does not exhibit any pattern with respect to distance offshore within the nearshore zone. The only indication of a relationship between distance from shore and Chl. a is the lower concentrations in the samples collected 500 m from the shoreline. Turbidity, dissolved oxygen, pH and temperature measurements also do not indicate any consistent variation with respect to distance from shore or depth.

Table 3 shows Dept. of Health specific criteria for chemistry parameters in open coastal waters. DOH criteria are different for "wet" and "dry" conditions, which are defined as environments which receive either more (wet) or less (dry) than 3 million gallons per day (mgd) of freshwater discharge per shoreline mile. Mink, in his report on groundwater conditions at Pupukea-Paumalu, calculates a groundwater input of about 1.5 mgd per mile. Thus, in the following discussion DOH "dry" criteria are applied to the Lihi Lani data.

It can be seen by comparing Tables 1 and 3 that geometric means for 3 of the 6 measured specific water chemistry parameters ($NO_3^- + NO_2^-$, turbidity and Chl. a) exceed DOH standards for dry conditions. Measurements of $NO_3^- + NO_2^-$ within 10 m of the shoreline on transect 1 also exceed the "more than 10% of the time" criteria.

BIOLOGICAL COMMUNITY STRUCTURE

Benthos

As mentioned above, physical forces from breaking waves are the major determinant of biological community structure in the nearshore reef area fronting the development area. Because of the seasonal extremes in wave stress, physical parameters for development of extensive benthic communities must be considered sub-optimal. As a result, the area is not characterized by well-established coral communities that comprise high percentages of bottom cover in areas where wave stress is severe.

Within the nearshore boulder zone, the only observed organisms are benthic algae; reef building corals and motile organisms were not observed. It appears that the occurrence of algae in the boulder zone is seasonal, with blooms occurring in the summer when wave stress is minimal.

Further offshore on the reef platform, the dominant benthos remains benthic algae. However, in this zone hermatypic (reef-building) corals also occur. Because corals are essentially "permanent" features of the biotic community in that they do not recolonize an area seasonally, they must be able to withstand the full range of environmental stresses inherent in the physical environment. Growth forms of corals observed in the survey area are generally restricted to flat encrustations, an adaptation that favors resistance to breakage from wave stress. Nine species of corals were observed on the reefs off Pupukea. Bottom coverage by corals increases with distance offshore, grading from about 1% coverage at the shoreward border of the reef platform zone to about 20%, 500 m from shore. Coverage was highest on boulders or other protrusions off the bottom, owing to protection from scouring sediment. By far the most abundant coral species was Porites lobata. This species is generally the most abundant coral on Hawaiian reefs, occurring in a variety of growth forms that are adaptations to predominating physical conditions. Observed coral and algal species are listed in Table 4.

Motile benthos, such as sea urchins (Echinoderms) and sea cucumbers (Holothuria) were generally rare off the subject site. The most common urchin observed was Echinometra matheai, a species that bores into calcium carbonate surfaces and occupies depressions within the reef platform.

Reef Fish Communities

The fish community off the proposed development was characterized by a low population density and generally small body size of most individuals. This is probably a result of both scarcity of shelter in the physically stressed habitat, and the effects of overfishing. Although a total of 49 species were noted, only a few species were common (see Table 5). In particular, the saddleback wrasse (hinalea lau-wili, Thalassoma duperrey) and small convict tang (manini, Acanthurus triostegus) were the most abundant species observed. Schooling surgeonfishes (Acanthuridae) were common at some sites. Most other species were represented by only occasional or rare individuals.

In the shallow nearshore boulder-sand zone, fish species were observed that are adapted to a high surge habitats. These included the christmas wrasse (awela, Thalassoma trilobatum) and the blackspot sergeant (kupipi, Abudefduf sordidus), as well as the aforementioned saddleback wrasse and convict tang.

Deeper water areas on the reef platform harbored a somewhat richer fish fauna, particularly in areas where bottom structure was dominated by large undercut grooves and depressions. When approached by divers, mixed-species schools of surgeonfishes quickly retreated to the shelter afforded by these features. Although these schools were dominated by convict tangs, other species included the whitebar surgeonfish (maikoiko, Acanthurus leucopareius), the orangeband surgeonfish (ne'ena'e, A. olivaceus) and the ringtail surgeonfish (pualu, A. blochii).

Apparent overfishing in the survey area is evidenced by the virtual absence of some sought-after fish groups such as goatfishes (kumu and weke, Mullidae), jacks (papio, Carangidae), squirrelfishes (u'u,

Holocentridae) and parrotfishes (uhu, Scaridae). Species of surgeonfish commonly taken as food tended to be small, and nearly all fishes quickly retreated or took shelter upon approach of a diver. Combined with the scarcity of shelter, this apparent overfishing has produced a significantly depleted fish fauna.

Threatened or Endangered Species

Three species of marine animals that occur in Hawaiian waters have been declared threatened or endangered by Federal jurisdiction. The threatened green sea turtle (Chelonia mydas) occurs commonly along the shoreline of the major Hawaiian Islands and is known to feed on selected species of macroalgae. The endangered hawksbill turtle (Eretmochelys imbricata) is found infrequently in waters off Hawaii. Several small green sea turtles were observed in the nearshore area during the course of the present survey, and such sightings are common for the entire north shore of Oahu.

Populations of the endangered humpback whale (Megaptera novaeangliae) are known to spend the winter months in the Hawaiian Islands. The present study was carried out during the period when whales were absent.

POTENTIAL IMPACTS TO THE MARINE ENVIRONMENT

In order to assess the potential for future impacts it is necessary to understand the environmental regime of the subject area prior to development. Such an understanding can serve as a "baseline" from which actual changes can be determined. With respect to alteration from water quality from activities on land, a proven method for establishing a functional baseline involves scaling the concentration of materials in question to conservative mixing. The essence of this methodology is based on simple mixing and is presented graphically in Figure 3. If waters with two different compositions are mixed, relative admixtures will produce straight lines on 2-dimensional plots as long as there are no additional sources or sinks. With no such external sources or sinks, mixing is said to be "conservative". In the present case, the conservative component of mixing is salinity. End members are offshore seawater, with salinity near 35 $^{o}/oo$ and low nutrient concentration, and groundwater, with salinity of essentially zero and high nutrient content. It follows that plots of any material (Y) (i.e. nutrient concentration) versus salinity should yield straight lines if only mixing is involved.

On a salinity versus Y plot, points that deviate from the straight line between end members imply some additional source or sink of material Y. In cases where the environment is acting as a net sink for material introduced as non-point source discharge, data points comprising a measured mixing line will fall below the conservative mixing line. The magnitude of such a sink (represented by R_y) can be calculated as the difference between the Y intercepts of the tangents to the measured mixing line at the locations (i.e. salinities) in question. On the other hand, if material applied on land constitutes a source of additional input to the nearshore environment, the measured distribution of salinity vs. nutrient data points will occur above the conservative mixing line. In this case, magnitude of the source (R_y) can be evaluated as the difference between the Y intercepts of the tangents to measured mixing lines at the locations under consideration.

It is important to understand that R_y is the net source or sink for Y within the system or sub-system under investigation. If some subset of processes contributing to R_y is known, then the remaining net value can be found. This calculation embodies the specific application of assessing the effects of man-induced impacts on non-point source discharges in Hawaii. For example, if golf courses add a known quantity of sewage or other fertilizer to the soil zone between groundwater input source and the shoreline, then that input function (G_y) can be represented by the equation:

$$R_y = G_y + O_y$$

where O_y represents the net sources and sinks for Y other than the golf course additions. Because R_y and G_y are known, O_y can be determined. If O_y is a net sink (negative value of O_y), than it can be interpreted that biological-chemical processes within the soil rock system "filter" out added nutrients. Examples of such sinks may be simple adsorption of Y onto rock and soil surfaces, or active chemical processes such as organic production or denitrification. If O_y is a net source (positive value of O_y), then some "unknown" additional sources must be considered. Examples might be purely physical (e.g. other additions which have not been previously recognized) or internal reactions (e.g. nitrogen fixation as an additional source of dissolved nitrogen).

The shape of the measured mixing line also provides important information about ecosystem response to non-point source discharge. Curvature of the mixing line indicates non-conservative behavior; upward concave curvature indicates uptake of material, downward concave curvature indicates release of material. Considering dissolved nutrients, upward concavity implies community autotrophy, a possible signal of impending eutrophic condition. Downward concavity, on the other hand, suggests community heterotrophy, a potential response to increased particulate input.

Figure 4 shows plots of nutrients versus salinity in samples collected offshore of the proposed Ohbayashi Pupukea development. Conservative mixing lines are constructed by connecting end-point concentrations of open ocean samples and BWS well water. Materials considered are silica (Si), a nutrient leached from basaltic lava and not supplied in large quantities with fertilizers, and the plant nutrients dissolved inorganic nitrogen (DIN) which includes $NO_3^- + NO_2^-$ and NH_4^+, and dissolved inorganic phosphorus (DIP) which is orthophosphate phosphorus (PO_4^{3-}). DIN and DIP are important because they are the nutrient that are biologically active and are present in sewage and commercial fertilizer mixes.

It can be seen in Figure 4 that Si is behaving conservatively; all sample concentrations fall near the mixing line and show no indication of curvature. Such conservative behavior is consistent with the lack of Si subsidies in sewage, lack of siliceous organisms in the nearshore marine environment, and the relative speed of mixing processes relative to diagenetic reactions.

DIP concentrations show a fairly wide range of scatter around the conservative mixing line. There is

no indication, however, of enrichment of DIP relative to conservative behavior, so there is no indication of nutrient subsidy.

The plot of DIN vs. salinity shows a distinctly different trend than either DIP or Si. It can be seen that the majority of DIN concentrations are greater than would be expected with conservative mixing. Such deviation from the groundwater-to-ocean mixing line indicates an additional source term for DIN. The most likely possibility of the origin of the source is sewage discharge via cesspools along the shoreline. Cesspools and injection wells introduce nutrient rich material directly into the aquifer. Thus, cesspool effluents are not subject to biological and chemical uptake processes associated with percolation through the plant-soil zone that occur with irrigants applied to golf courses. There is, however, no distinct indication of curvature in the measured mixing line. Lack of curvature suggests that biological uptake of the nutrient subsidies is slow compared to mixing processes.

It is possible to evaluate the magnitude of the net source of "cesspool nitrogen" into the nearshore system (see Dollar and Smith 1988 for derivation of equations). The equation for calculating the magnitude of the net source is:

$$R_y = F * (Y_o - Y_f(S_o\, dY/dS)$$

where F equals the magnitude of groundwater flow effluxing at the shoreline. Mink estimates groundwater flow to be 1.4 million gallons per day (mgd) per mile of shoreline (3×10^3 m^3 per km per day). The coastline length of the development property is approximately 1.3 km, thus groundwater efflux into the nearshore environment off the proposed development is approximately 4.1×10^3 m^3 per day. Y_o and Y_f are DIN concentrations in the ocean (0.2 µM) and in groundwater (35.5 µM), respectively. S_o is oceanic salinity (35.970/$_{oo}$), while dY/dS equals -2.16 between salinities of 34.00 ^{o}/oo and 34.97 ^{o}/oo, based on the best fit straight line through the data points. Solution of the equation using the values listed above results in a daily input into the marine environment of 166 moles of DIN.

Existing land use maps indicate that there are approximately 220 house lots fronting the proposed development. Using City and County statistics there are an average of 2.6 persons per household. Average sewage generated per person per day is approximately 400 l, while domestic sewage has a nitrogen content of approximately 20 mg/l (1.4 mM). Therefore, approximately 320 moles of nitrogen per day are delivered to cesspools fronting the proposed development. Solution to the equation based on non-conservative behavior of the DIN mixing line indicates that approximately 166 moles reach the nearshore marine environment. It appears from these calculations that there is a definite recognizable input of cesspool related nutrients into the marine environment at the present time.

It is also possible to estimate the sewage irrigant contribution to the nearshore zone from the proposed golf course. Projected peak capacity of the project sewage treatment plant is 190,000 gpd (7×10^5 l per day). Sewage effluent nitrogen concentration at Lihi Lani are expected to be about 5-7 mg/L (Robert Gearheart, personal communication). If all sewage nitrogen generated by the STP is used as golf course irrigant, a total of 260 moles of N will be applied each day. Existing literature states that golf course grasses remove about 95% of the N and 100% of the P applied as irrigants (Chang and Young 1977, Lau 1975). Thus, if 5% of applied N can percolate through the soil zone and reach groundwater, 13 moles may reach the nearshore environment, barring any further biological and chemical uptake processes during the transit to the ocean (a very unlikely occurrence). Thus, the maximum golf course contribution to groundwater nutrient subsidy is only about 4% of the 320 moles that is injected directly into the water table at the shoreline through cesspool disposal.

While the amount of sewage that may reach groundwater is small compared to the material added by cesspools at the shoreline, it is also important to know the contribution of sewage to total fertilizer. Murdoch and Green (1988) report that average golf courses in Hawaii require about 29 moles of N per acre per day. Approximately 90 acres of golf course at Lihi Lani will employ treated sewage as irrigant. Distribution of the 370 moles of N produced by the sewage treatment plant will result in application rates of about 4 moles N per acre per day. Thus, only about 14% of the necessary fertilizer N will originate from sewage effluent, with the remainder from commercial mixes.

Because sewage effluent does not differ qualitatively from commercial fertilizer mixes, and because sewage will constitute a relatively small fraction of the material used as fertilizer, it is perhaps more relevant to evaluate the potential effects to groundwater from all fertilizers applied to the golf courses. At the groundwater flow rate of 4.1×10^3 m^3 per day for the shoreline length of the development, and groundwater DIN concentration of 35.5 µM, approximately 145 moles of DIN is delivered per day to the nearshore marine environment. Total application of N to the golf course is estimated at 3×10^3 moles per day (Murdoch and Green 1988). Thus, all nutrient material to be added to the courses constitutes about 20 times the nitrogen that enters the ocean through natural input. If the golf course grass/soil complex takes up the expected 95% of material through biological and chemical processes, 150 moles per day can potentially enter groundwater. Such an input is about half of the estimated existing cesspool contribution to groundwater of approximately 320 moles.

Therefore, it appears that operation of the golf course has the potential to provide some additional nutrient subsidies to the nearshore marine environment. It is important to note, however, that the estimates are based on liberal estimates of groundwater percolation and do not take into account processes that occur during the transit from the site of percolation to efflux at the ocean. Perhaps the most important of these processes is denitrification, an anaerobic reduction of NO_3^- to N_2 gas. Such processes may result in substantial reduction of nitrogen in percolate reaching the ocean. In addition, the open coastline mixing regime that characterizes the environment during the entire year will probably disperse any nutrient subsidies rapidly, with no alteration to water quality or biotic assemblages. Benthic plants, which are abundant in the nearshore zone during the summer also serve as "scrubbers" which remove dissolved nutrients from the water column.

Other studies in the Hawaiian Islands also indicate that on open ocean coastlines, nutrient enrichment to the nearshore marine environment from golf course operation is not occurring. Dollar and Smith (1988) applied the conservative mixing model described above to water samples collected off of 4 existing golf courses on the west coast of the Island of Hawaii. The surveyed courses had been in operation for 8 to 23 years, and all employed treated sewage and/or commercial mixes for

fertilization. The only case where non-conservative behavior of DIN was noted was at Keauhou Bay, located directly downslope from a 27-hole golf course. It appears that reduction in mixing in the semi-enclosed bay, as well as groundwater focusing resulted in increased nutrient concentrations similar to those observed off Pupukea from cesspool input. No nutrient sources were detected from the 3 golf courses located on open coastlines. Mixing and dilution in open coastal areas is apparently sufficient to eliminate the detection of added fertilizers.

Equating the survey results from the Big Island to the proposed Pupukea project provides a basis to estimate the effects from the subject development. Mixing by nearshore processes at Pupukea is generally greater than the leeward areas where the Big Island golf courses are located. In addition, all of the golf courses on the Big Island were located directly on the coastline, without the buffer zone between the ocean and bluffs where the golf course will occur at Pupukea. Geologic structure of the younger Island of Hawaii is characterized by less weathered substrata, and essentially no naturally existing soil. Thus, percolation and lateral movement through the aquifer is probably faster on Hawaii than Oahu. All of these factors appear to indicate that the situation at Pupukea will not differ from that on Hawaii, where no negative impacts were determined.

In addition to subsidy from percolation to groundwater, storm runoff may also result in increased material delivery to the ocean. Dugan (1990) estimates the changes from present conditions to the fully developed Pupukea site in storm water runoff and constituents (N, P and suspended solids). Model storms in Dugan's estimates have durations of either 1 or 24 hours, and recurrence intervals of 2, 10, 50 and 100 years.

With respect to suspended solids, loading is expected to decrease for all storm scenarios with the full development in place, relative to present conditions. Suspended solids transported to the ocean via streamflow can result in decreased water clarity and potentially limit settlement and growth of biota. Hence, decreases in suspended solids can be considered an environmental benefit of the proposed development. Erosion during construction probably presents the greatest potential for alteration of water quality. However, if such events should occur, it is likely that inputs will be episodic in nature, and will be temporary in effect. Similar situations occur at present following intense storms which result in runoff entering the nearshore zone as sediment plumes which are dispersed by wave and current action.

Dugan's estimates of changes in nutrient delivery for nitrogen range from an increase of 12.2 lbs. (396 moles) in the 1 hr, 2 yr recurrence storm to a decrease of 121 lbs (4×10^4 moles) for the 24 hr, 100 yr recurrence storm. All of the 1 hour duration storms result in increases between about 12 and 20 lbs. of nitrogen, while three of the 24 hour storms result in decreases of nitrogen in storm runoff.

Thus, as is the case for suspended sediments, with the longer duration storm events, there appears to be lowered potential for N delivery to the nearshore ocean with the development in place relative to existing conditions. With respect to the storm events which appear to result in increases in N delivery, several important points should be considered. First, storm input occurs episodically, and is not a potentially chronic or long-term stress. If the highest projected N input from a 1 hour storm event

(19.9 lbs for the 100 yr recurrence event) is normalized for the interval between storms, incremental additions for the entire development would be 1.8 moles N per day. By comparison, it appears that about 143 moles of N enter the ocean each day via natural groundwater input, with an additional 166 moles a day via cesspool input. Thus, the contribution from increased runoff following the most severe scenario is equivalent to approximately 0.5% of the input that is presently occurring on a daily basis.

Projected changes in phosphorus input all show increases for the spectrum of storm events. Increases range from 7.6 lbs (539 moles) for the 1 hr duration, 2 yr recurrence event, to 438 lbs (31,098 moles) for the 24 hour duration, 100 yr recurrence event. Again normalizing the most severe of these inputs to a daily rate indicates that for the 24 hour event the increase will equal about 0.85 moles per day. Natural inputs of phosphorus from groundwater to the site are approximately 8 moles per day. Thus, the most severe event could result in an increase of about 10% of the phosphorus input to the nearshore ocean.

As uncontaminated groundwater is substantially higher in nitrogen and phosphorus than oceanic water, it is possible that the projected increases in phosphorus input from storm runoff could result in increased uptake by plant biota. However, several scenarios will likely prevent this community response. It is likely that during severe weather events, natural stresses to the environment in the form of wave action will probably prove substantially more damaging than increased nutrients in stream runoff. Mixing processes are likely to be maximal during storm events and will probably dilute the small amount of additional runoff rapidly to background levels after entry in the ocean. Thus, it is unlikely that community responses in the form of eutrophication will probably not occur owing to the rapidity of mixing of the nutrient subsidy.

RECOMMENDATIONS

Probably the greatest potential for detrimental impacts to the marine environment will arise from high intensity (rainfall) storms during construction. If possible, construction phases involving exposed lands should be scheduled during the summer months, when rainfall is lowest. Erosion will also be minimized by compliance with all governmental regulations and standards.

It has also been shown that there is a potential for nutrient enrichment from golf course fertilization. Realization of this potential is largely a matter of sound golf course management practice. Timing of fertilization with respect to heavy rainfall is a significant parameter in minimizing percolation to groundwater. As a large percentage (80-90%) of fertilizer material will be composed of commercial mixes rather than treated sewage effluent, it does not appear that situations will occur where sewage will accumulate. Because economics is an important aspect of golf course management, it is also unlikely that excess commercial mixes will be applied; nevertheless, this possibility should be carefully avoided.

It is also recommended that an ongoing monitoring program be instituted to assure that operation of

the development will not contribute to environmental degradation. The ideal methodology for implementing such a monitoring program would employ a conservative mixing model such as that utilized in the present study. Initial phases of the monitoring plan would involve defining the "pre-development envelope" of water quality parameters. Such an envelope would take into account the present nutrient enrichment that is apparently a result of coastal cesspools. Repetitive sampling during each phase of construction and operation of the development will indicate if parameters remain within the envelope. An advantage of using a mixing model as a monitoring tool is that the method is sensitive enough to identify changes in water quality parameters at levels within the natural tolerance of the biological communities. Thus, water quality changes can be identified before environmental degradation occurs. If it is determined that operation of the development is causing environmental changes, further mitigating measures could be instituted at an early stage, prior to serious environmental alteration.

CONCLUSIONS

1. The marine environment off the proposed Lihi Lani recreational development is characterized by seasonal intense wave activity which limits the development of reef biota to those assemblages which can withstand the impact of breaking waves. As a result coral community assemblages are limited to thin veneers. Reef fish communities are limited owing to lack of habitat shelter and apparent overfishing. Such community assemblages which are pre-adapted to high stress conditions are less susceptible to alteration from additional man-induced stresses. There does not appear to be any indication that the proposed development will cause any direct impact on nearshore biological communities or endangered and protected species.

2. Water chemistry analyses indicate that nutrients present in high concentrations in groundwater (NO_3^-+NO_2^-, Si) are also present in relatively high concentrations close to the shoreline. Nutrients and other chemical parameters not present in high concentrations in groundwater are distributed uniformly through the nearshore zone. There does not appear to be a distinct surface layer, and the entire water column appears to be well-mixed vertically.

3. Application of a conservative mixing model to nutrient data indicates that at the present time there is an external dissolved inorganic nitrogen source within the nearshore zone. The source is probably attributable to leaching from residential cesspools near the shoreline. There is no indication, however, that the nutrient subsidy is resulting in biological impacts in the nearshore zone. Thus, with respect to the proposed development, baseline conditions are characterized by man-induced alterations to the existing environment.

4. Operation of the golf course will include fertilization with commercial chemical mixes and treated sewage effluent. Effluent will comprise a small fraction of the total nitrogen fertilizer. However, chemical and biological uptake processes during transit through the aquifer will likely reduce the potential nutrient subsidy to the nearshore marine environment. Wave and current mixing in the nearshore environment is likely to dilute any nutrient subsidies to the extent that there will be no

degradation of water quality and biotic community structure. Studies of other golf course situations in Hawaii reveal that as long as the receiving environment is a well-mixed coastal area, nutrient contributions to the ocean are below the level of detection. It is extremely unlikely that the planned golf courses at Pupukea will result in detectable alteration to the marine environment.

5. Erosion during construction presents the greatest potential for changes in the nearshore ocean. Such effects will be minimized by careful planning and management. If high intensity erosion events do occur, it is likely that effects to water quality will be temporary, and not substantially different than events that occur at present.

6. Estimates of storm runoff characteristics indicate that delivery of suspended solids to the ocean will decrease following construction of the development relative to existing conditions. Freshwater and dissolved phosphorus input is projected to increase during all theoretical storm events, while nitrogen will increase during 1 hr duration events, and decrease during most of the 24 hr duration events. These projected subsidies, however, will be episodic in nature and will not constitute chronic stresses. The high mixing regime of the receiving environment will likely disperse storm inputs rapidly.

7. While negative impacts are unlikely, implementation of a monitoring program based on the principles employed in the baseline study will allow identification of adverse environmental alterations associated with the development at levels within natural limits of tolerance of reef communities. If such conditions are identified mitigating management practices can be implemented which can reverse the negative effects.

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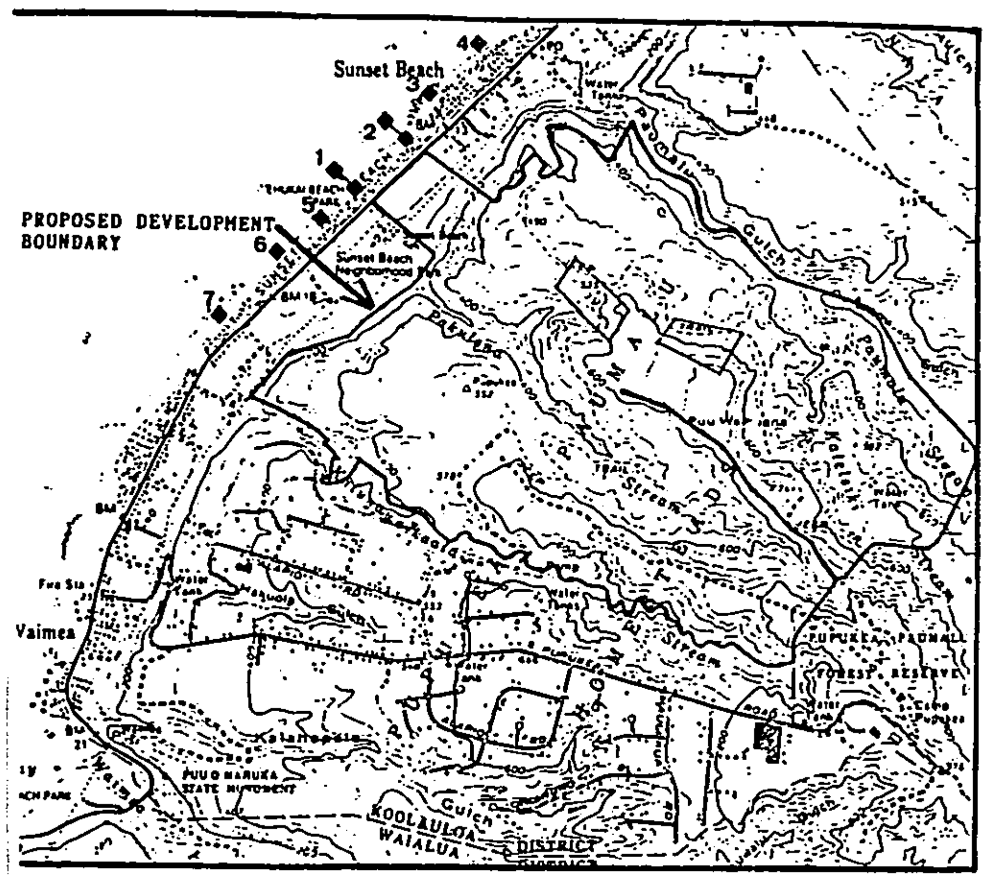

FIGURE 1. Map showing location of proposed Lihi Lani development boundaries, and water chemistry sampling stations.

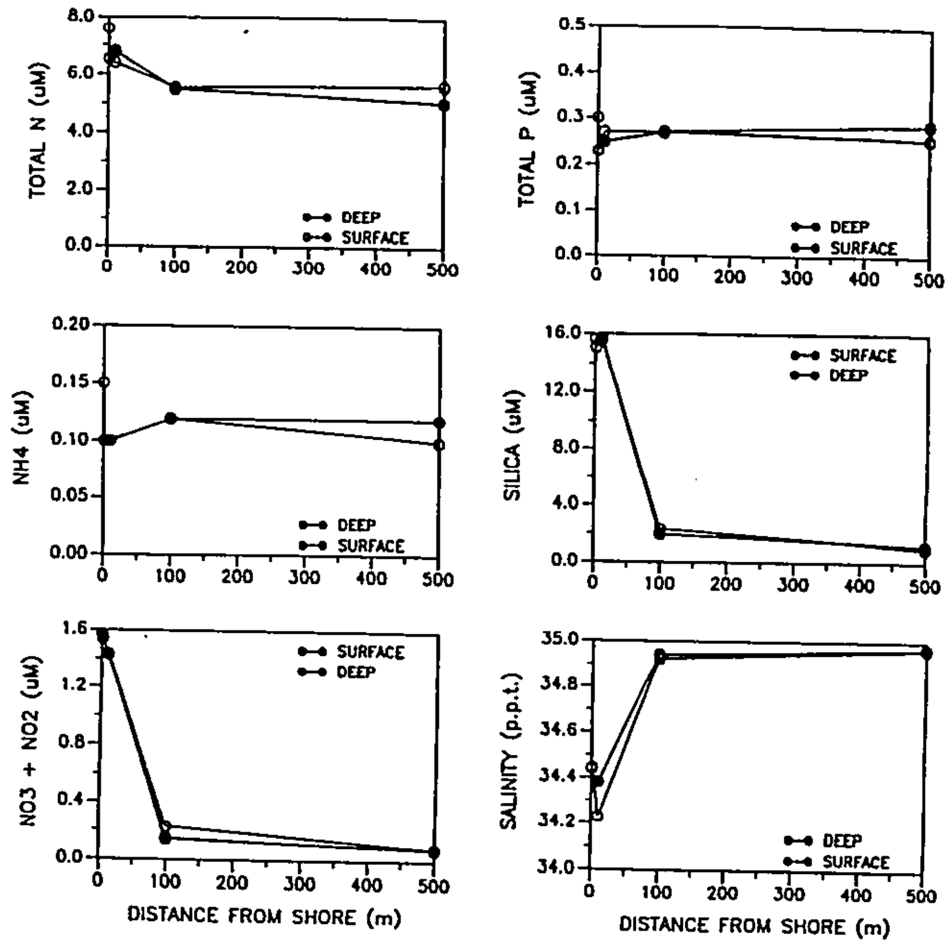

FIGURE 2. Plots of nutrient parameters and silica versus distance from shore. It can be seen that $NO_3^-+NO_2^-$, silica and salinity show distinct nearshore effects as a result of groundwater efflux. The similarity between surface and deep concentrations indicates that the entire water column is well-mixed vertically at all sampling locations.

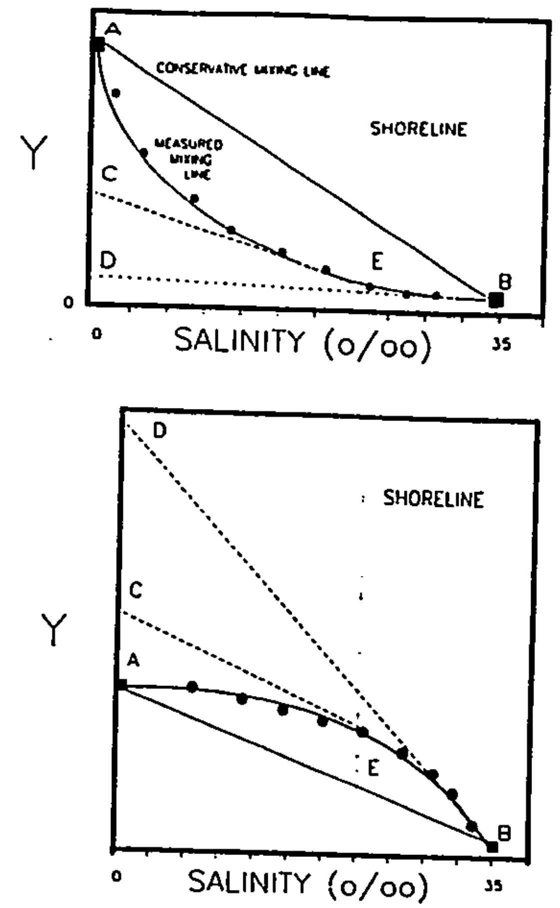

FIGURE 3. Hypothetical graphs showing characteristics of mixing models for net sink (top) and net source (bottom) of non-conservative material Y. The conservative mixing line is the straight line connecting concentrations of Y at the freshwater endpoint (A) and open ocean endpoint (B). Measured mixing lines pass through data points with E representing concentration of Y at the shoreline. The net sink of Y taken up on land equals the magnitude of A-C, with C representing the Y-intercept of the tangent line of the measured mixing line at E. The net sink of Y taken up by the nearshore ocean is C-D with D representing the tangent line of mixing curve at B. Similarly, net sources for material Y equal A-C on land, and C-D in the ocean.

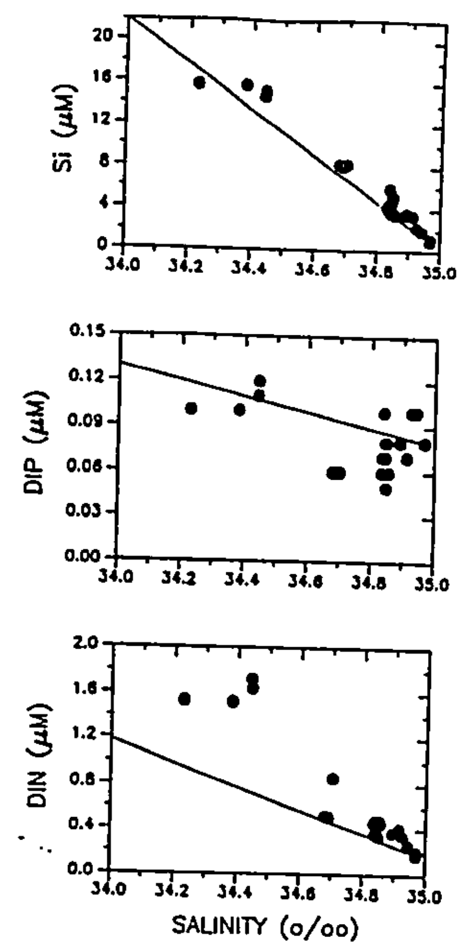

FIGURE 4. Plots of silica (Si), dissolved inorganic phosphorus (DIP) and dissolved inorganic nitrogen (DIN) versus salinity. Straight lines are conservative mixing lines constructed by connecting nutrient concentrations of open ocean water (34.97°/..) and BWS well water (0.3°/..). Si is behaving conservatively, while scatter of DIP data is too great to infer any trends. Distribution of DIN data points above the conservative mixing line indicates a definite external source of nitrogen to the nearshore zone. The most likely explanation of the source is percolation of ceespool related material into the marine environment.

TABLE 1. Water chemistry constituents in marine water samples collected off the proposed Lihi Lani development. For sampling locations, see Figure 1.

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	TOTAL NITROGEN		AMMONIA NITROGEN		NITRATE + NITRITE NITROGEN		ORTHO-PHOSPHATE PHOSPHORUS		TOTAL PHOSPHORU		SILICA		CHL. a	TURBIDITY (Nephelometric turbidity units)
		(uM)	(ug N/L)	(uM)	(ug N/L)	(uM)	(ug N/L)	(uM)	(ug P/L)	(uM)	(ug P/L)	(uM)	(ug S/L)	(ug/L)	
1	0	7.59	106.26	0.15	2.10	1.57	21.98	0.12	3.72	0.30	9.30	15.65	438.20	0.28	0.41
	1	6.54	91.56	0.10	1.40	1.54	21.56	0.08	2.48	0.23	7.13	15.07	421.96	0.30	0.47
	10 (surface)	6.40	89.60	0.10	1.40	1.43	20.02	0.10	3.10	0.27	8.37	15.65	438.20	0.28	0.46
	10 (deep)	6.79	95.06	0.10	1.40	1.43	20.02	0.10	3.10	0.25	7.75	15.65	438.20	0.31	0.28
	100 (surface)	5.53	77.42	0.12	1.68	0.22	3.08	0.10	3.10	0.27	8.37	2.29	64.12	0.21	0.18
	100 (deep)	5.48	76.72	0.12	1.68	0.14	1.96	0.12	3.72	0.27	8.37	1.91	53.48	0.23	0.32
	500 (surface)	5.65	79.10	0.10	1.40	0.08	1.12	0.08	2.48	0.26	8.06	0.95	26.60	0.09	0.19
	500 (deep)	5.07	70.98	0.12	1.68	0.08	1.12	0.08	2.48	0.29	8.99	1.14	31.92	0.19	0.25
	TRANSECT 1 GEOMETRIC MEAN	6.08	85.12	0.11	1.54	0.42	5.88	0.10	3.10	0.27	8.37	4.78	133.84	0.22	0.30
2	0	5.87	82.18	0.09	1.26	0.43	5.32	0.06	1.86	0.22	6.82	8.26	231.28	0.22	0.35
	1	5.16	72.24	0.10	1.40	0.38	5.32	0.10	3.10	0.22	6.82	5.91	165.48	0.26	0.40
	10 (surface)	5.76	80.64	0.10	1.40	0.38	5.32	0.08	2.48	0.21	6.51	4.58	128.24	0.22	0.30
	10 (deep)	5.60	78.40	0.10	1.40	0.38	5.32	0.08	2.48	0.18	5.58	4.58	128.24	0.22	0.27
	50 (surface)	5.41	75.74	0.12	1.68	0.24	3.36	0.07	2.17	0.18	5.58	3.43	96.04	0.16	0.24
	50 (deep)	5.54	77.56	0.12	1.68	0.22	3.08	0.05	1.55	0.19	5.89	5.15	144.20	0.16	0.26
	100 (surface)	5.65	79.10	0.10	1.40	0.27	3.78	0.08	2.48	0.15	4.65	3.63	101.64	0.26	0.17
	100 (deep)	6.79	95.06	0.10	1.40	0.30	4.20	0.07	2.17	0.14	4.34	3.43	96.04	0.29	0.18
	TRANSECT 2 GEOMETRIC MEAN	5.70	79.80	0.10	1.40	0.31	4.34	0.07	2.17	0.18	5.58	4.67	130.76	0.21	0.26
3	0	5.76	80.64	0.06	0.84	0.40	5.60	0.07	2.17	0.17	5.27	3.78	105.84	0.17	0.37
4	0	6.00	84.00	0.11	1.54	0.34	4.76	0.06	1.86	0.16	4.96	3.58	100.24	0.15	0.26
5	0	5.86	82.04	0.06	0.84	0.40	5.60	0.06	1.86	0.14	4.34	4.17	116.76	0.19	0.30
6	0	5.60	78.40	0.21	2.94	0.65	9.10	0.06	1.86	0.17	5.27	8.26	231.28	0.18	0.25
7	0	5.70	79.80	0.11	1.54	0.40	5.60	0.06	1.86	0.18	5.58	8.06	225.68	0.15	0.24
	GRAND GEOMETRIC MEAN	5.86	82.11	0.10	1.48	0.37	5.30	0.07	2.41	0.20	6.38	4.83	135.24	0.21	0.28
BWS well		35.89	502.46	0.07	0.98	35.46	496.44	1.98	61.38	2.07	64.17	780	21840		

TABLE 2. Non-specific water chemistry parameters listed in DOH water quality standards. For station locations, see Figure 1.

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	Dissolved Oxygen (% sat.)	Dissolved Oxygen (mg/l)	Salinity (p.p.t.)	pH	Temperature (deg. C)
1	0	102	6.82	34.440	8.178	26.5
	1	101	6.38	34.442	8.226	26.2
	10 (surface)	99	6.12	34.227	8.227	26.3
	10 (deep)	103	6.59	34.380	8.221	26.5
	100 (surface)	102	6.45	34.924	8.215	26.4
	100 (deep)	100	6.18	34.941	8.234	26.6
	500 (surface)	106	6.70	34.967	8.171	26.4
	500 (deep)	90	5.57	34.970	8.222	26.4
2	0	100	6.80	34.801	8.157	26.3
	1	109	7.22	34.838	8.147	26.3
	10 (surface)	100	6.68	34.844	8.184	27.6
	10 (deep)	112	7.40	34.850	8.195	26.7
	50 (surface)	120	8.10	34.834	8.231	27.0
	50 (deep)	128	8.90	34.846	8.235	25.7
	100 (surface)	124	8.38	34.890	8.183	25.5
	100 (deep)	120	8.25	34.912	8.198	25.2

TABLE 3. Specific criteria specified by DOH water quality standards for open coastal waters

Parameter	Geometric mean not to exceed the given value	Not to exceed the given value more than 10% of the time	Not to exceed the given value
Total Nitrogen (ug N/l)	150.00* 110.00**	250.00* 180.00**	350.00* 250.00**
Ammonia Nitrogen (ug N/l)	3.50* 2.00**	8.50* 5.00**	15.00* 9.00**
Nitrate +Nitrite Nitrogen (ug N/l)	5.00* 3.50**	14.00* 10.00**	25.00* 20.00**
Total Phosphorus (ug P/l)	20.00* 16.00**	40.00* 30.00**	60.00* 45.00**
Chlorophyll a (ug/l)	0.30* 0.15**	0.90* 0.50**	1.75* 1.00**
Turbidity (Nephelometric Turbidity Units)	0.50* 0.20**	1.25* 0.50**	2.00* 1.00**

*"Wet" criteria apply when the open coastal waters receive more than three million gallons per day of fresh water discharge per shoreline mile.

**"Dry" criteria apply when the open coastal waters receiveless than three million gallons per day of fresh water discharge per shoreline mile.

Applicable to both wet and dry conditions:

pH units shall not deviate more than 0.5 units from a value of 8.1.

Dissolved oxygen - Not less than 75% saturation.

Temperature - Shall not vary more than 1 deg. C from ambient conditions.

Salinity - Shall not vary more than 10% from natural or seasonal changes considering hydrologic input and oceanographic factors.

TABLE 4. Benthic species observed in the nearshore marine environment off the proposed Lihi Lani development. Abundance code is: X = rare (1-10 individuals or colonies sighted), XX = common (10-50 individuals or colonies sighted, and XXX = abundant (> 100 individuals or colonies sighted).

Species	Abundance Code
CORALS (Scleractinia)	
Porites lobata	XXX
Porites compressa	X
Pocillopora meandrina	XXX
Montipora patula	XX
Montipora verrusoca	X
Monitipora flabellata	XX
Pavona varians	XX
Leptastrea purpurea	X
Palythoa tuberculosa	XX
ALGAE	
Green Algae	
Codium spp.	XX
Enteromorpha spp.	XXX
Halimeda opuntia	XXX
Brown Algae	
Dictyopteris spp.	XXX
Dictyota acutiloba	XXX
Lobophora variegata	X
Padina japonica	X
Ralfsia pangoensis	XX
Sargassum echinocarpum	XX
Sphacelaria furcigera	XXX
Turbinaria ornata	XX
Red Algae	
Corallina spp.	XX
Galaxaura fastigiata	XX
Galaxaura rugosa	XXX
Hydrolithon reinboldii	XXX
Hypnea chordacea	XXX
Lithophyllum spp.	XX
Mesophyllum mesomorphum	XXX
Neogoniolithon frutescens	XXX
Plocamium sandvicense	XXX
Porolithon onkoides	XXX

TABLE 4. continued.

SEA URCHINS (Echinoidea)	
Echinothrix diadema	X
Tripneustes gratilla	X
Echinometra matheai	XX
Echinometra oblonga	XX
Echinostrephus aciculatus	X
SEA CUCUMBERS (Holothuroidea)	
Actinopyga mauritiana	X
Holothuria atra	X

TABLE 5. Reef fish observed in the nearshore marine environment off the proposed Lihi Lani development. Abundance code. X = rare (< 10 individuals), XX = common (10-100 individuals), and XXX = abundant (> 100 individuals).

FISTULARIDAE	
Fistularia petimba	X
KYPHOSIDAE	
Kyphosus bigibbus	XX
CIRRHITIDAE	
Cirrhitus pinnulatus	XX
Paracirrhites arcatus	X
MULLIDAE	
Mulloidichthys flavolineatus	X
Parupaneus multifasciatus	XX
P. cyclostomus	X
LUTJANIDAE	
Lutjanus kasmira	X
LETHRINIDAE	
Monotaxis grandoculis	X
CHAETODONTIDAE	
Chaetodon lunula	X
C. quadrimaculatus	X
C. unimaculatus	X
C. multicinctus	X
C. auriga	X
Forcipiger flavissimus	X
POMACENTRIDAE	
Abudefduf abdominalis	XX
A. sordidus	X
Plectro. johnstonianus	X
P. imparipennis	X
. ·, gastes fasciolatus	XX
..comis ovalis	XX
LABRIDAE	
Cheilio inermis	X
Bodianus bilunulatus	X
Coris gaimard	X
C. venusta	X
Anampses cuvier	X
Thalassoma duperrey	XXX
T. trilobatum	X
T. ballieui	X
Labroides phthirophagus	X
Stethojulis balteata	X

TABLE 5. Continued.

SCARIDAE	
Calotomus sp.	X
Scarus rubroviolaceus	X
Juvenile Scarus	X
ACANTHURIDAE	
Acanthurus triostegus	XXX
A. leucopareius	XX
A. olivaceus	XX
A. dussumieri	X
A. blochii	XX
A. nigrofuscus	XXX
Ctenochaetus strigosus	X
Naso lituratus	X
N. unicornis	XX
ZANCLIDAE	
Zanclus cornutus	X
MONOCANTHIDAE	
Pervagor spilosoma	XX
BALISTIDAE	
Rhinecanthus rectangulus	X
Sufflamen bursa	X
S. fraenatus	X
TETRADONTIDAE	
Canthigaster jactator	X

APPENDIX N

PAUL H. ROSENDAHL, Ph.D., Inc.
Consulting Archaeologist

Report 363-032988

ARCHAEOLOGICAL RECONNAISSANCE SURVEY
AND LIMITED SUBSURFACE TESTING
PUPUKEA-PAUMALU DEVELOPMENT PROJECT AREA

Lands of Pupukea and Paumalu
Koolauloa District, Island of Oahu
(TMK:1-5-9-05:38; 1-5-9-06:1,18,24)

by

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May 1988

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SUMMARY

During the periods January 11-20, and January 29-March 10, 1988, Paul H. Rosendahl, Ph.D., Inc. (PHRI) conducted a 100% pedestrian surface reconnaissance and limited subsurface testing (backhoe and hand-trowel) within the c. 1,130 ac Pupukea-Paumalu Development project area, located in the District of Koolauloa, Island of Oahu (TMK:1-5-9-05:38; 1-5-9-06:1,18,24). The basic purpose of the reconnaissance and testing was to identify and evaluate all sites of possible archaeological significance within the project area.

Subsurface testing was conducted on January 15, 1988. Nine backhoe trenches were excavated—eight to assess the possible presence of buried agricultural or cultural deposits, and a ninth to confirm Site T-15 as an historic irrigation ditch. Subsurface probes (using hand trowels) were conducted at 20 rockshelters. Approximately 165 man-days of labor were expended on the reconnaissance and testing field work. Upon completion of the work, survey findings and preliminary conclusions--including tentative evaluations and recommendations—were discussed with Dr. Joyce Bath, staff archaeologist in the State Department of Land and Natural Resources-Historic Sites Section (DLNR-HSS) (January 22, and April 15, 1988). Dr. Bath will formally review project findings upon submission of this final report.

During the current project, 60 sites were identified. Six of the 60 sites were located immediately outside of the project area. These sites will not be affected by project development activity. The 54 sites within the project area appear to represent three temporal periods: 25 sites date to the late prehistoric and/or historic period; 22 sites date to about 1880 to 1920; and seven sites date to 1920 to 1970. Most of the sites reflect economic and subsistence activities; however, several sites are related to either military activity or mortuary/ceremonial activities. Most of the features in the project area are stone structures, most of which have been damaged to varying degrees either by cattle grazing, by agricultural clearing, or by natural occurrences such as landslides, alluviation, and stream erosion. Thirty-one of the 54 sites in the project area have been assessed as having minimal archaeological significance; no further work is recommended for these 31 sites. Further data collection is recommended for the remaining 23 sites. The remaining 23 sites are almost all prehistoric or early historic, and almost all of them are within natural caves/rockshelters. Several sites contained human burials. One site, Site T-70 (complex), contained four rock shelters and a petroglyph gallery; three of the four rock shelters contained burials.

Cover: Petroglyphs at Site T-13, Feature G (PHRI Neg.764:9).

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (CONT.)

TABLES

INTRODUCTION

BACKGROUND

At the request of Mr. Ralph Portmore, project manager for Group 70, on behalf of Group 70 client, Ohbayashi Hawaii Corporation, Paul H. Rosendahl, Ph.D., Inc. (PHRI) conducted a combined surface (100% pedestrian reconnaissance) and subsurface (limited backhoe trenching) archaeological reconnaissance survey at the 1,130 ac Pupukea-Paumalu Development project area, located in the Lands of Pupukea and Paumalu, Koolauloa District, Island of Oahu (TMK:1-5-9-05:38; 1-5-9-06:1,18,24). The primary objective of the survey was to provide information appropriate to and sufficient for an Environmental Assessment (EA) being prepared in support of application for a State Land Use Boundary Amendment and a City or County Special Management Area Use Permit.

The present report is the final report on the survey; it includes (a) background information, (b) a description of the survey area, (c) a description of field procedures, (d) a discussion of findings and results, and (e) significance evaluations and recommended general treatments for each identified site. Field work for the survey was conducted January 11-March 10, 1988, under the supervision of PHRI Supervisory Archaeologist James D. Mayberry and PHRI Senior Archaeologist Dr. Alan E. Haun. Approximately 165 man-days of labor were expended on the field work. Preliminary findings of the field work--including tentative conclusions and evaluations--were discussed with Dr. Joyce Bath, staff archaeologist with the Department of Land and Natural Resources-Historic Sites Section (DLNR-HSS) (January 22-April 15, 1988). Dr. Bath will formally review the findings upon receipt of this final report.

SCOPE OF WORK -

The basic purpose of the combined surface and subsurface reconnaissance survey was to identify--to discover and locate on available maps--all sites and features of possible archaeological significance in the project area. A reconnaissance survey is extensive rather than intensive in scope, and is conducted to determine the presence or absence of archaeological resources within a specified project area. A reconnaissance survey indicates both the general nature and variety of archaeological remains present, and the general distribution and density of such remains. A reconnaissance survey permits a general significance assessment of the archaeological resources, and facilitates the formulation of realistic recommendations and estimates for such further archaeological work as might be necessary or appropriate. Such further work could include intensive survey--further data collection involving detailed recording of sites and features, and selected test excavations; and possibly subsequent mitigation--data recovery research excavations, interpretive planning and development, and/or research, interpretive, and/or cultural values.

The specific objectives of the present survey were four-fold: (a) to identify (find and locate) all sites and site complexes present within the survey area; (b) to evaluate the potential significance of all identified archaeological remains; (c) to determine the possible impacts of proposed development upon the identified remains; and (d) to define the scope of any subsequent archaeological work that might be necessary or appropriate.

The reconnaissance survey was carried out in accordance with the minimum requirements for reconnaissance-level survey recommended by the Society for Hawaiian Archaeology (SHA). These standards are currently used by DLNR-HHS and the State Historic Preservation Office (SHPO) as guidelines for the review and evaluation of archaeological reconnaissance survey reports submitted in conjunction with various development permit applications.

PROJECT AREA DESCRIPTION

The Pupukea-Paumalu Development project area consists of c. 1,130 ac located in the Lands of Pupukea and Paumalu, Koolauloa District, Island of Oahu (TMK:1-5-9-05:38; 1-5-9-06:1,18,24) (Figure 1). The project area ranges in elevation from 15' to 775' AMSL (above mean sea level). It is bounded on the northeast by Paumalu Stream; on the east by Pupukea-Paumalu Forest Reserve; on the south and southwest by Kalunawaikaala Stream and on the west and northwest by residential districts.

The project area is characterized by three vegetation groups--xerophytic shrubs (in coastal lowlands), mixed open forest and shrubs (in western uplands), and shrub and closed forest (in wet uplands) (Nagata 1988). A recent botanical survey by Nagata (1988) illustrates the effects modern agriculture has had on the project area. Nagata indicates that vegetation in most of the project area is comprised of introduced species that thrive in disturbed areas. Uplands of the project area retain dense ironwood forests (Casuarina equisetifolia [L.]), some eucalyptus trees, and some open pasture comprised of grasses and 'uhaloa (Waltheria americana [L.]). Vegetation in the major gulches is generally comprised of strawberry guava (Psidium cattleianum Sabine), Christmas-berry (Schinus terebinthifolius Raddi), Java plum (Eugenia javanica Lamb.), ironwood, grasses and 'uhaloa. Vegetation in the SHA portion of the project area has been described as a "lowland wasteland, a vegetational mosaic of ironwood, kiawe, grasses and a host of other exotic trees and shrubs" (Nagata 1988).

According to Nagata (1988:8), there is very little native flora left in the project area. Only a few species can be found in any quantity: huehue (Cocculus ferrandianus Gaud.) in the uplands and higher slopes, and ulei (Osteomeles anthyllidifolia [Sm.] Lindl.) and pala'a (Stenoloma chinensis [L.] Bedd.), mostly on exposed upper slopes. The few native trees in the project area include sandalwood (Santalum freycinetianum), halapepe (Pleomele halapepe), and four specimens of Koolau Eugenia--the only examples known to exist.

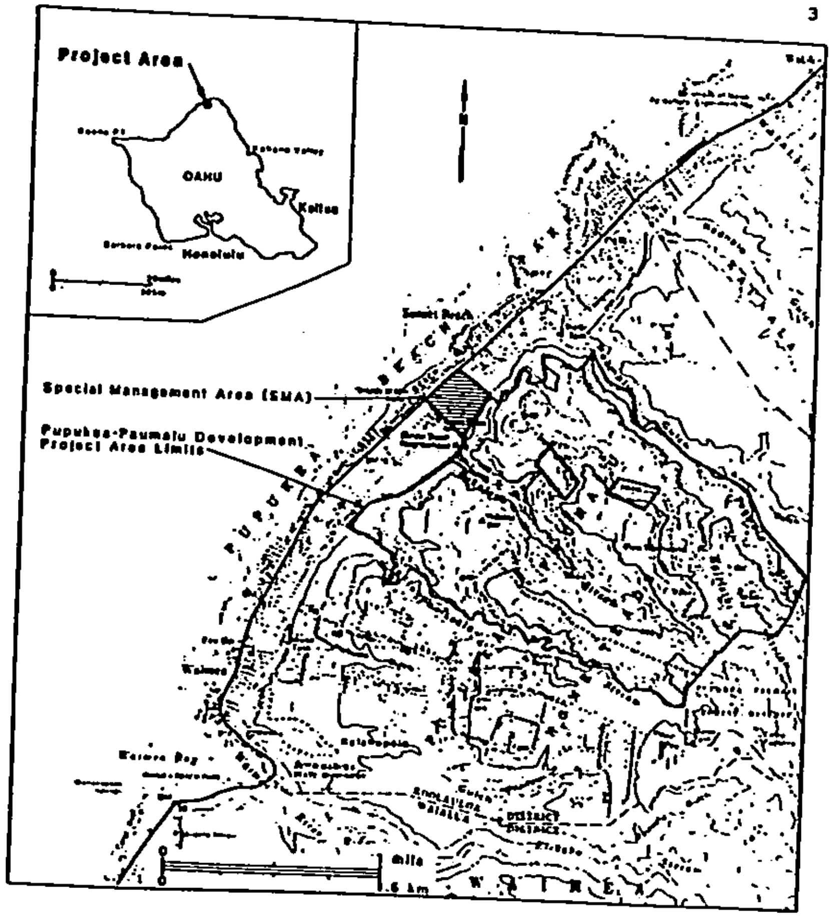

FIGURE 1. PROJECT AND SURVEY AREA LOCATION MAP

Archaeological Reconnaissance Survey
and Limited Subsurface Testing
Pupukea-Paumalu Development Project Area
Lands of Pupukea and Paumalu, Koolauloa District
Island of Oahu (TMK:1-5-9-05:38; 1-5-9-06:1,18,24)

PHRI 87-363 January 1988

The project area, which receives approximately 40-60 inches of rainfall per year (primarily in December to February), contains no permanent water sources. In the past however, a sizeable spring is said to have been present in Paumalu Gulch (Handy and Handy 1972:88), and the major streams in the project area, although insufficient for irrigation agriculture, may have flowed year around. The availability of fresh water in the past probably was not the environmental constraint that it is today. In the past, the hydrologic conditions in the project area were probably very different, especially prior to the 19th century. In the 19th century the area underwent almost total deforestation followed by intensive agriculture.

The topography of the project area is somewhat unique. It has been described as "two large plateaus separated by a large gulch [created by Pakulena Stream] and bordered on either side by large gulches [created by Paumalu and Kalunawaikaala Streams]" (Nagata 1988:1). The project area contains four major streams--the three above and Kaleleiki Stream. These streams over the ages have cut deeply into the two plateaus. The gulches are narrow and their sides are steep. The bottoms of the gulches, occupied entirely by streambeds, are usually dry. The plateaus rise moderately to the southeast. The plateau between Kaleleiki and Pakulena Streams rises to 730 ft AMSL (at Puu Waihena).

Most of the uplands of the project area are comprised of deep, moderately sloping well-drained soils. The uplands on either side of Pakulena Gulch are comprised of Paumalu Badlands Soil, which is a silty clay comprising what has remained after surface Paumalu soils have been eroded off by wind and water (Foote et al. 1972). Other portions of the uplands are comprised of either Wahiawa silty clay, Paaloa silty clay, or Kemoo silty clay. Present primarily in Paumalu Gulch is Manana silty clay. Portions of Paumalu Gulch, and much of the western portion of the project area consists of exposed basalt bedrock, which covers 25-90% of the ground surface. The western portion lowlands, below the cliffs in the western portion, are comprised primarily of Waialua silty clay and Kaena stony and very stony clay, the former found only near Kamehameha Highway. Helemano silty clay is restricted to the drainage of Kalunawaikaala Stream.

PREVIOUS ARCHAEOLOGICAL WORK

Over the past 15 years, a number of archaeological investigations have been conducted in the Lands of Pupukea and Paumalu; however, most of the investigations have been specific to Waimea Valley--only a limited amount of work has been done outside of the valley.

Archaeological work within Waimea Valley includes work by Mitchell (1976, 1977), Moore and Luscomb (1974), and Takemoto (1974). While all the the past work in the valley is relevant to the present project, one valley site is of particular interest. This site, D7-26, excavated in the

1970s, has been identified as a kuleana site--a single-family habitation and farm, with agricultural terraces and small mounds thought to have been used for cultivating sweet potatoes (Mitchell 1977). Dated to about 1840, this site may be contemporary with a single-family farmstead tentatively identified in the present project area (Site T-13).

Archaeological investigations outside Waimea Valley include studies by Dennison (1979), Rogers (1976), and Yent (1979). Rogers recorded a burial cave in a seaward cliff less than half a kilometer southwest of the present project area. The cave, Site 50-Oa-F1-10*, though only 8.4 square meters in area, contained the remains of at least nine individuals. Two individuals were in wooden coffins. One secondary burial was in a wooden canoe. Remains of other individuals (long bones) were bundled in braids of sennit. A wide range of artifacts was found in the cave--a coconut bowl, gourd calabashes, glass bottles, and a wooden walking stick with a rubber tip. After the contents of the cave were inventoried, the cave's entrance was sealed by the Department of Anthropology, University of Hawaii. The cave, which was estimated to date to between the 1700s and the early 20th century, was interpreted as a burial cave for several generations of a single family (Rogers 1976).

During the study by Dennison, a walled enclosure was identified a short distance southwest of the present project area (1979). This enclosure, which measured approximately 330 sq m, was interpreted as an historic animal enclosure of little significance. It has since been destroyed.

During the 1979 study by Yent, two burials were identified just northeast of the present project area, in the sand dunes at Sunset Beach (Yent 1979). Exposed by winter storms, the burials (disarticulated male and female bones) were later reinterred in the more stable inland portion of the dunes. Apparently due to the method of interment, the burials were thought to be associated with the extensive prehistoric midden deposits preserved in the dunes at Sunset Beach.

The only site previously recorded in the project area (listed as Site T-34 in the present report) was first discovered by Gary McCurdy, a nearby land owner. McCurdy, who found the site a year or two before Hurricane Iwa struck the Islands, reported it to the Bishop Museum. According to McCurdy, Bishop Museum reported that the site consisted of a small cave containing two secondary burials--burials of an adult male and possibly a juvenile female. Present with the burials were several fragments of a burial canoe. Checks with Bishop Museum during March and April of this year, yielded no records of the site.

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*B.P. Bishop Museum (BPBM) site designation system: all site numbers prefixed by 50-Oa-F1 (50=State of Hawaii, Oa=Island of Oahu, F=District of Koolauloa, 1=Land of Paumalu).

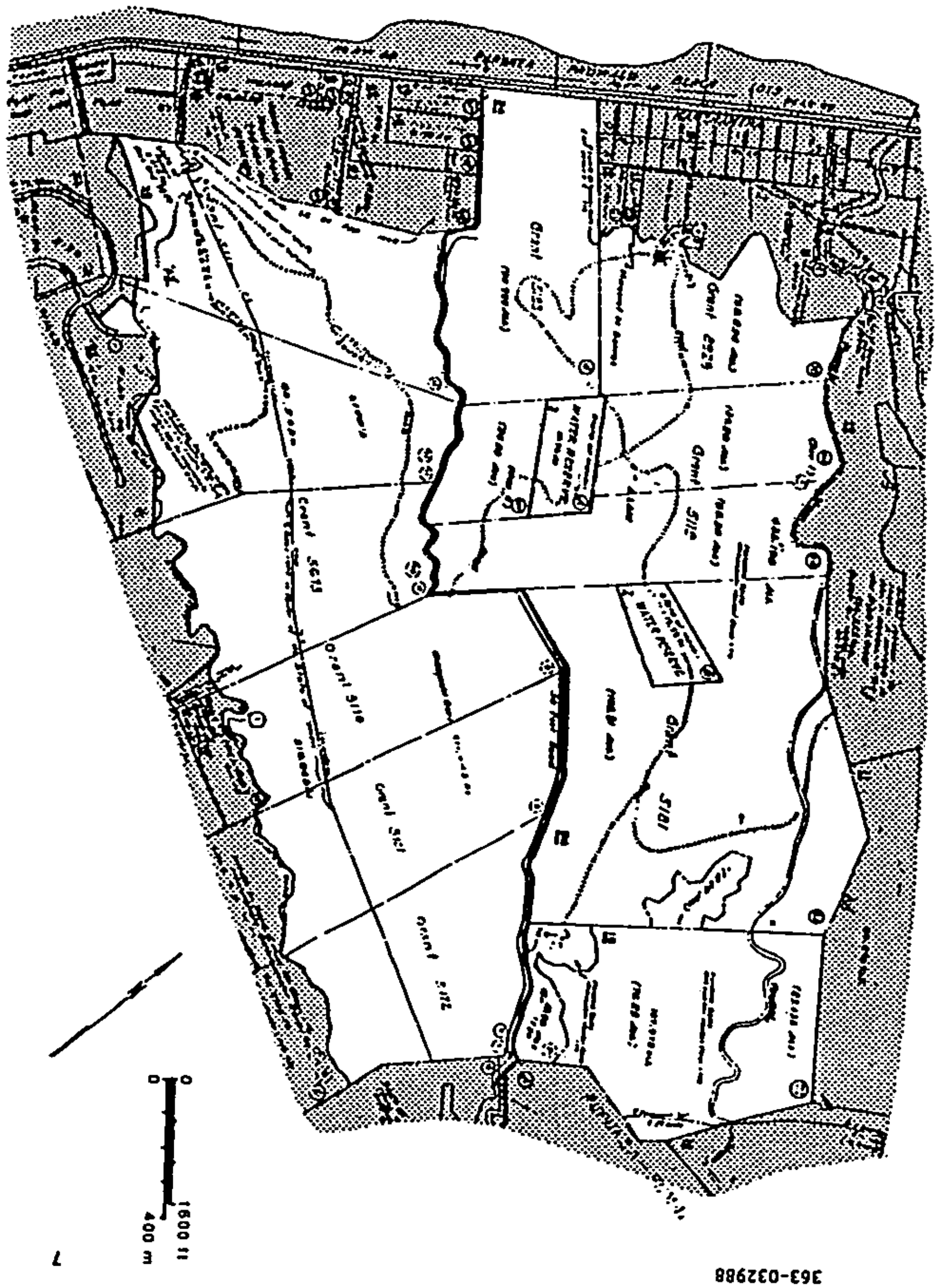
HISTORICAL BACKGROUND

The earliest written descriptions concerning the Lands of Pupukea and Paumalu coincide with early landings of European and American sailing ships at Waimea Bay. The earliest landing of a ship at Waimea Bay was by Captain Cook in 1779. Subsequently, other ships landed, encouraged by the abundance of fresh water in the area of the bay and the sheltered anchorage the bay afforded (Takemoto 1974:6). One early landing at Waimea Bay is particularly notable. When the British ship Daedalus landed in May of 1792, Hawaiians ambushed the landing party, killing three of the party, including the commander. This led the British to retaliate; the guns of the Daedalus bombarded Waimea Valley and heights adjacent to the valley. The bombardment damaged Puuo Mahuka Heiau, a well-known luakini heiau, a monument since 1898 (Estioko-Griffin 1986).

Other than the above, there is little early historical written data on the Lands of Pupukea and Paumalu. This is probably due to the lands' remoteness from Honolulu--historically as well as presently the center of activity on Oahu--and due to the agriculturally marginal nature of the lands, which did not attract many people (Handy and Handy 1972:463). A 1904 tax map indicates that only 86.71 acres of Pupukea were part of Land Commission Awards (LCAs)(Figure 2). The 86.71 acres were awarded to 19 individual kuleanas; these kuleanas were all located in "flat areas between the sea and the pali," and were all comprised of small houselots, saltlands, and sweet potato fields (Estioko-Griffin 1986:22). The rest of Pupukea was owned by King Kamehameha III, and was used as grazing land for wild goats and cattle, which were common on Oahu by 1809 (Morgan 1948:69).

During the early- to mid-historic period, Hawaii underwent many changes. One major change concerned land use, which changed from agricultural use to use for cattle production. Cattle production in Hawaii began in the late 1700s, and by the 1840s and 1850s there were about 60,000 head of cattle on Oahu. It is estimated that 25,000 of the 60,000 head were totally wild (Morgan 1948:170). A Wailua missionary named Emerson noted that the "greatest evil" local farmers faced during that period was wild cattle, owned mostly by whites (Morgan 1948:169). Emerson noted that "the natives [were] not...in the habit of fencing land. Also, the means of fencing were scarce." Thus, the uncontrolled livestock damaged the crops, and many small kuleanas, including some in Pupukea-Paumalu, had to be abandoned. The cattle became such a problem in nearby Kahuku that the entire village was abandoned (Morgan 1948), the native inhabitants unable to take recourse against the white owner of the cattle. Although laws protecting farmers from these depredations were passed in 1846 and 1848, they were not enforced.

Concurrent with the cattle production period came the "sandalwood boom"--a period during which sandalwood trees were intensively logged. The boom began in 1791 and climaxed during the period 1810-1818. By 1829, Oahu was almost totally deforested (Morgan 1948:66). Deforestation led to a number of environmental changes. The water table was lowered, and there was increased flooding and loss of arable land. Also during this period



came the loss of traditional Hawaiian crafts, due to metal becoming commonly available. By 1804, metal tools, once considered precious by Hawaiians, were replacing the traditional shell, bone, and lithic tools (Morgan 1948).

The early history of Hawaii also includes the bloody interisland wars of Kamehameha I (1780-1810), and epidemics in 1804, 1826, 1839, and throughout the 1840s and 50s--epidemics of European origin (Morgan 1948:116) which devastated the Hawaiian population (Atlas of Hawaii:102). It also includes the introduction of Christianity, which quickly replaced the traditional polytheism; by the early 1820s "the Hawaiian religion had come to an end" (Mitchell 1977:31). In Pupukea-Paumalu, the end of the Hawaiian religion was symbolized by the abandonment and destruction of numerous heiau and the establishment in 1832 of a Protestant mission in Waialua (Takemoto 1974:10).

During the 1860s, small-scale farming in the Pupukea-Paumalu area gave way to large-scale plantation agriculture. Originally, sugarcane was produced in the coastal lowlands (Morgan 1948:187); from 1900-1910 the coastal highlands of the north shore, including the present project area, were opened up for pineapple production (Estioko-Griffin 1986:22). Over the years, plantation agriculture on the north shore continued to expand, fueled in part by the extension of the Oahu Railroad & Land Co. railway along the coast from Waialua to Kahuku; the Oahu Railroad & Land Co. had been created specifically to encourage the production of first sugarcane, then after 1899, pineapples (Hungerford 1963). As shown on a 1906 railway schedule and map, the 9.8 mile run from Waimea Station to Kahuku took 24 minutes and passed through but did not stop at the village of Paumalu (Hungerford 1963).

The plantations' greatest period of prosperity was 1920-1925 (Hungerford 1963:26). This period was followed by 20 years of first economic depression, then World War II. In 1928 many of the pineapple plantations in Pupukea were being replaced by avocado orchards. Gradually, there was a lessening of agriculture in the area. A major factor in the decline of the north shore plantations was the railroad lines outside of Honolulu being abandoned in 1947, partly due to their being damaged by the 1946 tsunami. From 1950 to the present, there has been much turnover of prime north shore agricultural lands, including lands in Pupukea-Paumalu, to residential communities (Estioko-Griffin 1986:23). In the present project area, the abandonment of the plateau fields and avocado orchards has led to their being used since the early 1960s as grazing land (J. Hitch, pers. comm.).

FIELD METHODS AND PROCEDURES

Field work was conducted January 11-20, and January 29-March 10, 1988 under the supervision of PHRI Supervisory Archaeologist James D. Mayberry, assisted by PHRI Field Archaeologists Mikele Fager, Edward Kaler, Barbara Strance, and Diane Guerriero. PHRI Senior Archaeologist Dr. Alan E. Haun provided overall supervision and direction for the project. Approximately one thousand, three hundred seventeen (1,317) man-hours of labor were expended in conducting the field work. One hundred percent surface coverage of the survey area was accomplished by means of high- to medium-intensity pedestrian sweeps oriented roughly northeast to southwest. Distance between sweeping crew members was 8-20 m, depending on vegetation cover, terrain, and extent of ground disturbance encountered. Identified sites were assigned a sequential PHRI temporary field number prefixed by "T-," and the numbers were marked on site flags. Certain T- sites upon subsequent closer inspection were dropped, due to a number of factors. Several were found to be natural stone features (T-6, -12, -41, -61); some had been constructed within the last 20-25 years (T-39, -68); and one was an agricultural land clearing rock pile (T-60). Some T- sites were subsumed as features of other sites. The following is a list of these subsumed T-sites and their current designations:

Former T- number	Presently subsumed as:
T-8	Feature L of T-13
T-9	Feature N of T-13
T-10	Feature K of T-13
T-11	Feature M of T-13
T-24	Feature D of T-22
T-26	Feature B of T-25
T-27	Feature B of T-33
T-28	Feature D of T-33
T-29	Feature C of T-33
T-37	Feature D of T-36
T-44	Feature B of T-45
T-51	Feature B of T-52
T-63	Feature B of T-49

All identified sites were plotted on 1=400' scale maps and aerial photos provided by Group 70 and were recorded on standard PHRI site record forms. Recordation included (a) mapping all sites to scale using tape and compass, (b) at least one 35 mm black-and-white photograph of each site (PHRI Roll No.679), and (c) tagging of each site with an aluminum strip bearing the site number, PHRI project number (87-363), and the date. Finally, strips of pink plastic flagging tape bearing the same information as on the aluminum strip were wrapped around trees adjacent to the site to aid site reidentification.

The subsurface reconnaissance, which was conducted in the SMA portion of the project area, included nine backhoe trench test excavations. Each trench was 4-5.0 m long, and a total of 43 linear meters of trench was dug. Stratigraphic levels in the trenches were recorded, and representative cross-section drawings of trench stratigraphies were drawn. Soil samples were collected from possible agricultural deposits in the trenches. At present, analytical results of the samples are unavailable.

FINDINGS

During the present reconnaissance survey of the Pupukea-Paumalu Development project area, 60 previously unrecorded archaeological sites were identified. These sites are summarized in Table 1 according to site number, formal type, tentative functional interpretation, and cultural resource management value mode assessment; and the locations of the sites are indicated on Figure 3.

The sites included the following formal feature types: mounds, alignments, modified outcrops, terraces, freestanding walls, petroglyphs, rockshelters, concrete bunkers, retaining walls, concrete slabs, a chimney, gun turret bases, caves, modern concrete and wood structures, a stone dam, modified trenches, a bottle and rubbish dump, cobbled roads, water crossings, irrigation ditches, a stone-lined well, a large earthen berm, animal enclosures, rock features (possibly having ceremonial or ritual agricultural significance), and a 20th century agricultural and ranching camp. The feature types comprised the following functions: agricultural, ceremonial or religious, transportation, water control, habitation, quarry, temporary habitation, coastal defense, burial, property line, and rock art.

PORTABLE REMAINS

Pre-modern artifacts were found at 12 of the 60 identified sites. These artifacts included small pieces of coral with possible ceremonial significance, non-cortical flakes of volcanic glass, broken pieces and cortical flakes of volcanic glass, angular broken pieces of exotic basalt, a small coral abrader, a polished basalt cobble, a worked flake tool, and the remains of a burial canoe. The small pieces of coral were found at Sites T-1, -69, and -79--sites which are presumed to have had ritual or ceremonial significance. The coral pieces may have been offerings.

The two non-cortical flakes of volcanic glass were present at Feature A of Site T-64, in a scatter of approximately 12 pieces of exotic basalt. The two non-cortical volcanic glass flakes were collected for dating analysis. The cortical flakes and broken pieces (12+ total) of volcanic glass were present at Feature A, Site T-18. The broken pieces and flakes, also collected for dating analysis, were present on the floor of the feature (shelter). Two volcanic glass flakes from Feature A at Site T-64 and the flake from Site T-18 were submitted to MOHLAB, State College, Penn. for hydration-rind age determination and source-affinity analysis. The broken pieces of angular basalt were present on the floor of Feature A of Site T-66, and at Site T-2. The pieces, assumed to have been introduced to the site, do not appear to be the result of core reduction.

Table 1.

SUMMARY OF IDENTIFIED SITES – PUPUKEA-PAUMALU DEVELOPMENT PROJECT AREA

Site Number	Formal Site/Feature Type	Tentative Functional Interpretation	*CRM Value Assess. R	I	C	Comments
T-1	Linear mound	Agricultural(?)/ ceremonial(?)	H	L	L	Possible disturbed terrace; coral offerings?
T-2	Alignment and basalt scatter	Agricultural(?)	L	L	L	Bulldozed/disturbed by cattle
T-3	Mod. outcrop	Agricultural(?)	L	L	L	Bulldozed
T-4	U-shaped earthen berm	Railroad siding(?)	L	L	L	Early 20th century(?)
T-5	Terrace	Agricultural	H	L	L	High, well-preserved terrace wall
T-7	Cairn	Trail or property marker(?)	L	L	L	Collapsed; early historic(?)
T-13	(Complex of 13 features)	Habitation; agricultural; rock art	H	L	H	Late prehistoric/ early historic
T-14	Well and foundation	Water source	L	L	L	Early to mid-20th century(?)
T-15	Ditch	Irrigation	L	L	L	Early 20th century(?)
T-16	Linear mound	Water diversion(?)	L	L	L	Poss. diverted water away from Site T-5; early historic or prehistoric
T-17	Ditch	Irrigation	L	L	L	Early 20th century(?)

*Cultural Resource Mgmt.--Nature: R = scientific research, I = Interpretive, C = cultural
Value Mode Assessment

Degree: H = high, M = moderate, L = low

Table 1. (Cont.)

Site Number	Formal Site/Feature Type	Tentative Functional Interpretation	CRM Value Assess. R	I	C	Comments
T-18	Rockshelter	Temp. habitation; quarry	H	L	L	Short stone wall present near shelter
T-19	Rockshelters [2]	Temp. habitation	H	L	L	Artifacts include coral abrader, polished basalt
T-20	Reinforced concrete bunker	WII coastal defense	L	H	L	Outside project area
T-21	Retaining wall	RR or wagonroad bed	L	L	L	From early 20th century plantation
T-22	(Complex of 4 features)	WWII coastal defenses	L	L	L	Includes a tiered concrete bunker
T-23	(Complex of 9 features)	Poss. plantation manager's home	H	L	L	Early 20th century(?); in poor condition
T-25	Retaining walls [2]	RR or wagonroad bed	L	L	L	Road is on 1904 map
T-30	Rockshelters [3]	Temp. habitation(?)	H	L	L	Prehistoric with internal and external walls
T-31	(Complex of 6+ features)	Agricultural	H	H	H	Outside project area; early historic(?)
T-32	Retaining wall	RR or wagonroad bed	L	L	L	Road on 1904 map
T-33	(Complex of 4 features)	RR or wagonroad beds	L	L	L	Portions of site on 1904 map
T-34	Cave	Burial	H	L	H	Early historic/ prehistoric; previously recorded?

[#] Number of features

Table 1. (Cont.)

Site Number	Formal Site/Feature Type	Tentative Functional Interpretation	CRM Value Assess. R	I	C	Comments
T-35	Retaining wall	Indeterminate	L	L	L	Outside project area
T-37	(Complex of 4 features)	RR or wagonroad bed;retaining walls; water crossing	L	L	L	Early 20th century
T-38	Pumphouse	Water source	L	L	L	Operated 1950 to 1970
T-40	(Complex of 2 features)	WWII command post(?)	L	L	L	Includes collapsed shed, steps, concrete slabs
T-42	Dam	Agricultural	L	L	L	Outside project area; comprised of basalt boulders
T-43	Reinforced concrete bunker	WWII coastal defense	L	L	L	Part of system formed by T-20, -22, and -40
T-45	(Complex of 3 features)	Trench complex	L	L	L	WWII related; mostly outside project area
T-46	Retaining wall	RR or wagonroad bed	L	L	L	Early 20th century
T-47	Bottle and rubbish scatter	Trash dump	H	L	L	Early 20th century(?)
T-48	Mounds [2]	Agricultural clearing (?)	L	L	L	Early 20th century
T-49	Retaining wall	RR or wagonroad bed	L	L	L	Early 20th century (?)
T-50	(Complex of 3 features)	Wagon road	L	L	L	Road on 1904 map

Table 1. (Cont.)

Site Number	Formal Site/Feature Type	Tentative Functional Interpretation	CRM Value Assess. R	I	C	Comments
T-52	(Complex of 2 features)	Animal pen	L	L	L	c. 1900(?)
T-53	Retaining wall	RR or wagonroad bed	L	L	L	Early 20th century(?)
T-54	Rockshelter	Temp. Habitation(?)	H	L	L	Prehistoric/early historic(?)
T-55	Wall	Boundary(?)	L	L	L	c. 1900(?)
T-56	Retaining wall	RR or wagonroad bed	L	L	L	Early 20th century(?)
T-57	Enclosure	Animal control	L	L	L	Mostly outside project area
T-58	(Complex of 3 features)	RR or wagonroad bed	L	L	L	Road on 1904 map
T-59	Retaining wall	RR or wagonroad bed	L	L	L	Early 20th century(?)
T-62	Linear mound	Agricultural clearing(?)	L	L	L	Early 20th century(?)
T-64	Rockshelter with wall	Temp. habitation	H	L	L	Early historic/ prehistoric; volc. glass collected
T-65	Rockshelter with wall	Temp. habitation	H	L	L	Early historic/ prehistoric(?)
T-66	Rockshelter	Temp. habitation	H	L	L	Early historic/ prehistoric scatter of exotic basalt
T-67	Rockshelter	Burial/ temp. habitation(?)	H	L	H	Early historic/ prehistoric

Table 1. (Cont.)

Site Number	Formal Site/Feature Type	Tentative Functional Interpretation	CRH Value Assess. R	I	C	Comments
T-69	(Complex of 2 features)	Ceremonial(?); agricultural; heiau(?)	H	H	H	Outside project area
T-70	(Complex of 5 features)	Burials; temp. habitation; rock art	H	H	H	Prehistoric/ early historic
T-71	(Complex of 3 features)	Temp. habitation(?)	M	L	L	Prehistoric/ early historic
T-72	Rockshelter	Temp. habitation/ burial	H	M	H	Prehistoric/ early historic
T-73	Rockshelters[2]	Temp. habitation	M	L	L	Prehistoric/ early historic; may contain hearth deposit
T-74	Wall	Boundary	L	L	L	Outside project area
T-75	(Complex of 3 features)	Temp. habitation	M	L	L	Prehistoric/ early historic; internal walls present
T-76	(Complex of 4 features)	Agricultural	L	L	L	Early 20th century
T-77	Rockshelter with wall	Burial (?)	M	L	L/H	Probably prehistoric
T-78	Cave	Temp. hab./quarry	M	L	L	Prehistoric
T-79	Cave	Shrine (?)	M	L	L	Prehistoric
T-80	Cave	Burial	H	L	H	Disturbed

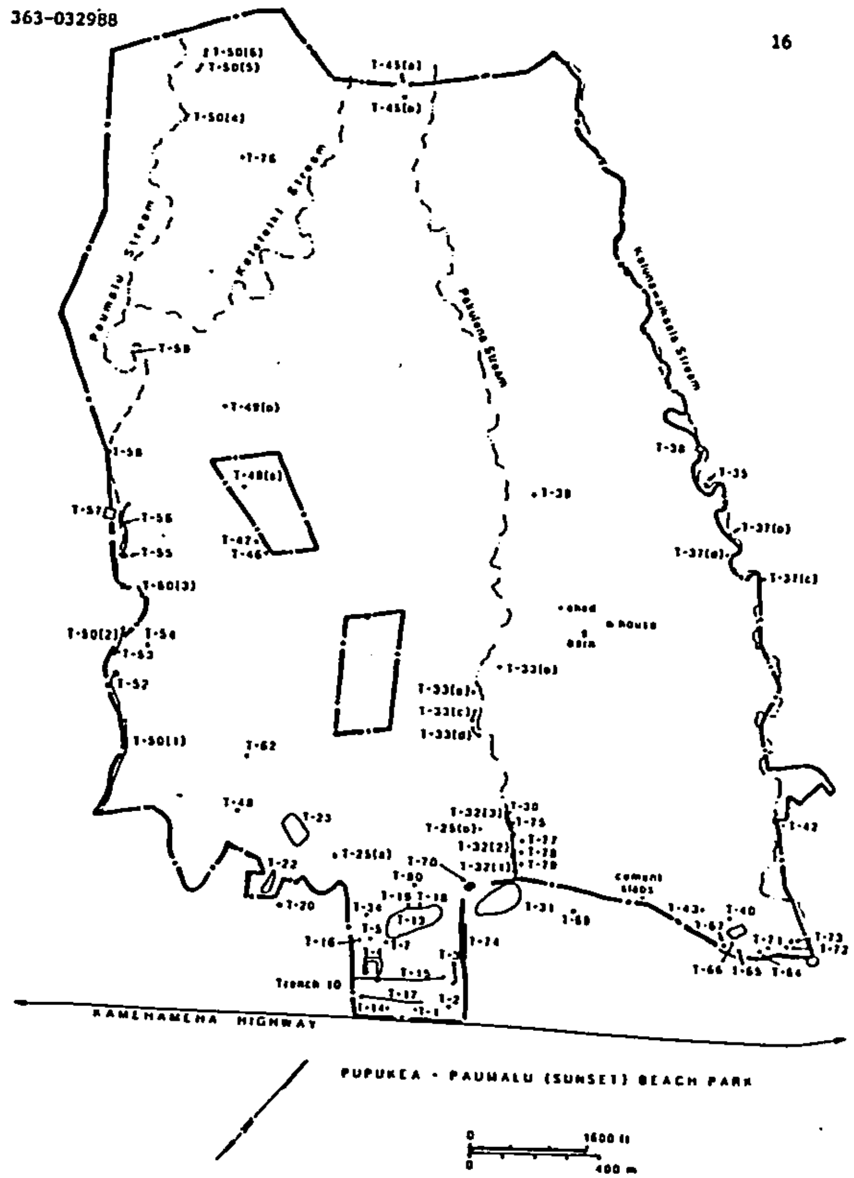


FIGURE 3. SITE LOCATION MAP

The small coral abrader and the polished basalt cobble were found in Feature B of Site T-19. The worked flaked tool was found in Feature B, Site T-70. The remains of the burial canoe were found within Feature A (rockshelter) at Site T-34. The canoe remains consist of three pieces of carved wood (koa). The largest piece measures 1.4 m long by 15-75 cm wide by 2-3 cm thick. This piece, from the top of the canoe's side, has been smoothly finished, except in areas where rough adze marks are visible. Six small oblong holes, each 3-4 cm long by 1 cm wide are carved along the piece.

Several historic sites also include portable remains; most of the remains, however, are of little archaeological value. Littering the hillside to the north, west, and south of Feature I of Site T-23 are a number of concrete blocks. Downslope of Feature A of Site T-40 are a number of concrete blocks and metal pipe. Present at Site T-47 is a 70-sq-m bottle and rubbish dump which contains the remnants of at least 24 bottles, plus earthenware and other ceramics--some of which date to about 1900. Some of the bottles are buried under 15-20 cm of alluvium.

BACKHOE TRENCH TEST EXCAVATIONS

Subsurface reconnaissance of the SMA portion survey area was comprised of nine backhoe trench test excavations. These excavations were located in areas which were thought to have potentially been under rice or taro cultivation. The trenches (except Trench 10) were located in the most western portion of the SMA portion survey area (Figure 4). The most western portion is a low lying area. Each trench was 4-5.0 m long, and the trenches varied in depth from 0.9 to 2.2 m deep. All trenches were excavated to basal coral reef or to the culturally sterile stratum overlying the reef. Overall dimensions and stratigraphic summaries of the trenches are presented in Table 2. Trench 6, originally located between Trenches 5 and 7, was not excavated because it was felt its stratigraphy would only be a repetition of similar stratigraphies in Trenches 5 and 7.

A total of 43 linear meters of trench was dug. Cultivation activities involving pondfield taro cultivation elsewhere on Oahu had often produced clay-like gleyed deposits, lenses of orangish oxidized soil, and carbonized macroflora. The soils present in the backhoe trenches in the SMA portion survey area roughly correlated with the USDA soil survey description of Waialua silty clay (Foote et al. 1972:128). The soils were fairly homogeneous and deep (190-220 cm). No cultural material or evidence for intensive taro cultivation was observed in any trench. Four pollen samples were taken from strata in four different trenches (Trenches 1, 3, 8, and 9) where mottled soils with small pockets of gley-like clay and lenses of oxidized soil offered possible evidence of non-intensive agricultural practices.

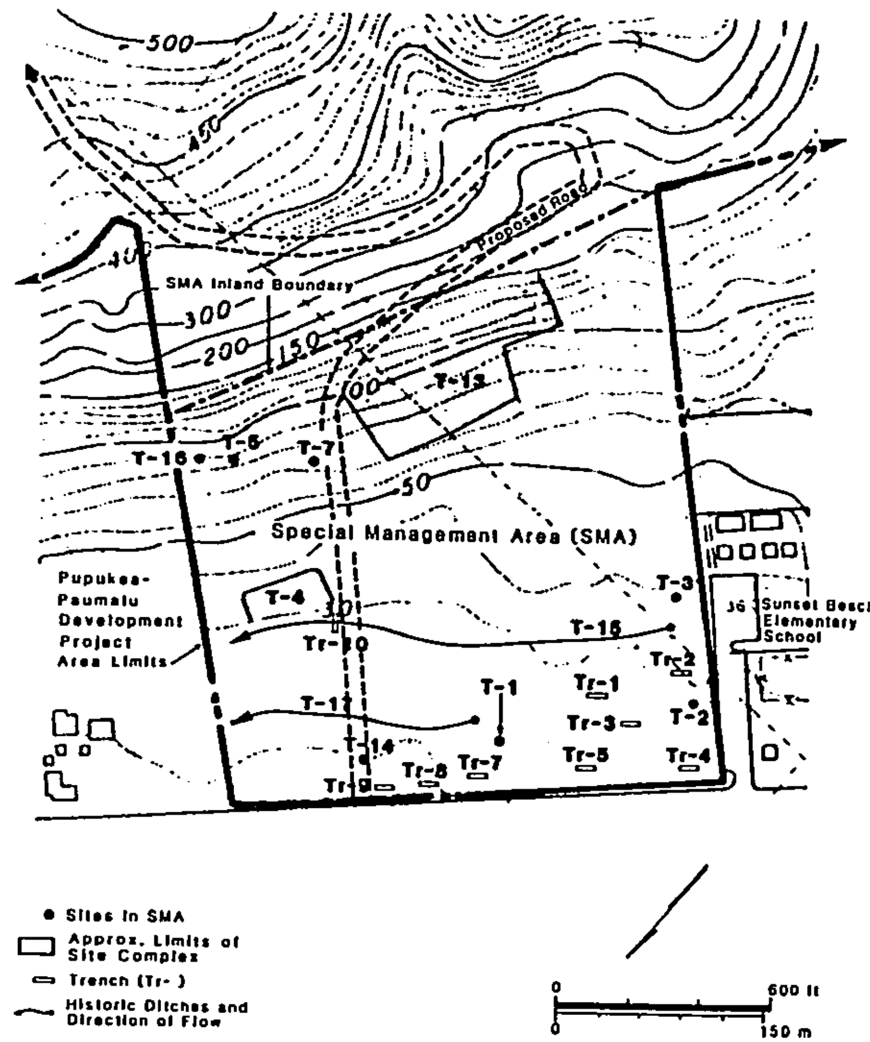


FIGURE 4. BACKHOE TRENCH LOCATION MAP

Table 2.

**SUMMARY OF BACKHOE TRENCH TESTING RESULTS
SPECIAL MANAGEMENT AREA (SMA) PORTION
PUPUKEA-PAUMALU DEVELOPMENT PROJECT AREA**

Trench No.	No. of Layers	Length (m)	Depth (m)	Layer Notes
1	5	5.0	2.2	I=0-100 cmbs*; II=100-135 cmbs; III=135-200 cmbs; IV=200-220 cmbs; V=220+ cmbs
2	5	5.0	2.0	I=0-110 cmbs; II=110-140 cmbs; III=140-180 cmbs; IV=180-195 cmbs; V=195+ cmbs
3	4	4.0	2.0	I=0-120 cmbs; II=120-180 cmbs; III=180-220 cmbs; IV=220+ cmbs
4	4	5.0	2.0	I=0-50 cmbs; II=50-90 cmbs; III=90-165 cmbs; IV=165-200+ cmbs
5	3	5.0	1.8	I=0-50 cmbs; II=50-120 cmbs; III=120-175 cmbs
6				Not excavated
7	5	5.0	1.2	I=0-20 cmbs; II=20-50 cmbs; X=70-90+ cmbs; XI=50-70 cmbs
8	5	5.0	1.5	I=0-10; VI=10-30 cmbs; VII=30-85 cmbs; VIII=85-100 cmbs; IX=100-110 cmbs; X=110-150 cmbs
9	3	4.0	1.1	VII=0-50 cmbs; VIII=35-65 and 85-110+ cmbs; IX=65-85 cmbs
10	3	5.0	1.0	See text for description

*cmbs=Centimeters below surface.

Trench 10, excavated inland of the other trenches, bisected a suspected historic irrigation ditch (T-15). In Trench 10, a channel hand-cut through the sandstone substratum was found; this channel measured 95 cm deep and 65 cm wide (Figure 5). Trench 10 was filled with a dense deposit (Layer I). Excavation of Trench 10 confirmed the trench was an irrigation ditch; the ditch probably dates to 1900-1925, and is probably associated with intensive sugarcane agriculture.

All nine trenches (1-5, 7-10) were faced and described; five trenches (Nos. 5, 7-10) were profiled in detail. The stratigraphy in all trenches was fairly uniform. For purposes of clarity, the same stratigraphic designations were used in all trenches. The following describes the stratigraphic layers of the trenches and indicates in which trenches the layers occur:

LAYER	DESCRIPTION
I	Dark brown to dark redish-brown silty and clay loam; coarse-grained recent alluvium 10 to 120 cm deep. Extensive root zone. Present in Trenches 1-5, 7, 8, and 10;
II	Mottled dark reddish-brown clay loam with lenses of oxidized soil and small amounts of charcoal, small pockets of grey gleyed deposits. Samples from this layer were taken from some trenches. Layer varies from 30 to 70 cm, and in texture, from relatively fine to coarse-grained. Layer II was present in Trenches 1-5 and 7. If the layer is agricultural in origin, it does not appear to represent irrigation agriculture;
III	Reddish-brown fine-grained clay to clay-loam. Quite moist with some basalt rocks and occasional small lenses of oxidized sandy soil. 40-75 cm thick; no roots. No samples were taken from this layer. Layer III was present in Trenches 1-5 and 7;
IV	Compact reddish-brown fine to coarse-grained clay with small amounts of grey coral regoliths. Thickness is 20-35 cm. Layer IV was present in Trenches 1-4;
V	Underlying fossil coral reef. Grey to very pale brown. This layer was encountered in Trenches 1 and 2 at 195-220 cmbs;
VI	An unusual stratum of crushed coral rocks immediately below the A/O-horizon in Trench 8. Extending from 10-30 cmbs, it is probably the only layer found in these trenches that is cultural in origin. The most obvious explanation for Layer VI is that it was perhaps a roadbed dating to c. 1900;

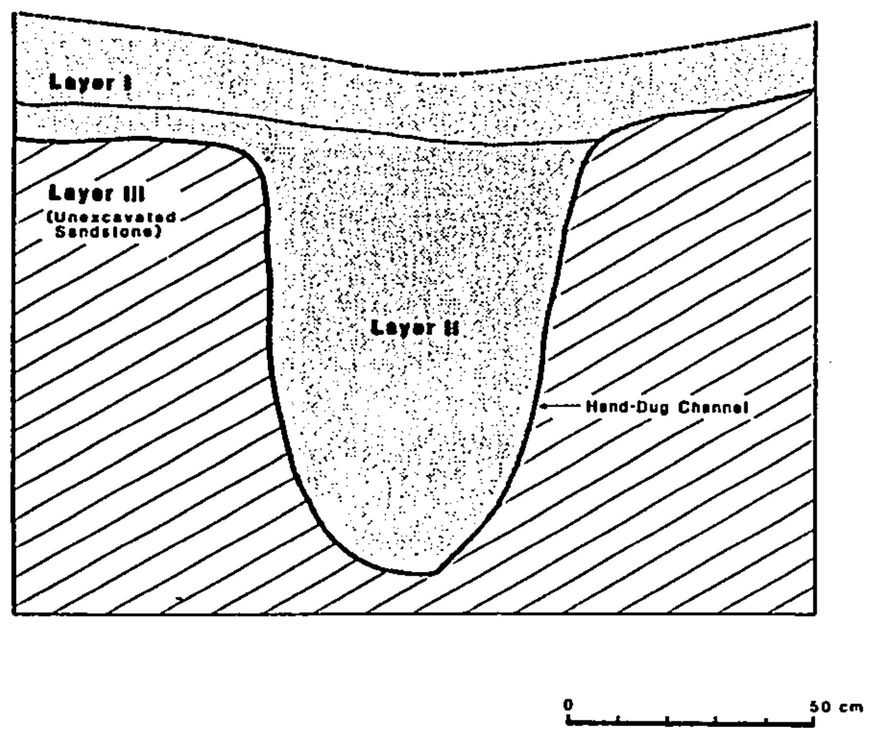


FIGURE 6. SITE T-16, TRENCH 10, NORTH FACE

LAYER	DESCRIPTION
VII	Found in Trenches 8 and 9; consists of a dark brown massive clay deposit. Fine-grained and moist; 45-50 cm in thickness. Samples were taken from this layer (from Trenches 8 and 9). Layer VII in Trench 8 grades into Layer VIII very gradually, producing a transitional stratum of clay-like sand 10 cm thick;
VIII	Coarse-grained reddish-brown dry sand 10-30 cm thick; in Trench 9 Layer VIII is subdivided into an upper deposit 30 cm thick, and a lower deposit of reddish-brown sandy clay 25 cm thick;
IX	Present in Trenches 8 and 9. Coarse-grained and well-drained; 10 to 20 cm thick;
X	Dark reddish-brown coarse-grained sand present in Trenches 7 and 8. Present at 70 cmbs in Trench 7 and at 110 cmbs in Trench 8;
XI	In Trench 7, Layer XI is a narrow (20 cm) stratum of reddish-brown coarse-grained sandy loam; Layer X forms a transition from the loam of Layer II above to the sandy deposit of Layer X underneath.

SITE DESCRIPTIONS

Site T-1 - Linear Mound

Site T-1 is a roughly linear mound comprised of waterworn basalt cobbles and small boulders. The mound, situated in a low lying area near the coast, measures 13.0 m long by 2.0 m wide by 0.4 m high. Most of the mound is one course high. Several pieces of waterworn coral were present at the northwest end of the mound, where the mound is crossed by a barbed-wire fence. Site T-1 may be a disturbed terrace, or it may have some religious significance (as indicated by the waterworn coral present).

Site T-2 - Alignment and Basalt Scatter

Site T-2, an alignment and a basalt scatter, is located c. 145 m southwest of T-1. The alignment, 1.6 meters long, is comprised of waterworn basalt boulders and cobbles. Surrounding the alignment is a thin, c. 270-sq-m scatter of broken, angular fine-grained exotic basalt. Based on an examination of its attributes, the basalt appears to have been broken by heavy equipment. There is evidence of disturbance by heavy equipment at the site.

Site T-3 - Modified Outcrop

Site T-3 is comprised of a natural basalt outcrop modified with a linear alignment of medium-sized basalt boulders. The feature, which measures c. 42.0 m by 10.0 m, runs parallel to a gentle slope and is interrupted by a bulldozer cut. The stones comprising several portions of the alignment appear to have been rearranged, possibly in connection with agricultural activities.

Site T-4 - U-shaped Earthen Berm

Site T-4 is large and flat-topped. It measures 42.0 by 60.0 m overall, and is 7.0 m wide at its base, 2.5 m wide at its top, and is c. 1.75 m high. The legs of the U-shape run up a gentle slope--which gets steeper above the site. Present on the slope, outside the northern arm, is a loosely stacked pile of lumber and some hollow (pier?) pilings. The pilings are distributed over an area which measures c. 16 m sq. Present about 20.0 m south of Site T-4 is a cairn which measures 1.0 m by 0.5 m high. Site T-4 may have been a siding for a railroad associated with the early 20th century sugarcane industry.

Site T-5 - Terrace

Site T-5 is situated in the middle of a moderately steep talus below sheer basalt coastal cliffs (Figure 6). The site measures (overall) c. 15.00 m long by 3.6 m wide by 1.3 m high. The wall of the terrace is comprised of stacked basalt cobbles and boulders (Figure 3) and is well-preserved; it measures 0.25 m wide by 15 m long and is five to seven courses high. Present on the north end of the wall is an upright boulder. The platform area of the terrace is soil-covered and slopes gently to moderately. The size of the terrace and it's sloping surface suggest the terrace was used for agriculture.

Site T-7 - Cairn

Site T-7 is comprised of a collapsed pile of basalt boulders. It measures 0.50 m high and covers an area 3.0 m sq. Site T-7 may have been an early historic or prehistoric trail or property marker, as it is situated among Sites T-5, -13, and -16, which date to those periods.

Site T-13 - Complex

Site T-13 is comprised of 13 features which may have functioned as agricultural or habitation features (Figure 7). One feature (Feature G) is comprised of five boulders on which are typical Hawaiian petroglyphs. The site is located near the top of a steep talus slope overlooking the coast.

Feature A is a low, single-stacked wall comprised of basalt boulders and cobbles. The feature measures c. 56 m long; for most of its length it

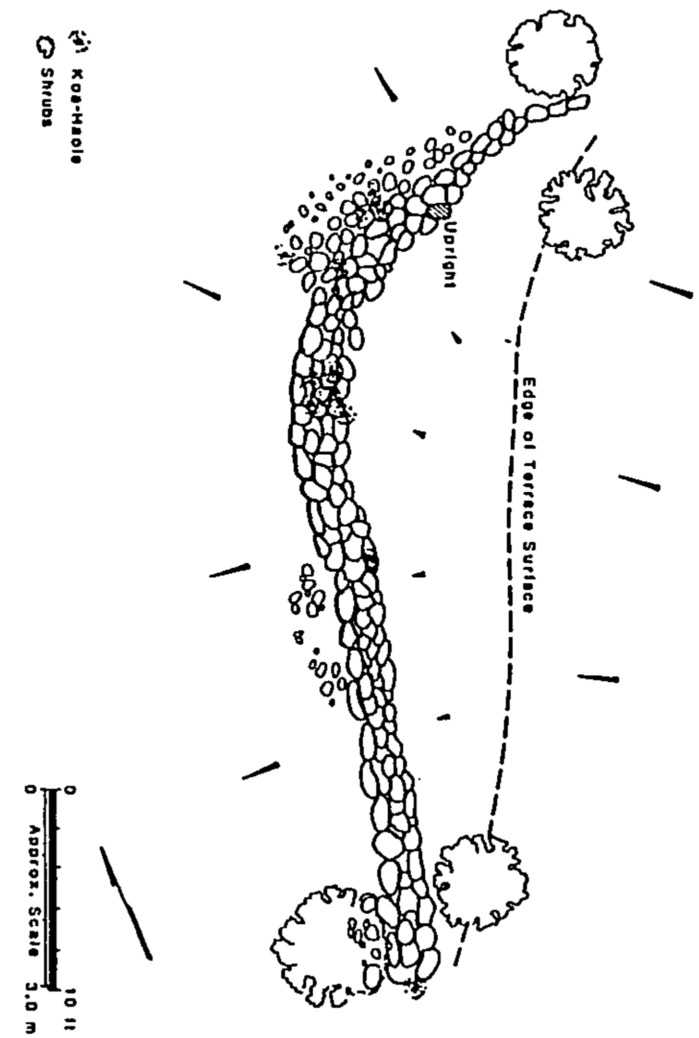


FIGURE 6. SKETCH MAP OF SITE T-6

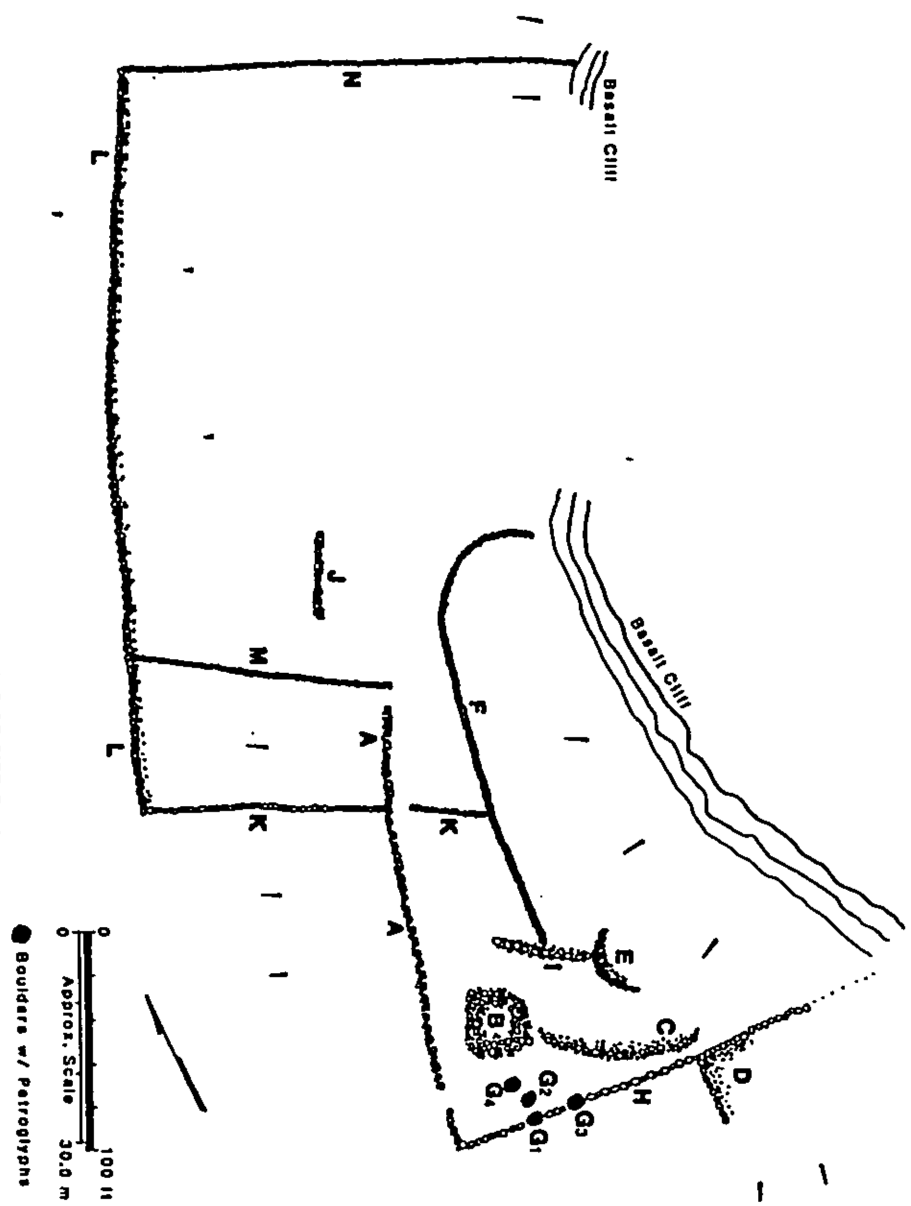


FIGURE 7. SKETCH MAP OF SITE T-13

forms part of the downhill western edge of Site T-13. Feature A has been extensively disturbed by cattle and bulldozing. The feature may have functioned as a terrace or enclosure wall; subsurface testing may help determine its original function.

Feature B is a low rectangular earthen terrace which measures c. 11.0 by 12.0 m (overall) by 40 cm high. The upper surface of the terrace, level and soil-covered, measures c. 4.5 meters square. Feature B may have served as a house site, as it is surrounded by what appears to be collapsed stone walls. No surface artifacts or midden were noted at Feature B; however, artifacts/midden may have been obscured by slope-wash deposition.

Feature C is a wall comprised of basalt cobbles and boulders. The wall runs from the northeast corner of Feature B upslope, and ends at Feature D. Feature C measures c. 20.5 m long. Like all the features at Site T-13, it has been disturbed by cattle grazing—it is collapsed and its stones are scattered. Feature C may have functioned either as an agricultural terrace or as a wall to restrict access to Feature B.

Feature D is a large terrace walled on two sides. The north wall of the terrace (28 m long), comprised of basalt cobbles and boulders piled six to seven courses high (1.75 m maximum height), is well-built and is partially faced. The west wall is essentially a partially altered natural talus alignment of basalt boulders (2.7 m maximum height). The south side of Feature D slopes gently downwards, and the east side of the feature climbs steeply upwards (30 degrees). The level portion of the upper surface of the terrace measures c. 9.0 by 9.0 m and slopes gently to the west (10 degrees). Above the level portion is an area of rocky loam which measures c. 60 sq m. Feature D is assumed to have been an agricultural terrace.

Feature E is a terrace measuring c. 5.0 by 8.0 m (overall). The walls of the terrace are comprised of natural and artificial alignments of basalt cobbles and boulders. The upper surface of the terrace measures 13.0 sq m. Feature E is interpreted as an agricultural feature.

Feature F is a 66.0 meter long, roughly J-shaped core-filled wall which runs downhill and abuts Feature K. Feature F is much better preserved than most of the walls at Site T-13 and may be more recent in date. Feature F probably functioned as an animal or garden enclosure or boundary wall.

Feature G consists of five basalt boulders on which are seven small faint anthropomorphic petroglyphs (Figure 8). Four of the boulders are located immediately south of Feature B; the fifth boulder is situated southeast of Feature H. The petroglyphs are pecked in both vertical and horizontal faces of the boulders. The largest petroglyph measures c. 30 cm long.

Two of the boulders which comprise Feature G are incorporated into Feature H. Feature H is a linear alignment of rough, waterworn basalt

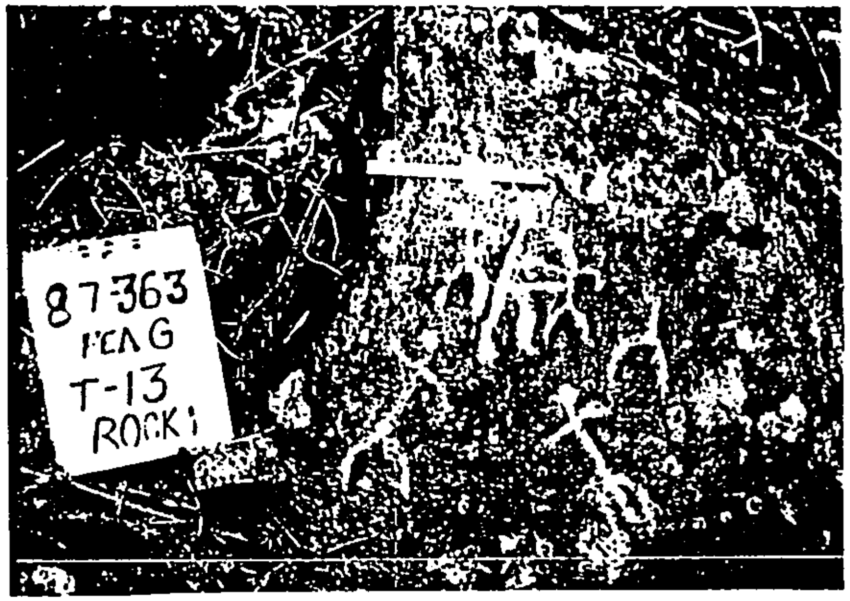


Figure 8. SITE T-13, FEATURE B, PETROGLYPHS. (PHRI Neg.764-9)

cobbles and boulders; it extends c. 32.0 m downslope from the southwest corner of Feature D and abuts Feature A.

Feature I is a wall which runs along the northeast side of Feature B, approximately 12.0 m from Feature E, downhill toward Feature A. Feature I is comprised of collapsed basalt cobbles and boulders. Prior to disturbance by bulldozing of a road, Feature I apparently abutted Feature A and perhaps restricted access to Feature B.

Feature K is a core-filled wall of basalt cobbles and boulders which extends c. 31.0 m uphill from Feature L, where it intersects Feature A. At this point Feature K is discontinuous for 4.0 m--cut through by a bulldozer--then it extends for another 10 m uphill to abut Feature F. Based on its well-preserved state, Feature K may date later than Feature A. Feature K forms a three-sided enclosure with Features L and N and may have functioned as an animal or garden enclosure wall.

Feature L is a c. 108.0-m-long low wall running perpendicular to the slope of the site. The top of the wall on the uphill side is nearly flush with the ground, while the downhill face of the wall is sloping and ramp-like. While the structural form of the feature suggests it was an agricultural terrace wall, Feature L may have been an animal enclosure wall, as it abuts with Features N and K. Prior to the slope wash deposition on its uphill face, Feature L may have been free-standing.

Feature M is a relatively short (c. 32.0 m) collapsed wall comprised of basalt cobbles and boulders; it runs parallel to Features K and N and abuts Feature L. Feature M is probably an enclosure wall.

Feature N is a well-preserved core-filled wall of basalt cobbles and small boulders. The wall runs parallel to the slope of the site. It abuts the NW terminus of Feature L and extends 56.0 m up a fairly steep slope toward a sheer basalt escarpment. Feature N is c. 80 cm high and 60 cm wide. It forms a three-sided enclosure with Features J, L, and M. The uphill wall of this three-sided enclosure is formed by a basalt escarpment and a boulder pile that abuts Features J and N.

<u>Site T-14 - Well</u>

Site T-14 is a small, partially stone-lined well which has been dug into limestone bedrock and filled-in; it measures 2.0 m in diameter and is 0.80 m deep. Modern pipes from the well extend 2.5 m northwest toward a concrete foundation. The foundation is two-chambered and measures 3.2 by 4.5 m by 0.2 cm high (overall); presently, the foundation is filled with mud. The site probably dates to the latter half of the 20th century.

<u>Site T-15 - Irrigation Ditch</u>

Site T-15 is a c.1900-1925 irrigation ditch which probably delivered water from Pakulena Stream (south and west of the site) to sugarcane fields located to the north. Site T-15 traverses the project area, running c. 223 meters southwest-northeast. It is 2.3 m wide and, having been filled-in with recent alluvium, is 25-50 cm deep along most of its length. A test trench (Trench 10) was excavated through T-15, c. 8.0 m west of the southwest corner of Site T-4. Excavation indicated that T-15 was originally a channel c. 80 cm deep by 65 cm wide which was hand-dug into sandstone bedrock.

Site T-16 - Linear Mound

Site T-16 is comprised of basalt cobbles and boulders; it measures c. 10.0 m long by 1.5 m wide. The site is situated parallel to the slope in the SMA portion of the survey area; it may have functioned as a water-diversion device. Presently, it diverts water in a small drainage channel off to the north. In the past Site T-16 may have served to divert water away from Site T-5. Thus, like Site T-5, Site T-16 may be prehistoric or early historic in origin.

Site T-17 - Irrigation Ditch

Site T-17 is an irrigation ditch which is about 180 m long; it is located c. 60.0 m from Site T-15--which it roughly parallels. It is in a poorer state of preservation than Site T-15; recent livestock grazing has damaged it. Site T-17 is assumed to have been associated with nearby sugarcane agricultural activities that took place c. 1900-1925.

Site T-18 - Rockshelter

Site T-18 is located at the base of sheer cliffs and at the crest of a talus which slopes steeply downward for 175 feet to the coastal lowlands (Figure 9). The site is comprised of a natural rockshelter (Feature A), 5.5 m wide by 3.0 m deep (maximum) by 1.3 m high (maximum), and a wall (Feature B). The rockshelter is situated 5.0 meters southeast of the wall. The floor of the rockshelter is littered with debitage and angular fractured pieces of very low-grade volcanic glass. The volcanic glass occurs naturally in the ceiling of the shelter. Five pieces of the volcanic glass were collected for dating analysis. No other artifacts were noted on the floor; however, the floor (comprised of light brown, silty loam) may contain buried cultural resources. The Feature B wall measures 2.0 m long by 0.70 m high and is comprised of rough basalt rocks. The wall encloses a 2.0 sq m area adjacent to the sheer basalt cliff that rises above the site. Site T-18 may have functioned as a quarry and as a temporary habitation. Feature B may have been used for storage, or less likely, as a retaining wall for a small garden plot, as it is situated to catch runoff from the cliff face. One volcanic glass flake which could definitely be attributed to quarrying or tool production activity was submitted for age determination. The sample yielded an age range at two standard deviations of AD 1663-1723.

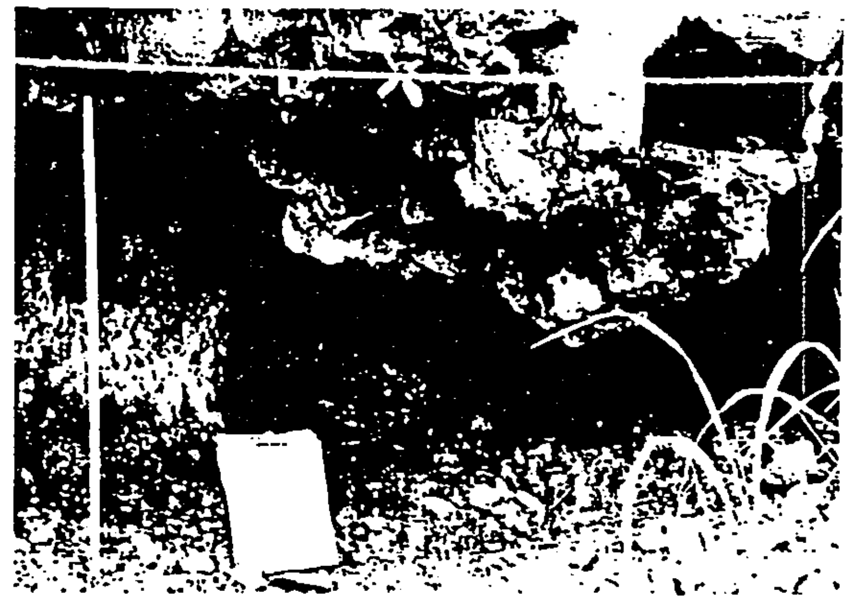


Figure 9. SITE T-18, ROCKSHELTER. (MHRI Neg.758-3)

Site T-19 - Rockshelters

This site is situated approximately 45.0 m southwest of Site T-18, at the base of the same cliff T-18 is near. Site T-19 consists of two small natural rockshelters (Features A and B) (Figure 10). Feature B is the smaller shelter; it measures 4.0 m wide by 1.8 m deep by 1.6 m high (maximum). The floor of Feature B is comprised of silty brown loam. Present on the floor was a coral abrader, a fragment of a polished basalt cobble, and charcoal flecks.

Feature A, 2.0 m north of Feature B, measures 7.0 m wide by 2.5 m deep by 1.6 m high. No artifacts were observed at Feature A; however, the floor of the feature, covered with brown silty loam, may contain buried cultural deposits. Site T-19 is interpreted to have functioned as an late prehistoric/early historic short-term temporary habitation.

Site T-20 - WWII Bunker

Site T-20 is a bunker situated outside the current project area atop steep cliffs. The bunker measures 19.0 by 7.0 m in area, is three-tiered, and is constructed of reinforced concrete. The highest tier stands 4.25 m above the base of the lowest tier. Apertures facing the ocean are present in each tier. The site is well-preserved, due in part to maintenance by a Mr. Claude Ortiz. Site T-20 was probably constructed during WWII.

Site T-21 - Retaining Wall

Site T-21 is situated on the plateau between Pakulena and Kalunawaikaala Gulches, on the edge of pastureland that was used for agriculture in the early 20th century (A. Aoki, pers. comm.). The site consists of a sloping wall comprised of rough basalt rocks. The wall measures about 2.5-m long by 1.8 m high, and is situated at the head of a small drainage. Site T-21 probably functioned as a terrace. The wall probably is associated with agriculture in the area c. 1900-1950.

Site T-22 - Complex

Site T-22 consists of four features associated with WWII coastal defense. The site, situated 450 feet above sea level at the crest of sheer basalt cliffs, provides a commanding view of the ocean. Site T-22 covers an area which measures 45.0 m (N-S) by 80.0 m (E-W). The site is roughly bisected by a dirt road. This road passes close to each of the four features, which suggests the road dates to use of the site.

Feature A, situated on the northwest edge of the site on a cliff, is a two-tiered bunker of reinforced concrete. The bunker measures approximately 8.0 by 3.5 m in area. The top of the higher tier stands 4.5 m above the base of the lower tier.

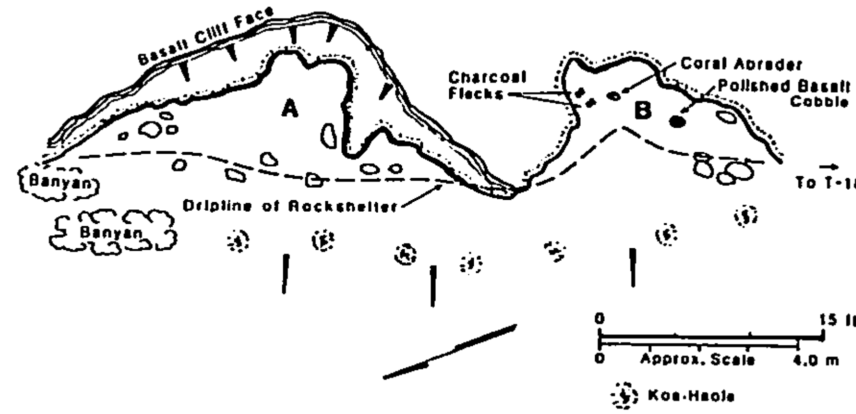


FIGURE 10. SKETCH MAP OF SITE T-19

Feature B consists of a tangled mass of corrugated steel situated about 21.0 m southeast of Feature A. The mass probably originally comprised a small superstructure atop Feature A. The mass measures about 6.0 by 2.5 m by 2.2 m high. Present on pieces of steel comprising the mass were small apertures--perhaps machine gun apertures.

Feature C, a circular concrete and steel gun turret base, is situated about 13.5 m south of Feature B. Feature C measures approximately 2.0 m in diameter by 0.35 m high (at apex of a thin steel rod which extends from the center of the base). Feature C has obviously been moved from its original position. Like Feature B, it may have been removed from Feature A.

Feature D, a turret base very similar to Feature C, is situated 30.0 m northwest of Feature C. Feature D measures about 2.2 m in diameter. The base of Feature D is presently at a 45 degree angle to the ground surface.

Site T-22 is one of a number of concrete bunkers situated atop the steep cliffs between the mouths of Kalunawaikaala and Paumalu Gulches. A site similar to T-22 is Site T-20, situated southwest of Site T-22. Site T-22 and the other coastal defense positions were probably constructed, used, and abandoned during WWII.

Site T-23 - Complex

Site T-23, situated on the plateau between Paumalu and Pakulena Gulches just inland of Site T-22, consists of nine features. The site covers 50.0 by 100.0 m. Feature A is a small concrete basin set in the ground. It measures 1.30 m long by 0.70 m wide by 0.60 m deep. This feature may have been used for water catchment or storage, perhaps in association with livestock.

Feature B, situated 14.0 m southeast of Feature A, is a concrete chimney set on a rock foundation. Feature B measures 0.95 by 0.95 m by approximately 6.0 m high. No fireplace was present in the feature.

Feature C consists of two broken concrete slabs. The slabs are situated 6.0 m and 10.5 m west of Feature A. Slab C1 measures 2.5 m long by 0.75 m wide by 0.15 m thick. Slab C2, situated about 4.5 meters from slab C1, measures 2.3 by 1.3 m by 0.15 m thick. Both slabs are thought to have at one time comprised a single, L-shaped foundation.

Feature D is an earthen terrace. The retaining wall of the terrace is L-shaped and measures 10.5 m long by 1.5 m wide by 0.25 m high. The platform area of the terrace, which extends about 2.0 m beyond the end of the short arm of the L, measures approximately 3.5 by 10.5 m. Feature D may have once been a structural foundation.

Feature E, a rectangular concrete slab, is situated approximately 26.0 m east southeast of Feature E. The slab is 2.65 sq m in area and is 0.15 m high. Feature E probably was a foundation for a small shed or outbuilding.

Feature F is a linear alignment of waterworn basalt rocks. The alignment measures 29.0 m long by 0.30 m wide by 0.30 m high. One end of Feature F is located 24.0 m southeast of Feature B. From this end, Feature F runs roughly southeast along the base of a gently sloping hill. Feature F may have once been a retaining wall for a dirt road.

Feature G is situated 11.5 m northeast (upslope) of the southeast end of Feature F. Feature G is a loosely stacked mound of waterworn basalt rocks and small boulders. The mound is oval in plan view and measures approximately 3.0 by 2.0 m by 1.0 m high. The age and function of Feature G are unknown.

Feature H, situated 13.5 m southeast of Feature G, is a large depression--the largest of several depressions on the lower northeast and south slopes of the Site T-23 hill. Feature H measures approximately 3.0 by 4.0 m by 1.5 m deep. Of the depressions on the Site T-23 hill, only Feature H contained portable remains--rusty pieces of metal (found in the base of the depression). The function of Feature H is unknown; however, the pieces of metal indicate the feature probably dates consistently with the other features of Site T-23.

Feature I is situated approximately 28.0 m northeast of Feature H, on the crest of the Site T-23 hill. Feature I consists of a large square wooden platform atop five smaller supporting platforms. The smaller supporting platforms, square in plan, taper toward the top; each small

platform measures 0.50 m high by 0.20 m by 0.2 m at its top. One small platform is situated at each of the four corners of the large square platform, with the remaining small platform supporting the center of the large platform. The small platforms cover an area which measures 3.6 m by 4.0 m. Feature I overall measures approximately 0.7 m high by 1.0 m on a side. The large square platform is hollow and is accessible through apertures on two sides, each of which contain small immobile wooden slats. Feature I may comprise foundations or footings for some type of elevated structure.

Site T-25 - Retaining Wall

This site consists of two spatially discrete retaining walls (Features A and B) thought to have comprised margins of the same roadbed. Feature A is located approximately 1,400' north northwest of Feature B. Both Features A and B are present on the margins of the same large plateau. Feature A is on the northwest margin of the plateau, at the top of a steep drop-off down to the coast; Feature B is on the plateau's southern margin at the top of a sheer drop into Pakulena Gulch. Feature A is approximately 470 feet above sea level; Feature B is approximately 500 feet above sea level.

Feature A is a curved retaining wall comprised of waterworn basalt cobbles and boulders. The wall measures 9.50 m long by 0.85 m (3-4 courses) high by 1.0 m wide. It is situated at the head of a small drainage which is located at the edge of an abandoned cow pasture. The cow pasture was once under cultivation (A. Aoki, pers. comm.). One side of Feature A (uphill side) acts to retain soil.

Feature B is a linear retaining wall comprised of waterworn basalt rocks. Feature B measures 6.0 m long by 0.5 m high (3-5 courses) by 1.0 m wide. It runs along the edge of a cow pasture, perpendicular to the steep slopes of Pakulena Gulch. Like Feature A, Feature B retains soil on its uphill side. The retained soil comprises a flat area which measures approximately 3.0 m wide. The location of Feature B, on the edges of an area intensively cultivated during the first half of the 20th century, suggests the feature is a remnant of either a railroad or wagon road that circled the cultivated area.

Site T-30 - Rockshelters

Site T-30 consists of a small rockshelter containing a semicircular wall and a possible terrace wall. The rockshelter (Feature B) is situated at the bottom of Pakulena Gulch, at the base of a basalt cliff. The shelter measures 3.0 m wide by 1.0 m deep by 0.95 m high (maximum). Present in the northwest corner of the shelter is a small semicircular wall comprised of rough basalt rocks. This wall (Feature A) measures 1.0 m long by 0.25 m high by 0.20 m wide. The wall encloses an area adjacent to the shelter; this area may have been used for storage. Present just east of the southern end of the rockshelter is a possible terrace (Feature C). The wall of this possible terrace is comprised of rough basalt rocks and measures 1.25 m long by 0.50 m high. The surface of the possible terrace comprises about 3.5 sq m. Feature A may have been a short-term temporary habitation shelter. Feature C may have been an activity area. No artifacts were observed at Site T-30; however, cultural deposits may be present in the floor of the shelter.

Site T-31 - Complex

Site T-31 is located immediately outside of the project area, inland of Sunset Beach School and seaward of Site T-70 and the mouth of Pakulena Gulch. The area of the site extends over much of the talus that runs from the cliffs above Site T-70 down to the coastal plain. The terrain of the site varies in elevation, from 90-130 ft above sea level, and is heavily vegetated. The site consists of an unknown number of agricultural terraces and walls. Because Site T-31 is outside of the study area, the site was not cleared to the extent necessary for proper recordation. At present, Site T-31 consists of at least six walls, primarily terrace walls, scattered across the talus between the mouth of Pakulena Gulch and Sites T-70 and T-74. Site T-31 may have been agricultural, and may have been associated with occupation at Site T-13, approximately 200 m to the northwest.

Site T-32 - Retaining Wall

Site T-32, comprised of three spatially discrete walls (Segments 1, 2, and 3) is situated in the lowest portion of Pakulena Gulch. The site extends from near the mouth of the gulch (c. 140 above sea level), upstream for 180.0 m, and ends at a point about 200 feet above sea level. Most parts of the walls run immediately adjacent and parallel to Pakulena Stream. The walls are comprised of rough and waterworn basalt rocks and small boulders. Each wall is stacked and core-filled with rubble.

Segment 1 is approximately 30.0 m long. It runs approximately 2.0 m north and west of Pakulena Stream, which it parallels. Segment 1 averages 0.70 m high and 0.60 m wide.

Segment 2 runs first on one side of Pakulena Stream, then continues on the other side of the stream. It runs mostly on Pakulena Stream's northwest bank. Segment 2 varies in height, from 0.85-1.50 m (4-5 courses), and is c. 0.60 m wide and 122.0 m long.

Segment 3 is situated in the middle of Pakulena Stream, about 50.0 m upstream of the mauka end of Segment 2. It is approximately 41.0 m long, 3.0 m wide, and 2.0 m high. The inland end of Segment 3 apparently was once connected to the bank of the stream, and retained a roadbed located between the stream and the cliffs of Pakulena Gulch. The connecting portion was probably eroded away by the stream.

Site T-33 - Complex

Site T-33 is situated on the lower slopes and bottom of Pakulena Gulch. Site T-33 consists of four spatially discrete walls (Features A-D). These walls, which retain rock and soil, are thought to be part of a road system which serviced the agricultural plateaus bordering both sides of Pakulena Gulch. Informants (A. Aoki, J. Hitch, and C. Ortiz, pers. comm.) indicate this system was constructed around 1900 and used up to about the time of WWII.

Feature A is an L-shaped wall comprised of waterworn basalt rocks. The legs of the L-shape measure approximately 9.0 m and 7.0 m long, and are about 0.7 m (2-4 courses) high. Feature A is situated immediately north of Pakulena Stream; it apparently comprises the point where the former roadbed (roadbed that ran parallel and adjacent to Pakulena Stream—now heavily overgrown and semi-flat) crossed the streambed.

Feature B lies approximately 15.0 m above Pakulena Stream on the southern slopes of Pakulena Gulch, 100.0 m southeast of Feature A. Feature B is a semicircular retaining wall comprised of waterworn basalt cobbles and small boulders. It measures 14.0 m long and is about 2.0 meters high (6-7 courses). Feature B curves over a drainage. The drainage has created a 1.0 m wide gap in the feature. The drainage probably was at one time a culvert alongside the roadbed. Feature B apparently comprises the area where the roadbed, after crossing the stream at Feature A, continues upslope, onto the southern plateau.

Feature C is situated on the northern side of Pakulena Stream, about 100.0 m northwest of Feature A. It is comprised of a linear wall of waterworn basalt rocks and small boulders. The feature is partly buried under 0.50-0.80 m of recent alluvium. The exposed portion of the feature measures about 13.0 meters long by 0.80 meters high (maximum)(3-5 courses). Feature C is interpreted as a former roadbed retaining wall.

Feature D is situated about 25.0 m from Feature C, downstream of the mouth of a large canyon which opens into Pakulena Gulch from the north. Feature D is a single-stacked, free-standing wall comprised of rough and waterworn basalt cobbles and small boulders. It measures 11.0 m long, 0.40 m wide, and is 0.35 m high. The feature runs parallel to the stream; it once functioned as a retaining wall for a roadbed located adjacent to the northern wall of Pakulena Gulch. From Feature D, the roadbed continued down Pakulena Gulch to join T-32, or perhaps climbed out of the gulch and joined Site T-25, at the edge of the northern plateau.

Site T-34 - Cave

Site T-34 is a cave located in the middle of a moderately steep talus. The cave was reportedly recorded in the early 1980s by the Bishop Museum after it was accidentally discovered (Gary McCurdy, pers. comm.). The cave 34 measures 7.75 m wide by 3.00 m deep by 0.80 m high. Within the cave are two human burials, the remains of a burial canoe, and two small walls comprised of basalt cobbles. Mr. Gary McCurdy states that he built the walls (to protect the burials) using rocks present within the cave--rocks which may have originally comprised walls constructed at the time of interment. Artifacts observed in the cave during the present investigation include three well-preserved fragments of wood (from a burial canoe) and two pig mandibles (perhaps offerings). The largest canoe fragment measures 1.30 m long by 0.25 m wide by 0.03 m thick. According to Mr. McCurdy, the burials comprised a large adult male and an adult female. During the present investigation, only a fragment of a femur, a vertebra, and another bone fragment were noted, but more remains are probably preserved under the rocks placed by Mr. McCurdy. Site T-34, based on the method of interment of the burials at the site, probably dates to the early historic or prehistoric periods.

Site T-35 - Retaining Wall

Site T-35 is located immediately outside the project area, in Kalunawaikaala Gulch. It is on land owned by John Hitch, a long-time resident of Pupukea. Mr. Hitch states that Site T-35 has been in existence since at least the 1920s. The site consists of a linear retaining wall comprised of waterworn basalt cobbles and small boulders. The wall measures 4.00 m long by 0.65 m wide by 1.00 m high. The wall retains a terrace of loamy soil approximately 40 sq m in area. Mr. Hitch states that there was a cattle road across the gulch in the pre WWII period, but the road, although nearby, was not close enough for Site T-35 to have been a part of it.

Site T-37 - Complex

Site T-37 is a complex consisting of three retaining walls (Features A, C, and D) and a cobble pavement (Feature B) (specifically, a low-water crossing). Features A and B of the site are outside the present project area, and Features C and D are within the project area. Features A, B, and C are situated at the bottom of Kalunawaikaala Gulch. Feature D is situated on the lower portion of the northern flank of the gulch.

Feature A is a free-standing double-stacked wall comprised of waterworn basalt cobbles and small boulders. The feature is situated on the east bank of Kalunawaikaala Stream, and parallels the stream. Feature A measures about 75.0 m long by 4.0 m wide by 2.0 m (4-6 courses) high (maximum). Feature A was once a retaining wall for a roadbed.

Feature B is situated on a former roadbed. The feature consists of a pavement of waterworn basalt cobbles which extends over a small drainage which runs into Kalunawaikaala Stream from the southeast. Feature B measures 4.00 by 4.00 m by 0.15 m high.

Feature C is a free-standing rock wall 130.0 m downstream of Feature A. The feature, which runs adjacent and parallel to Kalunawaikaala Stream, measures about 80.0 m long by 0.50 m wide by 0.75 m

(2-3 courses) high. Feature C is apparently an extension of Feature A.

Feature D is a roughly J-shaped retaining wall comprised of basalt rocks piled 2-4 courses high. The wall measures 0.75 m high by 8.00 m long by 0.50 m thick. Feature D is probably part of a former roadbed which extended from Kalunawaikaala Gulch to the agricultural fields on the plateau to the north--a roadbed dating to c.1900-1940.

Site T-38 - Pumphouse

Site T-38 is situated about 75.0 m upstream of Site T-35, just northwest of Kalunawaikaala Stream. The site consists of a small rectangular concrete and wood structure with a tin roof. The structure measures 6.0 m long by 3.5 m wide by 3.0 m high. Within the structure is a large cast-iron water-pump. The pump measures 1.1 by 2.0 by 2.0 m high. Two wooden power poles are present 4.5 m northeast of the structure. Mr. John Hitch (pers. comm.) states that Site T-38 is a pumphouse built over a 500-ft-deep well drilled in 1951. The well, which serviced a plantation camp south of Site T-38, was abandoned about 1970 because the well water increased in salinity. The pump is no longer functional.

Site T-40 - Complex

Site T-40 is a complex (16.0 by 9.0 m overall) consisting of three concrete and wood features (Features A-C). The complex is situated about 360 feet above sea level on the plateau south of Pakulena Gulch, in an area where the plateau begins to descend to the coast. Site T-40 is 45.0 m northeast of Site T-20 (WWII bunker) and 45.0 m south southeast of Site T-43, another bunker.

Feature A may have originally comprised a wood and concrete structure with a gabled roof; however, it is hard to distinguish the original feature as it is presently very collapsed. Feature A measures c. 1.4 m wide by 2.2 m long by 1.0 m high. Present 3.0 m east southeast of the structure is a concrete slab which measures 1.0 m by 0.75 m by 0.10 m thick.

Feature B is situated seven meters southeast of Feature A. Feature B is comprised of three rectangular (plan view) concrete footings which lie parallel to each other. The footings are of unequal length, and they lie perpendicular to the slope they are on. The footings measure 1.50 to 2.00 m long by 0.35 to 0.50 m high. Present on each footing are 4-5 large shallow grooves. The function of Feature B is unclear.

Feature C is situated 11.0 m southwest of Feature A. Feature C consists of a concrete stairblock (of two steps) which measures 1.00 m long by 0.60 m wide by 0.40 m high. Near Feature C is a foot trail which runs 45.0 meters to Site T-20. Site T-40 may have been a communication post or artillery spotter post associated with Site T-20.

Site T-42 - Dam

Site T-40 is situated immediately outside the project area, in Kalunawaikaala Gulch, at approximately 270' above sea level. The site consists of a dam built with waterworn basalt boulders. The dam, which spans the bottom of the gulch, measures 19.00 m long by 1.20 m wide (triple-stacked) by 1.96 m high. Alluvium has collected on the upstream side of the dam; the top of the dam on the upstream side is flush with the ground surface. The dam appears to have been constructed in the first half of the 20th century, and probably served for flood control and soil conservation.

Site T-43 - WWII Bunker

Site T-43 is situated approximately 50.0 m north northwest of Site T-40 (Figure 11). Like other WWII bunkers in the project area, T-43 is located atop steep cliffs which overlook the ocean (located at 360' above sea level). Site T-43 measures 3.4 m by 2.4 m by 1.85 m high. Present on the bunker are two apertures which face the ocean. Site T-43, fairly well-preserved, like the other coastal bunkers dates to WWII.

Site T-45 - Complex

Site T-45 is situated both inside and outside of the present project area's inland boundary. The site is located 730-770 ft above sea level on a ridgecrest between Pakulena and Kaleleiki Streams. Site T-45 consists of two trenches (Features A and B). Feature A, the larger trench, is situated outside and immediately east of the project area. It is comprised of a curvilinear trench 24.0 m long, 3.0 m deep (maximum), and averages 2.0 m wide. Present at the northeast terminus of the trench is a portion of the trench which has been roofed. The roof is earthen, and is supported by tin sheets and ironwood posts. Within a wall in the roofed portion is an aperture which measures 80 cm long by 15 cm wide; this aperture opens onto the slope which lies adjacent to the trench. Approximately 5.0 m southeast of Feature A is a 2.0 m in diameter depression of unknown origin.

Feature B is situated about 40.0 m northwest of Feature A. Feature B measures 7.0 m long by 2.0 m deep by 2.0 m wide. Feature B includes a roofed area similar in construction to the roofed area at Feature A. This roofed area measures 3.0 m long.

Features A and B are tentatively identified as military facilities dating to WWII.

Figure 11. SITE T-43. View to east. (PHRI Neg.757-25)

Site T-46 - Retaining Wall

Site T-46 is situated between Paumalu and Pakulena Gulches at the base of Puu Waihuena, which is southeast of the site. Site T-46 is a slightly curved retaining wall comprised of waterworn basalt rocks. The wall measures approximately 15.00 m long by 2.00 m wide by 0.80 m (2-3 courses) high. The wall, which is immediately downhill of a dirt road still in use, acts as a retainer for the roadbed. Site T-46 probably dates to c. 1900-1920. The roadbed it retains may have originally serviced agricultural areas of the nearby plateaus (A. Aoki, pers. comm.).

Site T-47 - Bottle and Rubbish Scatter

Site T-47 is situated about 125.0 m northeast of Site T-46. It is comprised of a small scatter of broken bottles, earthenware, pewter, porcelain, and metal fragments. The exposed area of the scatter, which is present in an eroded face of a bank, measures 10.0 by 7.0 m (long axis running horizontally across the eroded bank). The scatter includes green, brown, and purple fragments of 24 or more wine and medicine-type bottles. One bottle base bears the date "1888," and stylistically the bottles, like the other artifacts present, appear to date to about the turn of the century. Several artifacts were protruding from the eroded bank, suggesting more artifacts are buried in the bank. Some of the broken bottles at the site appear to have been used as targets for shooting practice. Site T-47 probably is associated with plantation cultivation on the plateaus c. 1900-1950.

Site T-48 - Mounds

Site T-48 is situated approximately 380' above sea level, on the plateau between Paumalu and Pakulena Gulches, immediately north of a small drainage. The site consists of two mounds (Features A and B) comprised of waterworn basalt boulders and cobbles. The mounds are adjacent to each other. Feature A, the eastern mound, is linear in plan and measures 20.0 by 3.0 by 1.5 m high. Feature B is 2.0 m away from Feature A. Feature B is oval in plan and measures 5.0 by 3.0 by 1.0 m high. Both mounds are loosely stacked. Features A and B are probably agricultural clearing mounds associated with early to mid-20th century agriculture. Several smaller probable agricultural mounds were noted west of Feature B.

Site T-49 - Retaining Wall

Site T-49 is situated on the plateau between Paumalu Gulch (to the north), Kaleleiki Gulch (to the east), and Puu Waihuena (to the south). The site consists of two retaining walls (Features A and B). Both walls are comprised of waterworn basalt boulders and cobbles.

Feature A, which is outside the project area, is situated about 1500' northwest of Feature B, which is inside the project area. Feature A is

curvilinear and runs along the downslope edge of a dirt road still in use. Feature A measures 11.0 m long by 1.5 m wide by 1.3 m (4-6 courses) high.

Feature B is linear and is situated at the downhill edge of an abandoned roadbed. The feature measures about 4.0 m long by 0.65 m wide by 1.5 m (3-4 courses) high. Features A and B are thought to be remnants of a road system which served nearby agricultural areas during the first half of the 20th century (A. Aoki, C. Ortiz, J. Hitch pers. comm.).

Site T-50 - Complex

Site T-50 consists of three features (Features A-C). Feature A consists of six segments of roadbeds. The segments, comprised of rough waterworn basalt cobbles, run adjacent to Paumalu Stream, and extend over the entire northeast boundary of the project area (see Figure 3). The segments once functioned either as roadbeds or low water crossings.

Segment 1 measures 160.0 m long by 3.5 m wide by 0.15-0.20 m high. It extends from a point 80' above sea level to a point 100' above sea level. Part of Segment 1 crosses the streambed, which is about 10.0 m wide.

Segment 2, situated 80.0 m upstream of Segment 1, is about 30.0 m long by 3.0 m wide. It runs along the southeast bank of Paumalu Stream.

Segment 3 is situated 275.0 m upstream of Segment 2. Segment 3 is a short, low water crossing. It measures about 6.0 m long by 2.5 m wide.

Segment 4, 110.0 m upstream of Segment 3, is a low-water crossing and roadbed remnant; it measures 15.0 m long by 1.5 m wide.

Segment 5, about 1,400.0 m upstream of Segment 4 is a low water crossing; it measures about 12.0 m long by 2.0 m wide.

Segment 6, 240.0 m upstream of Segment 5, is a low water crossing which straddles Paumalu Stream; it measures 12.0 m long by 1.5 m wide. Segment 6 ends at the eastern boundary of the project area. The paved segments comprising Site T-50 probably continue outside the project area.

Feature B is a double-stacked wall comprised of rough, waterworn basalt rocks. The wall runs parallel to portions of Segment 1 of Feature A, and acts as a buffer between the segment and Paumalu Stream. Feature B starts where Segment 1 of Feature A crosses Paumalu Stream and from that point extends upstream. Feature B measures about 85.0 m long by 0.60 m wide by 0.90 m high. Feature B appears to have functioned as both a soil retention wall and a water diversion wall.

Feature C is a remnant of an artificial channel; it runs parallel to Features A and B. The channel measures about 75.00 m long by 1.80 m wide by 0.80 m deep, and extends between Feature B to the south and basalt cliffs to the north. Feature C begins where Paumalu Stream loops to the south and runs across the low water crossing portion of Segment 1 of Feature A, and it ends where the stream loops back to the north. Feature C once functioned to channel water away from Festaure A.

Site T-52 - Complex

Site T-52 is situated on a gently sloping portion of a talus immediately southwest of Paumalu Stream. Site T-52 consists of a rectangular enclosure (Feature A) and a wall which adjoins the enclosure (Feature B). The walls of Feature A are single- and double-stacked. The walls are comprised of rough waterworn basalt boulders and cobbles. Two of the feature's walls incorporate basalt bedrock outcrops and very large boulders. The walls measure 0.70-1.00 m high (two to three courses), except where they incorporate the bedrock and boulders, and they enclose an area which measures approximately 55.0 sq m. Feature A contains no entryway and the area enclosed by the feature is too rocky and inclined to be used for agriculture. Feature A probably functioned as an animal enclosure sometime between c. 1880-1940.

Feature B is core-filled wall which adjoins the northern corner of Feature A. Feature B is 80.0 meters long by 1.0 m high (2-3 courses) by 2.0 m wide. It extends from Feature A northeast down a slope and ends near a dirt road at the bottom of Paumalu Gulch. The interior and exterior faces of the feature are comprised of rough waterworn basalt boulders and cobbles, and the core of the feature is filled with rubble. Feature B probably served as a field or property boundary and may be contemporary with Feature A.

Site T-53 - Retaining Wall

Site T-53 is situated about 150' above sea level on the lower slopes immediately southwest of Paumalu Gulch. The site consists of a small remnant of a stone retaining wall. The remnant consists of waterworn basalt rocks, and it measures 5.0 m long by 2.5 m wide (due to its slope) by 1.0 m high. Site T-53 has been heavily disturbed by cattle. Site T-53 probably functioned as a retaining wall for a roadbed. The site is probably associated with nearby Sites T-50 and T-56, and thus probably dates to the first half of the 20th century.

Site T-54 - Rockshelter

Site T-54 is a rockshelter situated 250' above sea level, on the steep southern slope of Paumalu Gulch, approximately 30.0 m above Paumalu Stream, at the base of a small cliff. The rockshelter measures approximately 3.75 wide by 1.80 m deep by 0.60 m high. The floor of the shelter is littered with the remains of a wild pig (including a molar, mandible, tibia and scapula). No cultural remains were noted on the floor. A trowel probe was informally placed into the floor. The probe yielded large pieces of charcoal and greasy-looking grey soil. Site T-54

may have functioned as a late prehistoric/early historic temporary habitation.

Site T-55 - Wall

Site T-55 is a wall situated on the lowest slopes south of Paumalu Gulch. The wall is core-filled. Both faces of the wall are comprised of rough waterworn basalt rocks, and the core of the wall is filled with rubble. The wall incorporates three natural bedrock outcrops and boulders. Site T-55 measures c. 20.0 m long by 0.50 m wide by 0.90 m high. The downhill end of Site T-55 adjoins Site T-56.

Site T-56 - Retaining Wall

Site T-56 is situated on the lowest slope above Paumalu Stream's flood plain, approximately 8.0 m south of and parallel to Paumalu Stream. Site T-56 consists of a well-preserved free-standing retaining wall. It is comprised of rough waterworn basalt cobbles and small boulders. The wall extends for 220.0 m in a roughly northeasterly direction, from the downhill terminus of Site T-55 upwards into Paumalu Gulch. The wall measures about 1.0 m (3 courses) high by 0.6 m wide. Much of the wall's downslope surface has been faced. Site T-56 probably originally adjoined Site T-50, Site T-58 or T-59, or perhaps it joined with Site T-49 on the plateau to the south. Site T-56 functions to retain a well-preserved roadbed which was probably used between 1880-1950.

Site T-57 - Enclosure

Site T-57 is situated on the lowest slopes immediately north of Paumalu Stream. All but the southern corner of the site is outside of the project area. Site T-57 consists of a roughly rectangular enclosure which encloses an area of about 2,700 sq m. The walls of the enclosure are core-filled, and the walls in several places incorporate bedrock outcrops and very large boulders. Both sides of the walls are faced with rough waterworn basalt rocks, and the core of the wall is filled with rubble. The walls measure about 1.0 m (3-5 courses) high by 3.0-4.0 m wide by 50-55.0 m long. Site T-57 may have been a large animal enclosure contemporary with Site T-52, a much smaller enclosure which is assumed to date to between 1880-1950.

Site T-58 - Complex

Site T-58 is situated immediately northeast of the juncture of Paumalu Streams and a small tributary drainage of the stream. The site consists of three stone features. Feature A is a wall on the inland side of the channel cut by the drainage. The wall, partially exposed and capped by 0.60 m of recent alluvium, measures 5.50 m long by 0.60 m wide by 0.80-1.80 m high.

Feature B is situated 16.0 m southeast of Feature A. Feature B is a retaining wall comprised of waterworn basalt rocks. This wall runs along a steep earthen bank next to the flood plain of Paumalu Stream and retains a roadbed. Feature B measures 10.00 m long by 0.50-1.00 m wide by 0.55-0.90 m (3-4 courses) high.

Feature C is a wall very similar to Feature A. Feature C is situated 1.5 m northwest of Feature A, on the seaward bank of the tributary drainage, opposite Feature A. Feature C measures 1.00 m long by 0.80 m high (2-3 courses) by 0.20 m wide. Like Feature A, Feature C is buried beneath 0.90-1.30 m of recent alluvium.

Features A and C are interpreted as bridge footings which perhaps supported a wooden bridge that crossed the tributary drainage. Site T-58 is interpreted as the point where the roadbed which runs along the tributary stream crossed the stream. The site is probably contemporary with Sites T-50, -53, -56, and -59, which date to c. 1880-1950.

Site T-59 - Retaining Wall

Site T-59 is situated in the base of Paumalu Gulch, just downstream of the mouth of Kaleleiki Stream. It consists of a retaining wall comprised of waterworn basalt cobbles and small boulders. The wall, which is discontinuous (in two segments--Segments 1 and 2) parallels Paumalu Stream, which is 1-6 m south of the wall. The segments are both single- and double-stacked; they average about 0.75-1.00 m wide by 1.0-1.5 m high. Segment 1 is approximately 5.0 m long; it has been heavily affected by cattle. Segment 2, about 80.0 m upstream east southeast of Segment 1, is about 25.0 m long and is much better preserved. Both segments retain on their uphill side a flat earthen roadbed. Site T-59, like the other Paumalu Gulch roadsites probably was constructed between the late 1800s and early 1900s.

Site T-62 - Linear Mound

Site T-62 is situated on the plateau between Pakulena and Paumalu Gulches, next to a small drainage a short way upstream (east) of Site T-48. The mound parallels the drainage channel, which is 4.0 south of the mound. Site T-62 measures 20.0 m long by 3.0 m wide by 0.80 m high. It is comprised of loosely stacked, unfaced waterworn basalt rocks. Some of the rocks have bulldozer blade scars on them. Site T-62 is probably an agricultural clearing mound dating to the first half of the 20th century.

Site T-64 - Rockshelter with Wall

Site T-64 is situated at the base of sheer basalt cliffs, on the top of a steep talus just north of the mouth of Kalunawaikaala Gulch. Site T-64 consists of a natural rockshelter (Feature A) and a rock wall

(Feature B). Feature A measures about 4.0 m wide by 3.0 m deep by 1.1 m high. The floor of Feature A is littered with modern trash--a straw mat, two pieces of plywood, bottles, and aluminum cans. Two pieces of high grade volcanic glass were found under a piece of plywood at the western end of the shelter. These pieces were collected for dating analysis and yielded age ranges of AD 1645-1689 and AD 1747-1767 (two standard deviations). Also noted at the shelter were 10 pieces of exotic basalt. The presence of volcanic glass and the basalt in the shelter suggests that cultural deposits may exist in the floor of the shelter. Feature A is interpreted as a temporary habitation used during the early historic/late prehistoric periods.

Feature B is situated 16.0 m north of Feature A, on a small flat bench at the base of a basalt face that leads to the base of Feature A. Feature B consists of a pile of rough basalt cobbles and small boulders. The pile measures about 5.0 m long by 3.0 m wide by 0.75 m high. Feature B may be a collapsed rock mound or perhaps a segment of wall.

Site T-65 - Rockshelter with Wall

Site T-65 is situated at the base of sheer basalt cliffs, at the top of a talus which drops about 150' to the coast, about 80.0 m north of Site T-64. Site T-65 consists of a short wall (Feature A) and a natural rockshelter (Feature B). Feature A, comprised of rough basalt rocks, is well built; it measures 6.0 m long by 1.2 m wide by 1.3 m high and lies perpendicular to a flat ledge that itself runs perpendicular to the slope. Feature B, situated about 12.0 m northeast of Feature A, measures 6.0 m wide by 4.0 m deep by 0.90 m high (maximum). The entrance to Feature B is partly blocked by a basalt boulder (2.0 m by 1.25 m) and banyan tree roots. Two trowel probes were excavated in the floor of the shelter; the probes yielded no cultural material. Site T-65, based on its form and similarity to nearby rockshelters, is interpreted as a probable late prehistoric to early historic temporary habitation.

Site T-66 - Rockshelter

Site T-66 is situated near the mouth of Kalunawaikaala Stream, in an area about 190' above sea level which has sheer basalt cliffs immediately below and above it, slightly to the north and above Site T-65. The site consists of a natural rockshelter with two chambers separated by a 0.5-m-thick natural rock wall. The larger chamber measures 5.5 m wide by 2.3 m deep by 0.90 m high. The smaller chamber measures 2.7 m wide by 2.0 m deep by 0.5 m high. The two chambers overall measure 9.0 m long by 2.3 m deep; combined, the floors of the chamber comprise 9.5 sq m. The only artifacts present in the rockshelter were modern trash and twelve or so pieces of angular, fine-grained basalt, which were scattered over the floors of both shelters. Judging by their composition, the basalt pieces appear to be from outside the site. The basalt pieces suggest the brown silty loam of the shelter floor may contain cultural deposits. Site T-66, based on its form and similarity to nearby rockshelters, is interpreted as a probable late prehistoric to early historic temporary habitation.

Site T-67 - Rockshelter

Site T-67 is situated approximately 180' above sea level, on a talus at the base of a large basalt cliff overlooking Ehukai Beach (Figure 12). Site T-67 is a natural rockshelter which has collapsed--the shelter is filled with roof fall. The roof fall has blocked the once wide shelter entrance, leaving only a small crawl-through on the west side of the shelter, and a slightly larger entrance on the eastern side. The east entrance is partly blocked by rolls of barbed wire. Site T-67 measures 8.0 m wide by 9.5 m deep by 1.5 m high. Present within the shelter were numerous human remains. Near the back of the shelter was a 1.5 m by 2.4 m scatter of human bones and bone fragments. Beneath an arch in the shelter floor was another dense scatter which included teeth, an ulna, vertebrae, digits, long bone fragments, and 30-40 bone fragments. Within the rockfall was another bone scatter which included an adult femur and three unidentified bone fragments. Beneath a small basalt boulder in the midst of the rock pile, was a relatively undisturbed burial consisting of the lower mandible, a femur, two tibia, one tooth, and a tibia of a juvenile. In all, the remains in the shelter comprise at least three individuals. Also present in the shelter were recent dog, pig, and mongoose bones; this suggests some of the human remains may have been disturbed by animals. Present within the west side of the shelter was an area unaffected by the rock fall. This area (c. 2.0 m sq) contained fine-grained silty brown loam, which suggests cultural material may exist under the rockfall. The method of burial, and the absence of historic artifacts associated with the burials, indicate that Site T-67 is a burial cave utilized during the prehistoric and early historic periods.

Site T-69 - Complex

Site T-69 is situated outside of the project area, at about 120 ft above sea level, in the center of a talus located between basalt cliffs (to the south and east) and low lying coastal areas (to the north and west). Site T-69 consists of a terrace (Feature A), and a rectangular enclosure (Feature B). Feature A is an east-northeasterly running terrace which adjoins the northern corner of the Feature B. Feature A, comprised of rough waterworn basalt rocks, measures 8.2 m long by 2.4 m wide by 0.8 m (2-4 courses) high. Feature B is a rectangular enclosure which measures about 12.0 by 16.0 meters (overall). The enclosure, constructed of waterworn basalt boulders and cobbles, is comprised of four segments (1-4). The interior area of the enclosure is somewhat level and measures about 90 square meters.

Segment 1 comprises the western wall of the enclosure. Segment 1, aligned perpendicular to the slope of the site, is constructed of rough waterworn basalt boulders and cobbles. The top of the segment on the uphill side is in places flush with the ground surface. Segment 1 measures c. 16.0 m long by 2.0 m wide by 0.95 m high (on exterior side). One piece of coral was found on the southwest end of Segment 1.

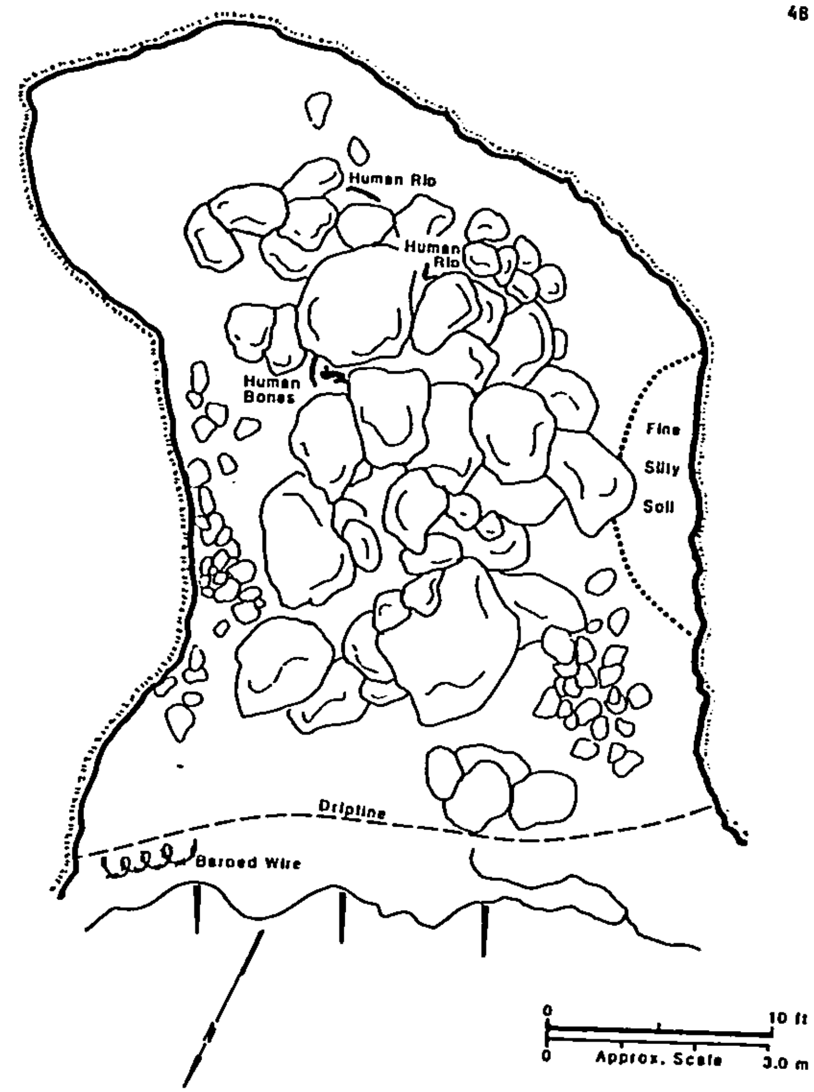


FIGURE 12. SKETCH MAP OF SITE T-67

Segment 2 comprises the southwestern wall of the enclosure; it measures 12.4 m long by 2.0 m wide by 0.40-0.60 m (2-3 courses) high. One piece of coral rock was found at the downhill end of Segment 2. Segment 3 comprises the southeastern wall of the enclosure. This segment is very badly damaged, perhaps by cattle; it resembles a tumbled low linear rock mound more than a wall. Segment 3 measures about 16.0 m long, and the most intact portion of it measures 0.6 m high by 2.0 m wide.

Segment 4 comprises the northeastern wall of the enclosure; it measures about 12.0 m by 2.0 m by 0.7 m high. Incorporated in the eastern end of the segment is a large basalt boulder (3.0 by 3.5 m). Two pieces of coral rock were found in about the middle of Segment 4.

Site T-69 structural form, massive walls, and presence of coral suggest it functioned as a shrine or small heiau. Its apparent isolation from residential structures supports a heiau interpretation.

Site T-70 - Complex

Site T-70 is situated at about 160-175' above sea level, at the top of a moderately steep talus inland of Sunset Elementary School, at the base of a basalt cliff just north and east of the mouth of Pakulena Gulch, immediately inside the project area Figure 13. Site T-70 is comprised of two petroglyph galleries (Feature A) and four rockshelters (Features B-E); it covers an area c. 60 m north to south.

Feature A consists of two small groups of petroglyphs. One group, situated on an uneven basalt cliff face, covers an area which extends from about 1.8 m above ground surface to at least 3.0 m up the cliff face. This group includes six or more small anthropomorphic figures and a petroglyph of a large fish or shark. Twelve meters north of the first group is another group of petroglyphs; this second group is mostly inaccessible without special equipment. One petroglyph in the second group depicts a dog, which stylistically, is typical of traditional Hawaii. The Feature A petroglyphs, because they do not depict later subject matter such as horses and ships, is thought to date to the prehistoric or early historic periods.

Feature B is situated about 4.0 m south of the main group of petroglyphs comprising Feature A. Feature B measures about 12.0 m high by 5.5 m wide by 2.5 m deep. Present on the floor of the feature was a bifacially worked basalt flake tool. The floor of Feature B, comprised of brown silty loam, may contain buried cultural deposits.

Feature C is situated about 21.0 m south southwest of Feature B (Figure 14). Feature C measures 4.5 m wide by 5.0 m deep by 1.7 m high. Present within Feature C were scattered human remains--among them two femurs, a tibia, a tibia, and a radius which together comprised at least one adult. Also present were two ischual crests, fragments of the pelvic girdle of a possibly juvenile, an incisor, and two unidentified

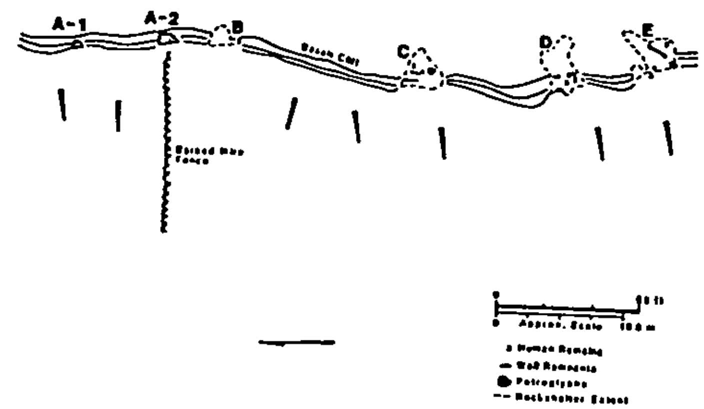


FIGURE 13. SKETCH MAP OF SITE T-70

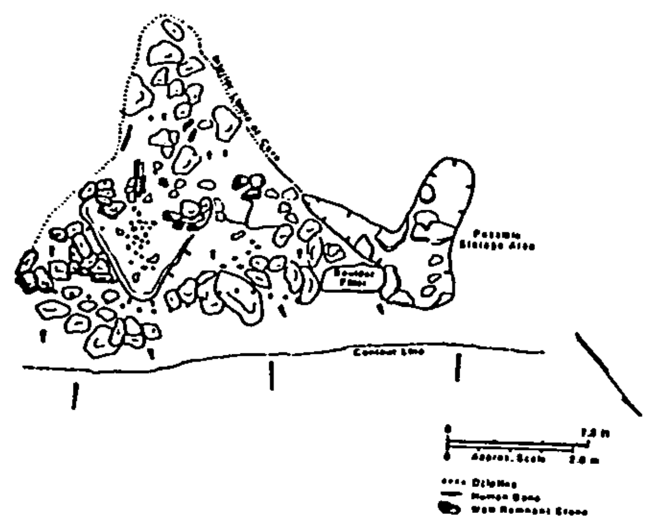


FIGURE 14. SKETCH MAP OF SITE T-70, FEATURE C

fragments. All the remains were probably once protected by a wall comprised of rough basalt cobbles--the remains of which are on either side of the shelter's entrance. Adjacent to Features C, to the northwest is a small blister which may have been used as a storage area. No soil buildup has occurred within Feature C; this indicates the feature was probably used strictly for burials, probably during the prehistoric to early historic periods.

Feature D, situated about 13.4 m south of Feature C, measures 4.5 wide by 6.0 m deep by 1.0 m high. Present in Feature D were at least two burials. Scattered about the mouth of Feature D were two femurs, a femur fragment, a radius, a scapula fragment, two toe fragments, a molar, a clavicle fragment, a pelvic fragment, and at least 17 small unidentified bone fragments. The method of burial, and the absence of historic artifacts associated with the burials suggest Feature D dates to the early historic and or prehistoric periods. The floor of Feature D may contain buried cultural material.

Feature E is situated about 6.0 m south of Feature D. It consists of two chambers separated by a c. 20-cm-thick natural rock wall. The north chamber of the feature measures 1.5 m wide, 1.1 m deep, and 0.8 m high. The other chamber is 1.35 m wide (at opening) by 5.25 m deep by 1.00 m high. Present on the floor of Feature E were a caudal vertebra, a metacarpal fragment, and an unidentified human bone fragment. Feature E may originally have been protected by a small wall comprised of rough basalt cobbles and boulders, as a remnant of such a wall is extant at the entrance to the larger chamber. This wall remnant measures 0.50 m long by 0.30 m thick by 0.30 m (2 courses) high.

Site T-71 - Complex

Site T-71 is situated about 180' above the coast, in the middle of steep basalt cliffs near the mouth of Kalunawaikaala Gulch, almost immediately above Site T-64. Site T-71 consists of a small rockshelter (Feature A) and two walls (Features B and C).

Feature A measures 3.0 m wide by 3.5 m deep by 1.0 m high. It is devoid of cultural remains.

Feature B is 1.75 m long, 0.25 m wide, and 0.63 m high (2-3 courses). It is at the northern end of Feature A, and thus, may have acted as a windbreak.

Feature C is situated 1.0 m south of Feature B, in the middle of Feature A. Feature C measures 1.25 m long by 0.40 m thick by 0.50 m high (2-3 courses). Half of the northern side of Feature C appears to be somewhat faced. Feature C, like Feature B, may have been used as a windbreak.

Based on its form and similarity to nearby sites, T-71 may have been used for very temporary occupation during the late prehistoric and early historic periods.

Site T-72 - Rockshelter

Site T-72, which overlooks Ehukai Beach, is situated approximately 35.0 m southwest of Site T-71, in the middle of a series of steep basalt cliffs located just north of the mouth of Kalunawaikaala Gulch. Site T-72 is a rockshelter which measures about 3.0 m wide by 7.0 m deep by 1.5 m high. Present with the shelter is an adjoining area which measures 1.0 sq m. Present on the surface of the shelter floor, near the shelter's northeast entrance, was a single human bone, a metacarpal. The floor of the shelter, measuring c. 16.0 sq m, consists of powdery, very pale brown silty loam. An informal trowel probe was excavated into the shelter floor; it yielded charcoal at approximately 10-15 cm below surface. Site T-72 may contain more human remains and the floor of the shelter probably contains buried cultural material. The site probably dates to the early historic/prehistoric periods and probably was used for both temporary habitation and human burial.

Site T-73 - Rockshelters

Site T-73 is situated immediately above and southeast of Site T-72. It consists of two rockshelters (Features A and B) approximately 6.0 m apart. Feature A, is closest to Site T-72; it measures 1.20 m wide, 1.20 m deep and 0.55 m high. An informal trowel probe was excavated into the 1.5 sq m silty, brown loam floor of Feature A. The probe yielded charcoal at approximately 20 cmbs, suggesting there are intact cultural materials buried in the floor.

Feature B is 5.0 m wide, 2.5 m deep, and 1.4 m high. An informal trowel probe was excavated into the 8.5 sq m silty rocky loam floor of the feature. The probe yielded abundant charcoal at 10-15 cmbs. Present on the surface of the Feature B floor were two pieces of marine shell. The abundant charcoal yielded by the probe indicates a hearth may be present. Site T-73 may have been occupied for brief periods during the prehistoric or early historic periods.

Site T-74 - Wall

Site T-74 is situated on a moderately steep talus immediately northeast of Sunset Beach Elementary School 1.0-2.0 m southwest of the project area boundary, which it parallels. Site T-74 is comprised of rough waterworn basalt rocks; it measures about 1.20 m high by 0.40 m thick, and is about 60.0 m long (extending from 50-100' above sea level. Site T-74 has been heavily affected by cattle; it probably served as a historic property boundary and/or as a cattle wall.

Site T-75 - Complex

Site T-75 is situated approximately 200 ft above sea level, in a sheer basalt cliff near the bottom of Pakulena Gulch. The site consists of a small rockshelter (Feature B) and two walls associated with the rockshelter (Features A and C). Feature B measures 4.50 m wide by 4.25 m deep by 0.50 m high. The floor of Feature B, near the mouth of the feature, is covered with brown silty loam which may overlay cultural deposits.

Feature A, which measures 1.5 m long by 0.5 m thick by 25.0 m high, is situated near the western edge of the entrance to Feature B. Feature A consists of single-stacked wall comprised of rough basalt cobbles. It may have once adjoined with Feature C to block off the interior half of the shelter.

Feature C, identical in construction to Feature A, is situated on the eastern edge of the shelter, opposite Feature A. Feature C measures 1.0 m long by 0.5 m wide by 0.4 m high.

Site T-75 may have been used for temporary habitation during the prehistoric or early historic periods.

Site T-76 – Complex

Site T-76 is situated about 540' above sea level on the crest of the ridge between Paumalu and Kaleleiki Streams. The site covers an area measuring about 36.0 m north-south by 26.0 m east-west. Site T-76 consists of four wood and metal features (A-D).

Feature A consists of a large wooden platform nailed onto telephone poles, 3 by 12 lumber, and 55-gallon drums partially supported by two pre-WWII porcelain bathtubs and topped with pieces of tin roofing. Feature A measures about 6.3 m by 5.5 m by 0.5 m high. Its function is unclear; it may have been a platform for a storage area.

Features B and C, situated about 3.0 m southeast of Feature A, consists of two identical wooden water tanks. The tanks are supported by wooden platforms; the wood pieces of the tank are banded together by metal straps. The tanks both measure 3.0 m in diameter by 2.0 m high.

Feature D is situated 2.0 m south southeast of Feature C. The southernmost water tank is the northern corner of Feature D. Feature D consists of a wooden corral and cattle-loading chute. Both the corral and chute are in poor condition (only the loading chute is intact). Feature D measures approximately 11.0 m by 11.5 m by 2.5 m high.

Present north and west of Feature A are items related to Site T-76--a 300-gallon fuel drum with spigot, a small vehicle axle with rubber tires, and several aluminum phone boxes. Site T-76 was a ranching and agricultural facility used for much of the 20th century (C. Ortiz and A. Aoki, pers. comm.).

Site T-77 – Rockshelter with Wall

Site T-77 consists of a small walled rockshelter situated in a nearly vertical cliff face on the south side of Pakulena Gulch, c. 10.0 m above the floor of the gulch and c. 15.0 m below the top of the cliff. The rockshelter is on a ledge which measures approximately 1.0-1.5 m wide and 8.0 m long. The sheltered area is approximately 3.5 m long, 1.00-1.25 m wide, and 1.50 m in height. Enclosing the sheltered area at the dripline is a crudely constructed, single-stacked wall. This wall consists of angular basalt boulders and cobbles and several incorporated roof-fall boulders. The wall measures approximately 3.50 m long, 0.30-0.50 m thick, and 0.30-0.75 m high. The floor of the rockshelter is partially covered by a shallow deposit of reddish-brown clay loam and roof-fall cobbles. No portable remains were visible on the floor. The smallness of the rockshelter, and its relatively inaccessible location, combined with the presence of an enclosing wall suggest the rockshelter may have been used for burial. The lack of visible skeletal remains may indicate they have been removed, or they may have decayed and/or are obscured by the deposit of sediment in the rockshelter.

Site T-78 – Cave

Site T-78 is a cave situated on the steep slopes on the south side of Pakulena Gulch. The cave is situated approximately 30.0 m above the floor of the gulch and 10-15.0 m below the top of the slope. At the mouth of the cave is a narrow sheltered bedrock ledge which comprises the cave floor. This ledge measures approximately 8.0 m long, 1.0-2.0 m wide, and 1.7 m high. Behind the ledge is a second bedrock ledge, 0.15-0.20 m higher than the first ledge. The cave measures approximately 3.50 m wide, 4.00-4.50 m deep, and 0.75-1.50 m high. The cave floor, which is covered with a deposit of reddish-brown clay loam and pebbles, is relatively level between the second ledge and a point approximately 2.0 m in from the second ledge. Beyond the second ledge the cave floor slopes upward toward the back of the cave.

Portable remains in the cave consisted of several volcanic glass flakes scattered around two exposures of surface chill volcanic glass. The flakes were present on the surface of the second bedrock ledge. The exposures showed evidence of flaking/quarrying activity. Other remains in the cave consisted of a sparse scatter of midden and one piece of volcanic glass. The piece of volcanic glass was situated at the east end of the sheltered outer ledge, in and adjacent to a small niche (c. 0.75 m deep, 0.50-0.60 m wide, and 0.20-0.30 m high) in the cliff face. The midden consisted of Echinoidea mouth parts, a Turbo shell fragment, kukui nut shell fragments, fish bone, and bird bone.

Site T-78, based on its form and range of portable remains, appears to have served as a prehistoric temporary habitation and quarry.

Site T-79 - Cave

Site T-79 is a narrow cave situated in the steep slope on the south side of Pakulena Gulch, approximately 35.0 m above the gulch floor, and 15-20.0 m below the top of the slope. The cave is approximately 2.0 m wide at the mouth, tapering to c. 0.50 m wide at the back of the cave, c. 5.0 m from the cave mouth. The cave is approximately 0.50 m high at the mouth and tapers to c. 0.20 m at the back. The relatively level cave floor is covered with a thin deposit of reddish-brown clay loam. The only evidence of cultural use of the cave is a single waterworn coral cobble situated on the floor of the cave approximately 4.0 m in from the entrance. A waterworn piece of vesicular basalt was noted on the steep slope outside the cave entrance.

The small size and relatively inaccessible location of the cave, combined with the presence of a possible offering (coral cobble) suggest a religious function for the site, either as a shrine or for burial. The lack of visible skeletal remains may indicate they have been removed, they have decayed and/or are obscured by the cave sediments, or that the cave is a small shrine and not a burial.

Site T-80 - Cave

Site T-80 is situated in the face of the cliff above Sites T-18 and T-19, approximately 5.0 m below the top of the cliff and 15.0 m above the base of the cliff. The cave fronts onto a ledge approximately 10.0 m long and 1.0-3.0 m wide. The cave has two openings separated by a pillar of rock. The cave is approximately 2.0-3.5 m wide, 3.0-4.0 m deep, and 0.5-1.5 m high. The floor of the cave is littered with roof fall cobbles and boulders. Scattered among the roof fall are human skeletal remains, including a mandible, vertebrae, teeth, and other bone fragments. The remains appear to represent a single, adult individual. The remains also appear to have been disturbed. Based on the lack of historic grave goods and the presence of skeletal material, Site T-80 is interpreted as a prehistoric burial cave.

CONCLUSION

DISCUSSION

During the combined surface and subsurface reconnaissance survey of the Pupukea-Paumalu Development project area 60 sites were identified, nine backhoe trenches were excavated, and hand-trowel probes were conducted at 18 rockshelters. Of the 60 identified sites, 50 are totally within the project area, four are partially within the project area, and six are totally outside the project area. The 60 sites are comprised of at least 112 features representing c. 15 feature types. Feature types include: terrace, retaining wall, free-standing wall, rockshelter, cave, pavement, enclosure, cairn, petroglyph, mound, and a variety of historic types including earthen, concrete, masonry, wood, and metal constructions.

The identified sites can be subsumed under the following 12 functional categories (Sites T-13, -18, -70, -72, and -78 have more than one function):

- Transportation (historic) - 13 sites
- Temporary habitation (prehistoric/early historic) - 12 sites
- Agriculture (WWII) - 11 sites
- Military (mid-20th century) - 5 sites
- Burials (early historic/prehistoric) - 4 sites
- Quarry (prehistoric) - 2 sites
- Ranching (historic) - 4 sites
- Trail or property markers (all periods) - 3 sites
- Ceremonial sites (prehistoric/early historic) - 2 sites
- Permanent habitation (all periods) - 2 sites
- Rock art (early historic/prehistoric) - 2 sites
- Dump (historic) - 1 site
- Age and function unknown - 3 sites

SITE CLUSTER ANALYSIS

For the purpose of discussing the ages and functions of sites identified during the current project, sites are categorized into eight clusters. Each cluster is comprised of sites which (a) are spatially associated, (b) are contemporary with each other, and (c) are of similar or interdependent function. Fifty-two of the 60 identified sites are subsumed in clusters. Eight of the sixty sites did not fall into any cluster. The site clusters are summarized in Table 3 and are depicted in Figure 15.

Cluster A - Seaward Cliffs

The eight sites comprising Cluster A (Sites T-64, -65, -66, -67, -71, -72, -73, and -80) are situated either on the cliffs that line the coast

Table 3.

SUMMARY OF SITE CLUSTERS

CLUSTER	SITES (N=)	DATE	TYPE OF SITES
A. Seaward Cliffs	T-64, -65, -66, -67, -71, -72, -73, -80 (N=8)	Early hist.; prehistoric	Temp. occupation; burial
B. Talus Slope	T-5,-7,-13,-16,-18, -19, -31, -34 -70 (N=9)	Early hist.; prehistoric	Agric., burial habitation, rock art
C. Paumalu Gulch	T-50, -52, -53, -55, -56, -57, -58, -59 (N=8)	Historic 1860-1950	Transportation, ranching
D. Upper Plantation	T-23, -25, -46, -47, -48, -49, -62 (N=7)	Early 20th Century c.1900-1950	Transportation, agricultural Habitation?
E. Lower Plantation	T-4, -14, -15, -17, -74 (N=5)	Late 19th-early 20th. century (1860s-1950)	Agricultural, transportation
F. WWII Coastal Defenses	T-20, -22, -40, -43, -45 (N=5)	WWII	Military
G. Pakulena Gulch	a. Rockshelters T-30, -75, -77, -78, -79 (N=5)	a.Prehist./ early hist.	a. Temp. hab. burials/ shrines (?)
	b. Roads T-32, -33 (N=2)	b.1900s to mid 1940s	b. Transportation
H. Kalunawaikaala Gulch	T-35, -37, -38 (N=3)	20th century (1900-1970)	Transportation, agriculture

(Outside of any cluster - Sites T-1, T-2, T-3, T-21, T-42, T-54, T-69, and T-76)

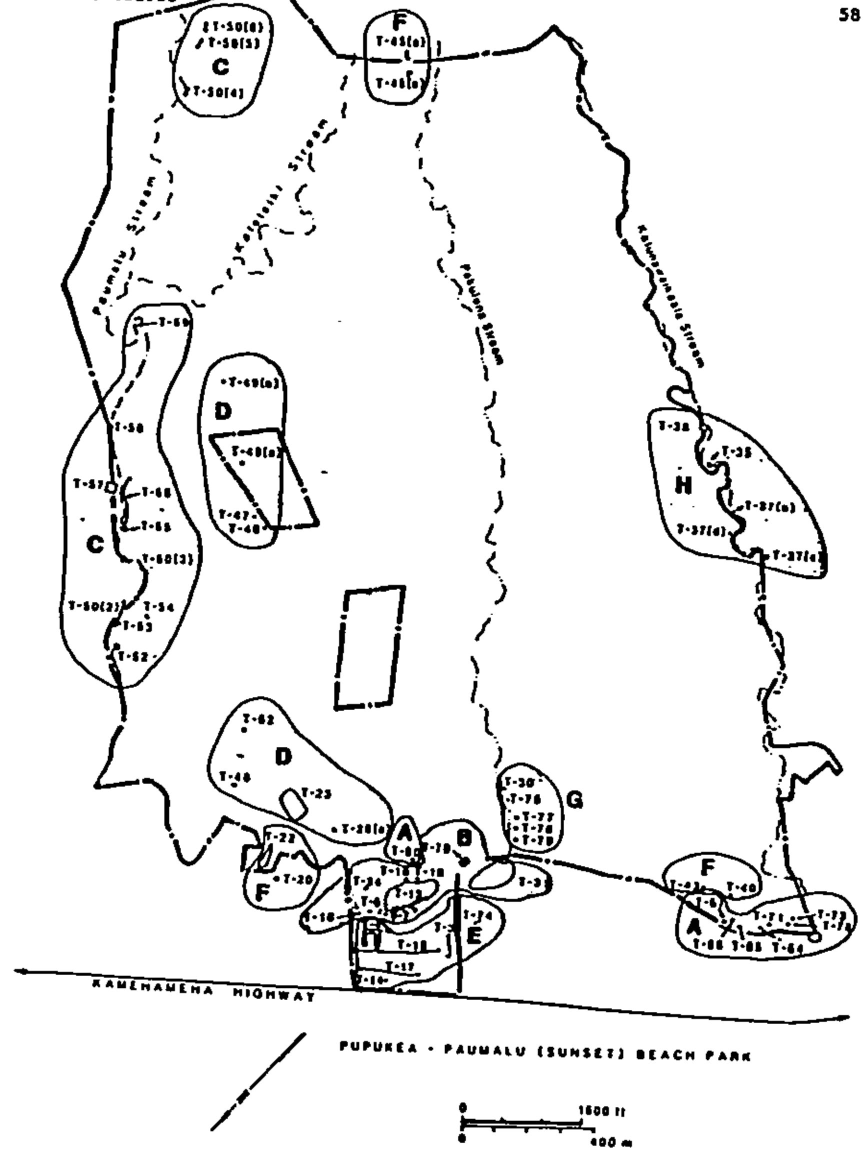


FIGURE 16. SITE CLUSTER LOCATION MAP

from Kalunawaikaala to Paumalu Gulches, or at the top of the talus fronting the cliffs. Cluster A covers 350.0 m (N-S) by 35.0 m (E-W). All the sites in Cluster A are rockshelters used either for temporary habitation or burials, and all the sites were utilized during the prehistoric and/or early historic periods. Evidence of temporary habitation (brief, perhaps overnight occupation) was found at Sites T-64, -66, -71, -73, and possibly at Sites T-65, -67, and -72. Sites T-67 and -72 each contained one or more human burials. Features present at the identified sites include internal and external walls (at Sites T-64, -65, and -71), a possible hearth (at Site T-73), and human burials (at Sites T-67, -72, and -80). Possible intact cultural deposits were noted at Sites T-64, -65, -66, -67, -72, and -73.

Site T-64 - Evidence for occupation of Site T-64 includes two non-cortical flakes of high grade volcanic glass and 10+ angular, broken pieces of fine-grained basalt. That Feature A is well-suited for temporary occupation is attested to by the fact that it has been recently used--modern artifacts litter its floor. Feature B of the site, a mound or wall remnant, may date later than Feature A. The function of Feature B is unclear.

Site T-65 - There is presently little evidence of temporary habitation at Feature B (rockshelter) of Site T-65. Two trowel probes excavated in Feature B failed to locate cultural material. However, in terms of size and configuration, the feature is similar to the shelter at Site T-64. Also, T-65 is proximate to T-64; thus, there is still a possibility that subsurface cultural material is present at the feature.

Feature A of Site T-65, a short wall, based on its structural form and its superior state of preservation (as compared to Feature B), is assumed to be late historic in origin--unrelated to the possible prehistoric and/or early historic occupation of Feature B.

Site T-66 - The modern trash at T-66 (rockshelter) indicates the shelter was used intermittently for brief periods over the past 20 or so years. Since no pre-modern historic artifacts were present at the shelter, and since lithic tools/implements were mostly replaced by imported goods by the mid 19th century, the 12+ angular pieces of basalt scattered on the floor of the shelter probably reflects intermittent brief periods of occupation during the early historic and prehistoric periods.

Site T-67 - The skeletal remains at Site T-67 indicate the site was used as a burial cave. The method of interment and the lack of historic artifacts associated with the burials indicate the site was used in the prehistoric or early historic periods. Prior to use as a burial cave, the site may have been used as a temporary habitation shelter. A 2.25 sq m deposit of fine-grained silty brown loam was present on the western side

of the shelter. Similar deposits of loam found at other Cluster A sites have yielded cultural material reflecting prehistoric and early historic temporary occupation. The floor of Site T-67 may contain more loamy deposit; however, the floor is presently almost completely covered with roof fall.

Site T-71 - Site T-71 (rockshelter) contains no midden on its floor; however, the site contains two short walls (Features B and C), one of which is crudely faced. These walls, which probably functioned as windbreaks, suggest the site was used for habitation; the lack of midden indicates the site was used very intermittently. The lack of historic artifacts at the site indicates that occupation took place probably during pre-Contact times.

Site T-72 - Site T-72 may have been used for both temporary occupation and human burial. Evidence at the site which suggests temporary occupation includes: a) a small amount of charcoal found within a trowel probe excavated into the site's floor, (b) a 1.0-m-sq area which adjoins the shelter (this area could have been used for storage), and (c) the somewhat unique soil in the shelter floor. Evidence which suggests the cave was used for a burial or burials includes a single metacarpal. The bone may indicate a burial is present in the floor, or the bone may be all that remains of a burial that has since been removed by animals. The absence of historic artifacts at the site indicates the cave was utilized before 1850.

Site T-73 - Site T-73 (two rockshelters, Features A and B) is the southernmost and highest in elevation of the Cluster A sites. Trowel probes at both shelters uncovered charcoal, 20 cmbs in Feature A and 15-20 cmbs in Feature B. Two pieces of marine shell were noted on surface of Feature B. As no historic artifacts were noted at Site T-73, Features A and B probably were intermittently occupied during the prehistoric and/or early historic periods. The charcoal and marine shell at the site suggests that food preparation and consumption may have taken place at the site.

Site T-80 - Scattered among the roof fall at this site are skeletal remains, including a mandible, vertebrae, teeth, and other bone fragments. The remains appear to represent a single, adult individual. The remains also appear to have been disturbed. Based on the lack of historic grave goods and the presence of skeletal material, Site T-80 is interpreted as a prehistoric burial cave.

Cluster B - Talus Slope

Site Cluster B is located on the slopes of the talus immediately north and west of the mouth of Pakulena Gulch. It consists of nine sites: T-5,

-7, -13, -16, -18, -19, -31, -34, and -70. Sites T-5 and -31 are agricultural features; Site T-7 is a cairn, Site T-16 is a mound, Site T-13 is a habitation, agricultural, and rock art complex, Sites T-18 and -19 are rockshelters that were probably occupied for brief periods (also, T-18 may have been used as a volcanic glass quarry); Site T-34 is a burial cave and Site T-70 is a complex of four rockshelters (three containing single or multiple burials) and a petroglyph gallery. Cluster B covers an area 270.0 m (north-south) by 150.0 m (east-west). All the features in the cluster appear to date to the early historic or prehistoric periods.

Exactly how interrelated the sites comprising Cluster B sites are is yet to be determined. If the sites are contemporaneous, it would not be improbable that they are associated with one group, perhaps comprising more than one generation of a single family. Cluster B may be contemporary to Cluster A. However, functionally and formally the clusters are quite dissimilar. The range of activities is much more varied at Cluster B sites; activities include lithic procurement and initial reduction, temporary and permanent habitation, ranching, agriculture, and mortuary and other ceremonial activities. All sites in Cluster B except Sites T-7, -16, and -31 (-31 being out of the project area) are recommended for further data collection.

<u>Sites T-5, T-7, and T-16</u> - Site T-5, a terrace, may be associated with Site T-16, a rock mound about 25.0 m to the north. Site T-7 is interpreted to be an early historic/prehistoric trail marker. Site T-16 may have functioned, as it does now, to divert water in a small drainage northward, away from Site T-5. The position of Site T-5, on a talus unprotected by encircling walls, means that it would have been exposed to free-ranging livestock, which were a problem on Oahu as early as 1809 (Morgan 1948:69). As such grazing would have impaired the agricultural productivity of Site T-5, the site is assumed to date to the early historic period at the latest.

<u>Site T-13</u> - The largest site in Cluster B is Site T-13, a complex of at least 14 stone features. Site T-13 may have been a single-family farmstead which was occupied prior to the widespread introduction of western plant and animal domesticates to the area.

Feature A of Site T-13, a low wall, may have retained soil for an activity area. This activity area was perhaps used by occupants of nearby Feature B.

Feature B, a terrace and possible house site, was probably the focus of occupation at Site T-13 and may have been, to a lesser degree, the focus of occupation at all of Cluster B. Due to its size, configuration, and method of construction Feature B is tentatively interpreted as a small, single-family dwelling probably occupied on a permanent basis. The complete absence of historic artifacts at the feature suggests it was occupied sometime during the prehistoric to early historic periods.

Feature C retains soil for a terrace area to its northeast. This terrace may have been used for agriculture. The feature also somewhat restricts access to Feature B.

Feature D is a large terrace which retains a c. 60-sq-m deposit of loamy soil. Feature D is assumed to have been an agricultural terrace. Whatever its function, the feature is well-planned; it opportunistically incorporates natural features. It is also obvious that a fairly large amount of labor was invested to produce the feature.

Feature E, 16.0 m northwest of Feature D, is interpreted as an agricultural terrace.

(Feature F discussed below.)

Feature G consists of five basalt boulders on which are pecked seven small faint anthropomorphic petroglyphs. Four of the boulders are within the project area; the fifth boulder is about 60.0 m southwest of the other boulders, outside the project area. Petroglyphs such as at Feature G have elsewhere been associated with early historic and prehistoric habitation sites. Feature G is probably associated with use of Feature B. That the petroglyphs do not represent cattle, horses, or ships (common at early historic petroglyph sites [Kirch 1985:271]) suggests Feature G dates to the prehistoric period.

Feature H, a single-stone alignment, is thought to be the foundation of a now vanished wall. As such, it would have formed an enclosure with Features A, C, and I--an enclosure which would have surrounded Feature B. Feature H is badly damaged by cattle; it may be impossible to verify its function.

Feature I, prior to bulldozing of a jeep trail, may have abutted Feature A and formed one wall of the possible enclosure which surrounded Feature B.

The T-13 features discussed thus far are all thought to be contemporary and interrelated. Tentatively, they are dated to either the early historic and/or prehistoric periods. The five other features at Site T-13 (F, K-N) may have been constructed later and may be unrelated to occupation of the site.

Features F and L, prior to being damaged by bulldozing and cattle, may have connected with Features K and M to form an enclosure. This enclosure may have adjoined another enclosure formed by Features M, L, F, and N (the uphill ends of Features N and F abut sheer basalt cliffs). This latter enclosure would have enclosed an area of approximately 3,500 sq m. The former enclosure would have enclosed about 1,550 sq m. Feature L retains on its uphill side slope wash deposition; however, the feature does not appear to have been used for agriculture. The size and height of the walls forming the possible enclosures suggest they were constructed to hold goats and cattle rather than to hold pre-contact domesticates such as pigs, which could have been penned in much more modest walls.

The walls that form the two possible enclosures are well-preserved, which suggests the walls post date the rest of Site T-13. If the rest of Site T-13 was contemporary with the walls, then the rest of the site would have had higher walls to keep out the animals; instead Features A, H, and I seem more typical of pre-contact structures at nearby Waimea Canyon (R. Mitchell, pers. comm.)--structures which were designed for pre-contact species like pigs and dogs. Apparently, two distinct functions are represented at Site T-13. The older portion of the site is associated with agriculture and permanent habitation during the prehistoric to early historic periods, and the newer portion is possibly related to 19th century or later cattle or goat ranching.

<u>Sites T-18 and T-19</u> - Feature A of Site T-19 contained a coral abrader and a polished basalt cobble fragment. Site T-18 contained, scattered on its floor, low grade volcanic glass. The presence of such artifacts, and the dearth of historic artifacts at the sites indicate occupation of the sites probably predates the 19th century.

<u>Site T-31</u> - Site T-31 is an agricultural complex. Because it is outside the project area it was only cursorily recorded. As no encircling walls or historic artifacts were noted at the site, the site is thought to date to sometime before 1850. The site may be associated with occupation at Site T-13.

<u>Site T-34</u> - Site T-34 is a burial cave estimated to be roughly contemporary with Site T-70. In the burial cave were pieces of a canoe,the largest of which contained along its side small oblong holes. Except for minor insect damage, the canoe fragments were well-preserved. Also found at the site were two pig mandibles (possibly offerings). The canoe fragments and the mandibles suggest that Site T-34 dates prior to the modern era.

<u>Site T-70</u> - Site T-70 is a group of four rockshelters (Features B-E) and a small petroglyph gallery (Feature A). Based on evidence at the site and due to the fact that the sites lack historic artifacts, the site is tentatively interpreted as early historic and/or prehistoric, perhaps contemporary with Site Cluster A and the older features of nearby Site T-13.

Feature A, a petroglyph gallery, consists of both anthropomorphic and zoomorphic petroglyphs. One petroglyph depicts a dog. The petroglyphs are thought to date to the early historic/prehistoric periods because they do not depict typical later subject matter such as ships and cattle.

Feature B, a rockshelter, contains an area covered with silty brown loam. This area may contain subsurface cultural material. That Feature B was used for temporary occupation seems likely, given the bifacially

worked fine-grained basalt cobble found on its surface. As such flake tools were replaced when modern metals became available, occupation of Feature B probably dates to the early historic period at the latest.

Features C and D contain at least two burials each. The remains at Feature D were mostly scattered at the mouth of the shelter. Probably the remains were scattered by scavenging animals; however, several long bones were found neatly stacked. Multiple burials like those at Features C and D are generally attributed to the prehistoric and early historic periods.

Feature E contained the remains of at least one individual. Feature E probably is contemporary with the other rockshelters at Site T-70.

<u>Cluster C - Paumalu Gulch</u>

Cluster C, which covers c. 2,200 sq meters, probably includes the oldest historic sites in the project area. The cluster is comprised of Sites T-50, -53, -56, -58, and -59 (road segments and complexes); Sites T-52 and -57 (walled animal enclosures); and Site T-55, a property or field boundary wall. Features present at Cluster C include cobble roadbeds, low water crossings, retaining walls, drainage ditches, rock walls, and rectangular enclosures. Most of the features are associated with wagon roads which served the agricultural areas on either side of Paumalu Gulch. Initial large-scale agriculture in north shore upland plateaus began about 1900 (Estioko-Griffin 1986:22), thus, 1900 is taken as the earliest possible date for the wagon roads. Large-scale agriculture continued in the area into the 1960s (A. Aoki, pers. comm.). By the 1960s, the wagon roads had probably been abandoned; this is indicated by the presence of deep slope-wash alluvium covering the roads, alluvium which must have taken a long time to accumulate. Sites T-52, -55, and -57 were probably related to the wagon roads. Site T-55 is a short core-filled wall abutting Site T-56, a road segment; Sites T-52 and -57 are interpreted as animal enclosures dating to the late 19th or early 20th century.

The lack of artifacts at Cluster C sites precludes refined dating. However, the absence of modern, mass-produced glass or metal artifacts at the sites suggests Cluster C has been abandoned for at least 50 years. None of the Cluster C features appear to represent cultural or archaeological values of any significance.

<u>Cluster D - Upper Plantation</u>

Cluster D sites (T-23, -25, -46, -47, -48, -49, -62) are situated on the seaward half of the plateau between Paumalu and Pakulena Gulches. The sites are scattered over an area which measures 1,500 m (E-W) by 800 m (N-S). Cluster D sites are related to agricultural and transportation systems that once covered the plateaus in the project area (J. Hitch, pers. comm.).

Site T-23 is a complex of nine concrete and stone features that local residents refer to as "the plantations manager's house" (A. Aoki and J. Narvaes, pers. comm.). Other Cluster D sites are either retaining walls for old railroad or wagon road beds (Sites T-25, -46, and -49) or are agricultural clearing mounds (Sites T-48 and -62). Cluster D sites are thought to date to about the same period as Cluster C sites--from about the turn of the century to the period shortly after WWII. However, Cluster D sites were probably used longer than Cluster C sites.

Cluster E - Lower Plantation

This cluster includes five sites located north and west of Sunset Beach School at the base of a talus. One of the sites, Site T-74, is outside of the project area. Cluster E covers 270 m (N-S) by 180 m (E-W). Feature types at the cluster include irrigation ditches (Sites T-15 and T-17), a stone-lined well and concrete foundation (Site T-14), a large earthen berm (Site T-4), and a rock wall (Site T-74).

Sites T-15 and -17 are long narrow depressions, each running over a hundred meters perpendicular to the gentle slope at the base of the talus. A backhoe trench (#10) was excavated across Site T-15 revealing a small channel cut into sandstone bedrock. This channel was identified as an irrigation ditch. Site T-4, a U-shaped earthen berm 60.0 m by 42.0 m by 1.75 m high, may have once been a railroad siding. Site T-14 consists of a filled-in stone-lined well. The well is probably contemporary with Sites T-4, -15, and -17. Adjacent to the well is a rectangular concrete slab. The slab may be a former pumphouse foundation. Site T-74, a short core-rubble wall, may date slightly earlier than the other Cluster E sites (c. 1880-1900?). Site T-74 may be a field or boundary wall.

Cluster E sites may be roughly contemporary with Cluster D sites. All Cluster E sites are thought to be associated with agriculture or ranching during the first half of the 20th century.

Cluster F - WWII Coastal Defenses

This cluster is comprised of Sites T-20, -22, -40, -43, and -45. Site T-20 is situated outside the project area. Cluster F is not confined to a single discrete area. Three sites (Sites T-20, -40, and -43) comprise one spatially discrete cluster, and two other sites (Sites T-22 and T-45) are situated 1,400 m and 1,500 m to the north and east of the main cluster--which measures about 150.0 m (N-S) by 90.0 m (E-W). All but Site T-45 are situated at the edge of the upland plateau, overlooking the coast.

Sites T-20, -22, and -43 are reinforced concrete bunkers. These bunkers were constructed by the U.S. military during WWII as part of an effort to fortify Oahu's coastline. Site T-40 consists of a small group of concrete foundations and a wood and concrete structure which may been an outbuilding. The site is thought to have been either a fire control post or a command center associated with the bunkers. Site T-45 is a

series of modified trenches. The trenches are thought to be military training facilities because they occupy good defensive positions, and because one of the trenches contains an aperture from which to fire downslope. Further historical documentary research could provide insight into exact period of construction/abandonment of Cluster F sites. No Cluster E sites are scheduled for further data collection.

Cluster G - Pakulena Gulch

This cluster consists of seven sites: Sites T-30, T-75, T-77, T-78, T-79 (small rockshelters/caves); and Sites T-32 and -33, multi-segment road sites (c. 1880-1940). Cluster G sites are situated in the bottom or on the lower slopes of Pakulena Gulch; the cluster covers an area of about 650.0 m (NW-SE) by 90.0 m (E-W).

Sites T-32 and -33 are retaining walls for historic roads. Site T-32 and portions of T-33 are shown as wagon roads on a 1904 map of the project area (Figure 2); thus, 1904 is taken as a general date for both sites. Both sites apparently were built to serve the agricultural areas of the surrounding plateaus.

Sites T-30, -54, -75, -77, -78, -79 represent the only evidence of prehistoric occupation inland of the coastal zone of the project area. Both Sites T-30 and -75 contain structural modifications. This indicates the shelters were used for some function. At T-75, the southeast walls may have once been joined together, as only a 1.0 m wide gap presently separates them. If the shelter was walled, it may indicate something inside the cave was protected by the wall, perhaps a burial. Perhaps clues to the contents of the cave are to be found in the soil deposit at the cave's entrance. Both Sites T-30 and -75 also lacked artifacts. This may indicate the sites date to the early historic period at the latest. Both sites are recommended for further data collection.

The floor of Site T-77 is partially covered by a shallow deposit of reddish-brown clay loam and roof-fall cobbles. No portable remains were visible on the floor. The smallness of the rockshelter, and its relatively inaccessible location, combined with the presence of an enclosing wall suggest the rockshelter may have been used for burial. The lack of visible skeletal remains may indicate they have been removed, or they may have decayed and/or are obscured by the deposit of sediment in the rockshelter.

Portable remains at Site T-78 consisted of several volcanic glass flakes scattered around two exposures of surface chill volcanic glass. The flakes were present on the surface of the second bedrock ledge. The exposures showed evidence of flaking/quarrying activity. Other remains in the cave consisted of a sparse scatter of midden and one piece of volcanic glass. The piece of volcanic glass was situated at the east end of the sheltered outer ledge, in and adjacent to a small niche (c. 0.75 m deep, 0.50-0.60 m wide, and 0.20-0.30 m high) in the cliff face. The midden consisted of Echinoidea mouth parts, a Turbo shell fragment, kukui nut shell fragments, fish bone, and bird bone. Site T-78, based on its form and range of portable remains, appears to have served as a prehistoric temporary habitation and quarry.

The small size and relatively inaccessible location of Site T-79, combined with the presence of a possible offering (coral cobble) suggest a religious function for the site, either as a shrine or for burial. The lack of visible skeletal remains may indicate they have been removed, they have decayed and/or are obscured by the cave sediments, or that the cave is a small shrine and not a burial.

Cluster H - Kalunawaikaala Gulch

Cluster H sites consists of three twentieth century sites--Sites T-35, -37, and -38. The sites, situated in the base or on the lowest slopes of Kalunawaikaala Gulch, cover an area of about 350.0 m (E-W) by 90.0 m (N-S).

Site T-35 is a short rock retaining wall situated outside the project area. This wall, which is associated with Site T-37, predates 1930 (C.J. Hitch, pers. comm.). Site T-37, a multi-segment retaining wall is downstream of T-35; part of T-37 is also outside the project area. Both Sites T-35 and T-37 are thought to be the remains of a road network servicing the agricultural areas on the plateaus to the north and south of Kalunawaikaala Gulch. Although not on the 1904 map, T-37 is thought to date to the same period as similar sites at Clusters C and G, i.e., to c. late 1800s to early 1900s.

Site T-38 is a wood and concrete pumphouse. According to J. Hitch, a life-long resident of the area, the pumphouse was built in 1951 and was used until 1970. The well serviced a labor camp on Pupukea Road, and then was abandoned due to the increased salinity of the water.

Sites Outside Clusters

Eight of the 60 sites identified during the present survey did not fit into any cluster. Of the eight sites, two sites (Site T-69 and -42) are outside the project area. The six of the eight sites within the project area are: T-1, T-2, T-3, T-21, T-54, and T-76.

Site T-1 is a mound situated adjacent to Cluster B. Four coral rocks on the surface of the mound (possible offerings) indicate the site may be a ceremonial or ritual feature of some type. The site is thought to date to the early historic or prehistoric period; however, actual function and date of the site will be more clear after further data collection.

Site T-2 is situated slightly to the southwest of T-1. Scattered about Site T-2 are fine-grained angularly broken pieces of exotic basalt. The

scatter is interpreted as the remains of lithic-reduction. The absence at the site of historic artifacts indicates the site dates to the early 19th century or earlier. Site T-2 has been heavily disturbed by agriculture; it was probably originally a much larger feature. Because of its size and its disturbed condition, no further work has been scheduled for the site.

Site T-3 is an alignment and modified outcrop situated inland of T-2. The site, based on its structural form, is interpreted as an agricultural or boundary feature of possibly prehistoric or early historic origin. Site T-3 may be roughly contemporary with Cluster B. In fact, it may be farming feature associated with Site T-13. No artifacts were recovered from T-3. Because of its disturbed condition, no further work is scheduled for the site.

Site T-21 is a retaining wall similar to other road retaining walls at Clusters C and D. The site is interpreted as a remnant of the road system which serviced the agricultural areas of the plateaus during the first half of the 20th century.

Site T-42 is a stone dam thought to be 20th century in origin. The dam is interpreted as associated with agricultural exploitation of the nearby plateaus. Site T-42 is probably contemporary with sites at Cluster D.

Site T-54 is a rockshelter in steep cliffs just south of Paumalu Gulch. The floor of T-54 is covered with brown silty loam. When a trowel probe was excavated into the floor, it yielded charcoal and a greasy-looking, grey-brown soil c. 15 cmbs. The absence of artifacts at the site suggests the site predates 1850.

Site T-69 is a terrace and rectangular enclosure. Based on its structural form and on the presence of four large pieces of coral (possible offerings) present in the walls of the enclosure, the site is interpeted as a shrine or heiau.

Site T-76 consists of two wooden water tanks, a large wood and metal platform, and a wooden corral. Site T-76 was used for 20th century ranching. The modern artifacts at the site suggest the period of ranching ended sometime after WWII, perhaps about 1960.

TEMPORAL PERIODS

The 60 identified sites within Pupukea-Paumalu Development project area fall into three general temporal periods (Table 4). Twenty-seven sites are prehistoric and/or early historic (pre-1860s); 23 sites date to c. 1860s to mid-1940s; and 10 sites date to about 1940s-present.

Table 4.

SUMMARY OF SITES BY TEMPORAL AND FUNCTIONAL CRITERIA

Group I - Prehistoric/Early Historic (Pre-1860s) (N=27)

A. Rockshelters (temporary occupation) (N=11) Sites T-18, -19, -30, -54, -64, -65, -66, -71, -73, -75, -78, (T-18 and T-78 are also quarries)
B. Agricultural features (N=5) Sites T-2, -3, -5, -16, -31*
C. Burial caves (N=5) Sites T-34, -67, -72, -77(?), -80
D. Heiau/shrines(?) (N=3) Sites T-1, -69*, -79
E. Complex - habitation, agriculture, rock art (N=1) Site T-13
F. Complex - 4 rockshelters, 3 graves, rock art (N=1) Site T-70
G. Cairn (boundary or property marker) (N=1) Site T-7

Group II - Sites Dating to 1860s to Mid-1940s (N=23)

A. Retaining walls (for roadbeds) (N=11) Sites T-21, -25, -32, -33, -37, -46, -49, -53, -56, -58, -59
B. Irrigation ditches (N=2) Sites T-15, -17
C. Earthen berm (railroad siding?) (N=1) Site T-4
D. Rock-walled animal enclosures (N=2) Sites T-52, -57
E. Agricultural clearing mounds (N=2) Sites T-48, -62
F. Rock walls (boundary?)(N=2) Sites T-55, -74
G. Complex - habitation (?), agricultural (N=1) Site T-23
H. Transportation (N=1) Site T-50
I. Rubbish dump (N=1) Site T-47

Group III - Sites Dating to Mid-1940s to Present (N=10)

A. WWII coastal defenses (N=5) Sites T-20, -22, -40, -43, -45
B. Well and foundation (N=1) Site T-14
C. Pumphouse (N=1) Site T-38
D. Dam (agricultural) (N=1) Site T-42*
E. Agriculture/Ranching Camp (N=1) Site T-76
F. Retaining Wall (unknown function) (N=1) Site T-35

*Outside project area

Prehistoric and/or Early Historic Sites (Pre-1860s)

During the prehistoric/early historic periods a number of activities took place in the project area. Most of the activities took place within Clusters A and B. Two sites in Cluster A were used for burial. Short term, probably repetitive temporary occupation occurred at four or five rockshelters in Cluster A. Also, woodworking and/or tool production occurred at two Cluster A sites, and one Cluster A site was the scene of preparation and consumption of food.

Cluster B sites apparently were utilized for a much wider range of activities. Agricultural features are found at four Cluster B sites, and a large agricultural terrace complex (Site T-31), which may be closely associated with habitation at Cluster B sites, is situated nearby, outside the project area. Cluster B includes three rockshelters which were probably occupied on a temporary basis. Artifacts (volcanic glass, basalt and a coral abrader) found in these shelters suggest tool production and initial lithic reduction took place in the shelters. The greatest range of activities in Cluster B took place at Site T-13. Site T-13 includes three agricultural terraces, a small petroglyph gallery, a possible house platform, and a cleared area adjacent to the platform. No portable remains were found at Site T-13. However, the structural remains at the site, especially the remains of the house platform, suggest there may portable remains beneath the rubble at the site. The platform may have been utilized for permanent occupation, perhaps by a single family. In addition, Cluster B includes a petroglyph gallery (at Site T-70) and four burial caves. One cave contained three fragments of a burial canoe. Further data collection, specifically of chronometric samples, may establish the exact dates of the Cluster B sites.

Prehistoric and/or early historic sites in inland portions of the project area include six rockshelters. Five of these shelters are in lower Pakulena Gulch; the other shelter is in Paumalu Gulch. One shelter, Site T-30, contains a small wall which encloses a possible storage area and an earthen terrace.

Sites Dating to 1860s to Mid-1940s

During this period, occupation in the project area moved inland, from the seaward cliffs and talus to the tops of the gulches and the plateaus. Large-scale pineapple agriculture on the plateaus, sugarcane cultivation in the coastal lowlands, and cattle ranching in other areas such as Paumalu Gulch characterize this period. Most of the twenty-four sites which date to this period are associated with the roads which served agriculture/ranching on the upper plateaus. As shown in a 1904 map (Figure 2) there were in Paumalu and Pakulena Gulches roads leading to agricultural areas on the plateaus. Seven sites in the project area are thought to be remnants of this road system. The plateaus were also serviced by wagon roads, and according to local informants A. Aoki and C. Ortiz, a small-gauge railway. Four sites recorded in the project area are thought to be remnants of the wagon roads or railway; two of the four sites are still in use.

Site T-23 is group of nine concrete and stone features. Local residents refer to it as the "plantation manager's house." Further investigation may help to date this site. Perhaps a rubbish pit could be found at the site. Site T-23 may be associated with early sugarcane cultivation and the OR&L railroad(?).

Two sites which date to this period are agricultural clearing mounds. These two sites are representative of the numerous clearing mounds situated on the plateaus. Two other sites which date to this period are animal enclosures linked to ranching. Site T-47 of this period consists of a small rubbish dump (mostly bottles) which is eroding out of a hillside. Site T-47 was probably associated with temporary occupation (labor camp?) in nearby agricultural areas.

Sites Dating to Mid-1940s to Present

This period includes 9 sites--sites mostly associated with WWII defenses or agriculture. The sites include WWII coastal defenses (Sites T-20, -22, -40, -43, -45), a well and foundation (Site T-14), a pumphouse (Site T-38), a dam (Site T-42), and an agriculture/ranching camp (Site T-76). Almost all the sites in the project area belonging to this period are of little archaeological value. Sites T-20, -22, -40, -43, and -45 date to WWII, when the coastline of Oahu was fortified.

Site T-76 is the most extensive example of small-scale ranching in the project area. Following the collapse of agriculture in the 1940s and 1960s, the avocado orchards and pineapple fields atop the plateaus and the sugarcane areas of the coast were given over to grazing. The ranching phase produced a number of features--watering troughs, corrals, concrete slabs, and assorted rock piles. Site T-76 includes four features: two wooden water tanks, a corral with a loading chute, and a large wood and tin platform of unknown function.

GENERAL SIGNIFICANCE ASSESSMENTS
AND RECOMMENDED GENERAL TREATMENTS

To facilitate State and County review, general significance assessments and recommended general treatments for the 54 sites identified within or partially within the project area during the reconnaissance survey are summarized in Table 5. Significance categories used in the evaluation process are based on the National Register criteria contained in the Code of Federal Regulations (36 CFR Part 60). The State Department of Land and Natural Resources-Historic Sites Section (DLNR-HSS) uses these criteria to evaluate eligibility for both the Hawaii State and National Register of Historic Places. Sites determined to be potentially significant for information content (Category A, Table 5) fall under Criterion D, which defines significant resources as ones which "...have yielded, or may be likely to yield, information important in prehistory or history." Sites potentially significant as representative examples

Table 5.

SUMMARY OF GENERAL SIGNIFICANCE ASSESSMENTS
AND RECOMMENDED GENERAL TREATMENTS
PUPUKEA-PAUMALU DEVELOPMENT PROJECT AREA

Site Number	Significance Category A	X	B	C	Recommended Treatment FDC	NFW	PID	PAI
T-2	-	+	-	-	-	+	-	-
T-3	-	+	-	-	-	+	-	-
T-4	-	+	-	-	-	+	-	-
T-7	-	+	-	-	-	+	-	-
T-14	-	+	-	-	-	+	-	-
T-15	-	+	-	-	-	+	-	-
T-16	-	+	-	-	-	+	-	-
T-17	-	+	-	-	-	+	-	-
T-21	-	+	-	-	-	+	-	-
T-22	-	+	-	-	-	+	-	-
T-25	-	+	-	-	-	+	-	-
T-32	-	+	-	-	-	+	-	-
T-33	-	+	-	-	-	+	-	-
T-37	-	+	-	-	-	+	-	-
T-38	-	+	-	-	-	+	-	-
T-40	-	+	-	-	-	+	-	-
T-43	-	+	-	-	-	+	-	-
T-45	-	+	-	-	-	+	-	-

General Significance Categories:

A=Important for information content, further data collection necessary (PHRI=research value);
X=Important for information content, no further data collection necessary (PHRI=research value, DLNR-HSS=not significant);
B=Excellent example of site type at local, region, island, State, or National level (PHRI=interpretive value); and
C=Culturally significant (PHRI=cultural value).

Recommended General Treatments:

FDC=Further data collection necessary (intensive survey and testing, and possibly subsequent data recovery/mitigation excavations);
NFW=No further work of any kind necessary, sufficient data collected, archaeological clearance recommended, no preservation potential;
PID=Preservation with some level of interpretive development recommended for consideration (including appropriate related data recovery work); and
PAI=Preservation "as is," with no further work (and possible inclusion into landscaping), or further data collection necessary.

Table 5. (Cont.)

Site Number	Significance Category A	X	B	C	Recommended Treatment FDC	NFW	PID	PAI
T-46	-	+	-	-	-	+	-	-
T-48	-	+	-	-	-	+	-	-
T-49	-	+	-	-	-	+	-	-
T-50	-	+	-	-	-	+	-	-
T-52	-	+	-	-	-	+	-	-
T-53	-	+	-	-	-	+	-	-
T-55	-	+	-	-	-	+	-	-
T-56	-	+	-	-	-	+	-	-
T-57	-	+	-	-	-	+	-	-
T-58	-	+	-	-	-	+	-	-
T-59	-	+	-	-	-	+	-	-
T-62	-	+	-	-	-	+	-	-
T-76	-	+	-	-	-	+	-	-
Subtotal: 31	0	31	0	0	0	31	0	0
T-1	+	-	-	-	+	-	-	-
T-5	+	-	-	-	+	-	-	-
T-18	+	-	-	-	+	-	-	-
T-19	+	-	-	-	+	-	-	-
T-23	+	-	-	-	+	-	-	-
T-30	+	-	-	-	+	-	-	-
T-47	+	-	-	-	+	-	-	-
T-54	+	-	-	-	+	-	-	-
T-64	+	-	-	-	+	-	-	-
T-65	+	-	-	-	+	-	-	-
T-66	+	-	-	-	+	-	-	-
T-71	+	-	-	-	+	-	-	-
T-73	+	-	-	-	+	-	-	-
T-75	+	-	-	-	+	-	-	-
T-78	+	-	-	-	+	-	-	-
T-79	+	-	-	-	+	-	-	-
Subtotal: 16	16	0	0	0	16	0	0	0
T-13	+	-	-	+	+	-	-	+
T-34	+	-	-	+	+	-	-	+
T-67	+	-	-	+	+	-	-	+
T-72	+	-	-	+	+	-	-	+
T-77	+	-	-	*	+	-	-	*
T-80	+	-	-	+	+	-	-	+
Subtotal: 6	6	0	0	6	6	0	0	6

*Provisional assessment pending results of further data collection.

Table 5. (Cont.)

Site Number	Significance Category A	X	B	C	Recommended Treatment FDC	NFW	PID	PAI
T-70	+	-	+	+	+	-	+	-
Subtotal: 1	1	0	1	1	1	0	1	0
Total: 54	23	31	2	5	23	31	1	5

of site types (Category B, Table 5) are evaluated under Criterion C, which defines significant resources as those which "...embody the distinctive characteristics of a type, period, or method of construction..., or that represent a significant and distinguishable entity whose components may lack individual distinction."

Sites with potential cultural significance (Category C, Table 5) are evaluated under guidelines prepared by the Advisory Council on Historic Preservation (ACHP) entitled "Guidelines for Consideration of Traditional Cultural Values in Historic Preservation Review" (ACHP 1985). The guidelines define cultural value as "...the contribution made by an historic property to an ongoing society or cultural system. A traditional cultural value is a cultural value that has historical depth" (1985:1). The guidelines further specify that "[a] property need not have been in consistent use since antiquity by a cultural system in order to have traditional cultural value" (1985:7).

Of the total 54 sites identified within or partially within the present project area, 48 sites are significant solely for information content. For 31 of the 48 sites, no further work is recommended. For 16 of the 48 sites, further data collection is recommended. Of the remaining seven of the 54 total sites, six are assessed as significant for information content and for cultural value. Further data collection and preservation "as is" are recommended for these six sites; however, if preservation is not compatible with development plans, further data collection is recommended for these sites. After further data collection is completed, physical preservation of these sites would not be considered essential, although some might be considered for inclusion into development landscaping. The last site, T-70, is assessed as significant for information content, as an excellent example of a site type, and as culturally significant. Further data collection and preservation with interpretive development is recommended for this site.

In order to facilitate future client management decisions regarding site treatments, sites are further evaluated in terms of three value modes which are derived from the previously mentioned state and federal evaluation criteria (Table 1). The archaeological sites are evaluated in terms of potential scientific research, interpretive, and/or cultural values. Research value refers to the potential of archaeological resources for producing information useful in the understanding of culture history, past lifeways, and cultural processes at the local, regional, and interregional levels of organization. Interpretive value refers to the potential of archaeological resources for public education and recreation. Cultural value refers to the potential of archaeological resources to preserve and promote cultural and ethnic identity and values.

The following are specific field work data collection tasks recommended for sites requiring further work if they are to be impacted by development plans:

T-1 - Subsurface testing and controlled excavations in and adjacent to the feature.

T-5 - Limited subsurface testing and acquisition of soil samples for flotation and pollen analysis to establish site as an agricultural area and reveal what crops were grown at the site.

T-13 -

Feature A: Trench excavation of terrace area.

Feature B: Sampling of both Feature B and the cleared area east of the feature using controlled excavations. Trench excavations should be conducted adjacent to and under the circular rock mound thought to be the remains of the walls of Feature B. Located features should be excavated.

Features C and D: Trench excavations to obtain stratigraphic information, and soil, pollen, and flotation samples to resolve feature function.

Feature E: Test excavation.

Feature G: Preservation of boulders in place, or relocation of boulders.

Feature H: Test excavation. Analysis of soil and flotation samples.

Feature I: Removal of rockfall from feature to determine original course of wall.

Feature J: Test excavation and analysis of soil and flotation samples.

Feature L: Test excavation and analysis of soil and flotation samples.

T-18 - Excavation of a 1-2.0 m sq unit to further define period and nature of occupation.

T-19 - Excavation of 2-3.0 m sq units at Features A and B to further define period and nature of occupation.

T-23 - Detailed recording, surface collection, and test excavation of pits, including wells and latrines. Further work may resolve if site was a plantation manager's house.

T-30 - Terrace area of Feature C and the floor of Feature B should be tested for cultural deposits.

T-34 - Detailed recording and surface collection and excavation of burials and artifactual material.

T-47 - Collection of diagnostic artifacts, especially bottles. Also, limited subsurface shovel testing. If testing yields significant cultural material, controlled excavation of c. 4-5.0 meters is recommended.

T-54 - Excavation of 1.0-2.0 square meters.

T-64 - Excavation of two 1.0 m sq units to refine nature and age of occupation.

T-65 - Subsurface shovel testing, possibly followed by excavation at Feature B.

T-66 - Excavation of 1.0 sq m each in Features A and B.

T-67 - Excavation of 1.0 sq m in each chamber to establish age and nature of occupation. Prior to removal of roof fall, a 0.50 m sq controlled excavation should be conducted in the remnant soil deposit. If subsurface cultural material is present, other areas may require excavation. The human remains at the site should be photographed, mapped, then removed for analysis.

T-70 - The petroglyphs at this site should be carefully recorded, and then they should be preserved with interpretive development. Excavation of one or two sq m at Feature B to refine function and age interpretation. All human remains from burial caves should be recorded, then removed and analyzed. After analysis, burials should be returned to their original places in a manner which will ensure no further disturbance. All soil deposits should be test excavated.

T-71 - Features B and C and any roof fall piles should be dismantled. Subsurface shovel testing, possibly followed by controlled excavation should be conducted at Feature A, B, and C.

T-72 - Surface collection of human remains and possibly excavation of one or two 1.0 m sq units.

T-73 - Excavation of three 1.0 m sq units--two units in Feature B, one in Feature A.

T-75 - Excavation of one or two sq m in area of brown silty loam at mouth of shelter.

T-77 - Detailed recording and test excavation (1 sq m) to determine if the site was used as a burial.

T-78 - Detailed recording, surface collection, and test excavation (1 sq m) to determine if a cultural deposit is present. Dating of volcanic glass, and charcoal if recovered during excavation, in order to determine age of use.

T-79 - Detailed recording and test excavation (1 sq m) to define nature of possible religious use.

T-80 - Detailed recording, surface collection, and excavation to remove burial.

While preservation "as is" is recommended as one option for sites containing human remains, in the present project area this option is less preferable to disinterment, analysis, and reinterment. This is because all burial sites show evidence of past disturbance. In most cases the remains are scattered and exposed to the elements and to potential vandalism. Thus, in the interest of long-term protection these remains should be collected, analyzed, and reinterred. The excavation and analysis of all human remains should be conducted in consultation with the Office of Hawaiian Affairs and in compliance with state law. After analysis the remains should be reinterred at a protected location in the project area.

The significance evaluations and recommended treatments presented in this report are based on the findings of the surface reconnaissance survey and very limited subsurface testing. Therefore, these evaluations and recommendations are given with the general qualification that during any development activity involving the extensive modification of the land surface, there is always the possibility--however remote--that previously unknown or unexpected cultural features, deposits, or burials might be encountered. In such a situation, immediate archaeological consultation should be sought.

RESEARCH QUESTIONS

Any further data collection should be guided by specific research questions. Potential research questions for Pupukea-Paumalu sites can be grouped into three categories: questions concerning chronology, questions concerning subsistence reconstruction, and questions concerning socio-religious patterns. The following are questions concerning temporal periods of occupation.

1. What is the date of the earliest use of the area?

2. When did the use of rockshelters as burial sites begin, and were the rockshelters used for burials after they were used for habitation?

3. When did occupation at Site T-13 begin and was it contemporary with occupation of the rockshelters?

4. What were the periods of use for the agricultural features at Sites T-5, -13 and -16, and are the features contemporary with each other or with Feature B of Site T-13?

5. Was Site T-13 constructed all at once or over a period of time?

6. What is the temporal range of the artifacts at Site T-47 and do they represent a single occupation?

7. Is Site T-23 a plantation manager's house? When was it constructed; when was it abandoned?

The following are questions relative to subsistence of the various groups that occupied or exploited the project area.

1. What subsistence practices took place at the temporary occupation rockshelters?

2. What plants were cultivated in the agricultural terraces at Sites T-5 and T-13, and did what was grown change over time; were western domesticates introduced?

The following are questions concerning socio-religious patterns in the project area:

1. Do the burials in the project area share similar attributes, in terms of offerings present, presence or absence of certain bones, position and treatment of the remains?

2. Are there indications of status differentiation within the burial caves? The offerings in the burial cave at Site T-34 are tentatively assumed to denote a higher status for the individuals buried there.

3. Do the artifacts at Site T-47 reflect a certain economic status or a specific ethnic groups?

4. If trash deposits at Site T-23 are found, do the deposits reflect a particular economic or ethnic group? If the site was the residence of a plantation manager, the material culture at Site T-23 should be more varied than the material culture at a labor camp.

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APPENDIX O

LIHI LANI RECREATIONAL COMMUNITY PROJECT

TRAFFIC IMPACT ASSESSMENT REPORT

January 3, 1991

PACIFIC PLANNING & ENGINEERING, INC.

TRAFFIC IMPACT ASSESSMENT REPORT

for

LIHI LANI RECREATIONAL COMMUNITY

Pupukea, Oahu, Hawaii
TMK 5-9-05: 38 and 5-9-06: 18 & 24

January 3, 1991

Prepared for:

Group 70

Prepared by:

Pacific Planning & Engineering, Inc.
1221 Kapiolani Boulevard, Suite 740
Honolulu, Hawaii 96814

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EXECUTIVE SUMMARY

Pacific Planning & Engineering, Inc. (PPE) was engaged to undertake a study to identify and assess traffic impacts caused by the proposed Lihi Lani Project.

This report identifies and evaluates the probable impacts to the roadway network due to forecasted traffic and project generated traffic. This report presents the findings and recommendations of the study.

Project Description

The Obayashi Hawaii Corporation is proposing to develop the Lihi Lani Recreational Community project at Pupukea in the Koolauloa District of the island of Oahu. The development will be located on approximately 1,143 acres of land presently zoned for residential and agricultural use.

The project will be a recreational planned community consisting of single-family residential units, a 18 hole golf course with clubhouse and driving range, tennis center, equestrian ranch with horse pasture, campground, and community facilities. The entire project is expected to be completed and occupied by 1997.

Methodology

Analysis was conducted at the following locations to determine the relative impact of the proposed project on the local roadway system:

- Intersection of Kamehameha Highway & project access road,
- Intersection of Kamehameha Highway & Sunset Beach Elementary School Driveway during normal school days,

- Intersection of Kamehameha Highway and Pupukea Road,
- Segment of Kamehameha Highway near Haleiwa Beach Park,
- Segment of Kamehameha Highway near the Kahuku Sugar Mill.

Traffic was forecasted by:

- Increasing through traffic on Kamehameha Highway using its historical growth rate, and
- Adding traffic generated by other planned/committed developments in the area that would impact the study intersections, including:
  - a) Kuilima Resort's Expansion
  - b) Kahuku Villages Development
  - c) Kahuku Residential Development

The Report assesses the impact on each intersection and roadway segment by determining the level-of-service (LOS) for existing, 1997 forecast without the project, and 1997 forecast with the project traffic conditions.

Conclusions & Recommendations

The proposed Lihi Lani Recreational Community project will have a slight impact on traffic flow along Kamehameha Highway and the study intersections when completed and fully occupied in 1997.

Presently, Kamehameha Highway is operating at LOS D or better except at Haleiwa Beach park during the weekend when it operates at LOS E. Traffic conditions were observed during November when the high surf attracts many tourists and spectators. During the weekend, congested conditions occurred at certain locations due to the following factors which contributed to the delays along Kamehameha Highway:

- Drivers parking along Kamehameha Highway at surfing locations causes traffic bottle necks due to parking maneuvers,

- Drivers slowing down to watch the surf, and
- City buses stopping at bus stops with no pull outs.

Even without the project by 1997, the level-of-service along Kamehameha Highway will decrease to LOS E. Vehicles exiting minor streets onto Kamehameha Highway at the study intersections will experience long traffic delays (LOS E or F). Drivers attempting left-turns from Kamehameha Highway into minor street will experience slight delays (LOS B or better).

Due to the expected delays for traffic exiting the minor streets, the study intersections should be studied in the future to determine if signalizing the intersections is warranted. This will minimize delays for vehicles exiting minor streets onto Kamehameha Highway.

With the project by 1997, the LOS at segments of Kamehameha Highway will remain the same as the without project case. The LOS for vehicles exiting minor streets onto Kamehameha Highway at the study intersections will remain the same as the without project case. Drivers attempting left-turns from Kamehameha Highway will experience slight to average delays (LOS B or C).

We recommend the following improvements at the Project Access Road:

- Provide a left-turn storage lane along Kamehameha Highway at its intersection with the project access road for southbound drivers attempting left-turns into the project. The left-turn storage lane should alleviate possible delays or back-ups along Kamehameha Highway caused by vehicles turning left into the project. This should also minimize rear-end collisions with vehicles slowing down or stopping to turn left into the project.

- Provide separate right and left-turn lanes at the project access road exiting the project site. This will permit left turning vehicles exiting the project to turn without creating unnecessary delays for drivers wanting to turn right onto Kamehameha Highway.

- In the future, study the possibility of signalizing the intersection of Kamehameha Highway with the Project Access Road.

The average percentage of total traffic along Kamehameha Highway in 1997 generated by future developments in the area are shown below in Table 14.

Table 14. Average Percentage of Total Traffic Along Kamehameha Highway

Development	Morning Peak Hour Percentage	Afternoon Peak Hour Percentage	Sunday Peak Hour Percentage
Kamehameha Hwy.	55%	65%	68%
Kahuku Villages	3%	4%	3%
Kahuku Residential	2%	1%	1%
Kuilima Resort Expansion	32%	21%	19%
Lihi Lani Community	8%	9%	9%
Total Percentage	100%	100%	100%

Construction-Related Traffic

An area of concern voiced by several people attending the project's Community Involvement Group meetings is the potential impact by project-generated construction vehicles on traffic along Kamehameha Highway. Our review of contemplated construction activities for the proposed project indicate that construction truck traffic will have minimal impact on traffic along Kamehameha Highway.

Trucks hauling construction materials such as cement, pipes, lumber, crushed rock; and asphalt concrete will average one or two trips per day initially. For a very short duration (two weeks), a maximum of 10 trucks per hour or 80 trucks per day hauling asphalt concrete to the job site. Traffic by construction workers will occur during the early morning hours and when workers leave the job site in the evening. An estimated 60 workers daily at the work site are expected to generate not more than 20 vehicles during the morning and afternoon peak hours. Most of the workers will be transported to the job site on company trucks from baseyards in Honolulu. Construction-related traffic entering and leaving the project will decrease beyond 1997 when the estimated work force is expected to drop to 10 to 30 workers daily.

Preliminary plans call for all earth moving operations to be confined to the project site, therefore, no trucks are expected to haul fill material onto the project or remove excess excavated material off the project site. This will further minimize truck traffic in and out of the project and along Kamehameha Highway.

PROJECT DESCRIPTION

The Obayashi Hawaii Corporation is proposing to develop the Lihi Lani Recreational Community project at Pupukea in the Koolauloa District of the island of Oahu. Figure 1 shows the project's general location and surrounding roadway network. The development will be located on approximately 1,143 acres of land presently zoned for residential and agricultural use.

The project will be a recreational planned community consisting of single-family residential units, a 18 hole golf course with clubhouse and driving range, tennis center, equestrian ranch with horse pasture, campground, and community facilities. Table 1 provides a breakdown of the various land uses for the project. The site plan for the proposed project is shown on Figure 2. The entire project is expected to be completed and occupied by 1997.

Table 1. Project Land Uses

Description of Land Use	Amount	Unit
Affordable Homes	180	units
Market Homes	120	units
Golf Course	139	acres
Tennis Center	12	courts
Campground	15	acres
Equestrian Ranch	19	acres
Horse Pasture	78	acres
Community Facilities	10	acres

The project's residential units will include both affordable and market single-family units. The market units are expected to be occupied by full-time residents, and part-time residents using them as second or vacation homes.

The golf course will be open to the public and have private memberships. The course and driving range will be open during normal daylight hours while the clubhouse will remain open into the night. The tennis center will be a semi-private facility open to the public, and also have private memberships.

The equestrian ranch will provide stalls for approximately 75 to 100 horses, and may provide facilities for occasional events. The community facility will provide various amenities such as a soccer field, swimming pool, meeting room and community garden. The campground will have about 8 to 12 cabins along with a mess hall, and will be open only during the weekends.

Vehicular access to and from the proposed development will be from Kamehameha Highway. A privately owned project access road will provide vehicular access from Kamehameha Highway into the project site and also provide circulation within the recreational community.

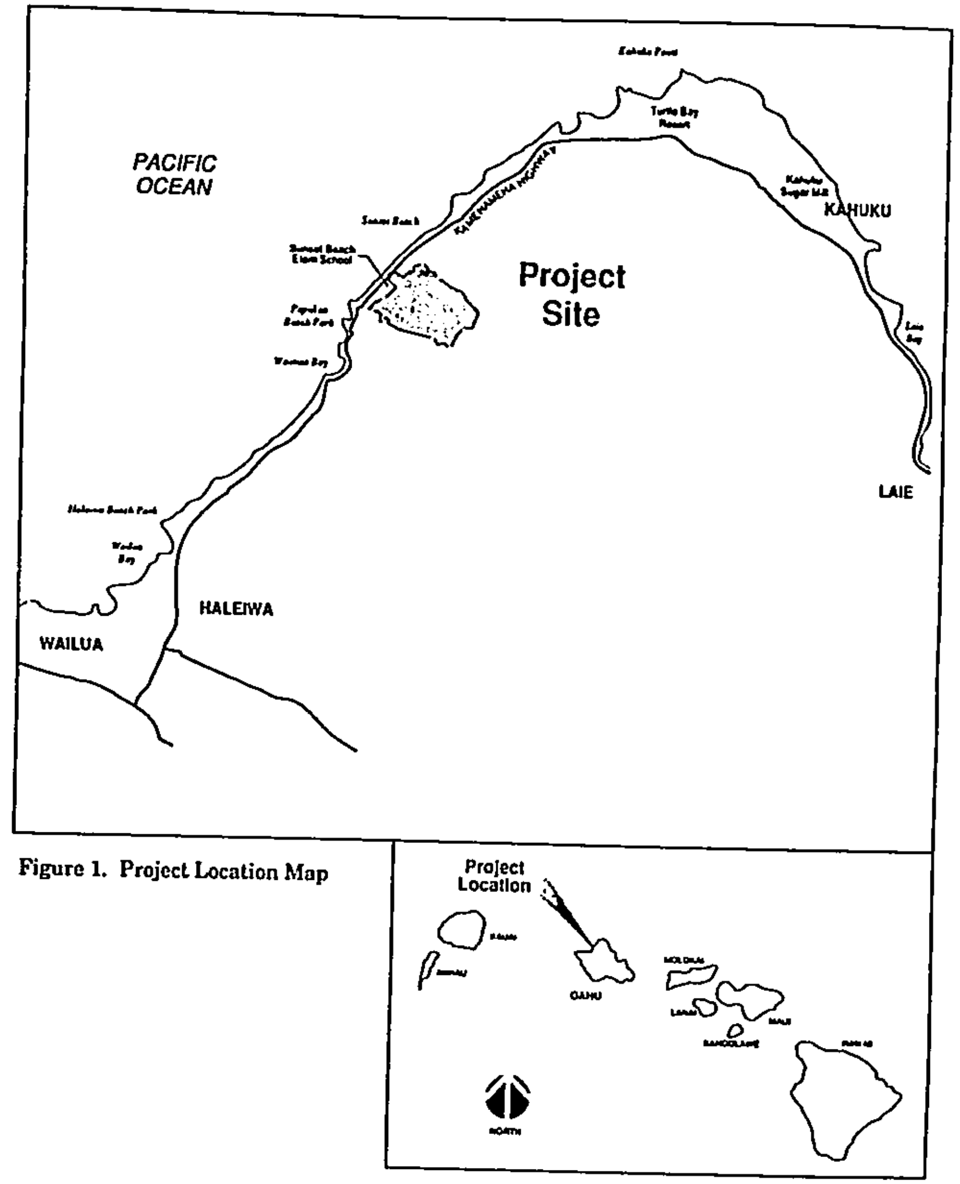

Figure 1. Project Location Map

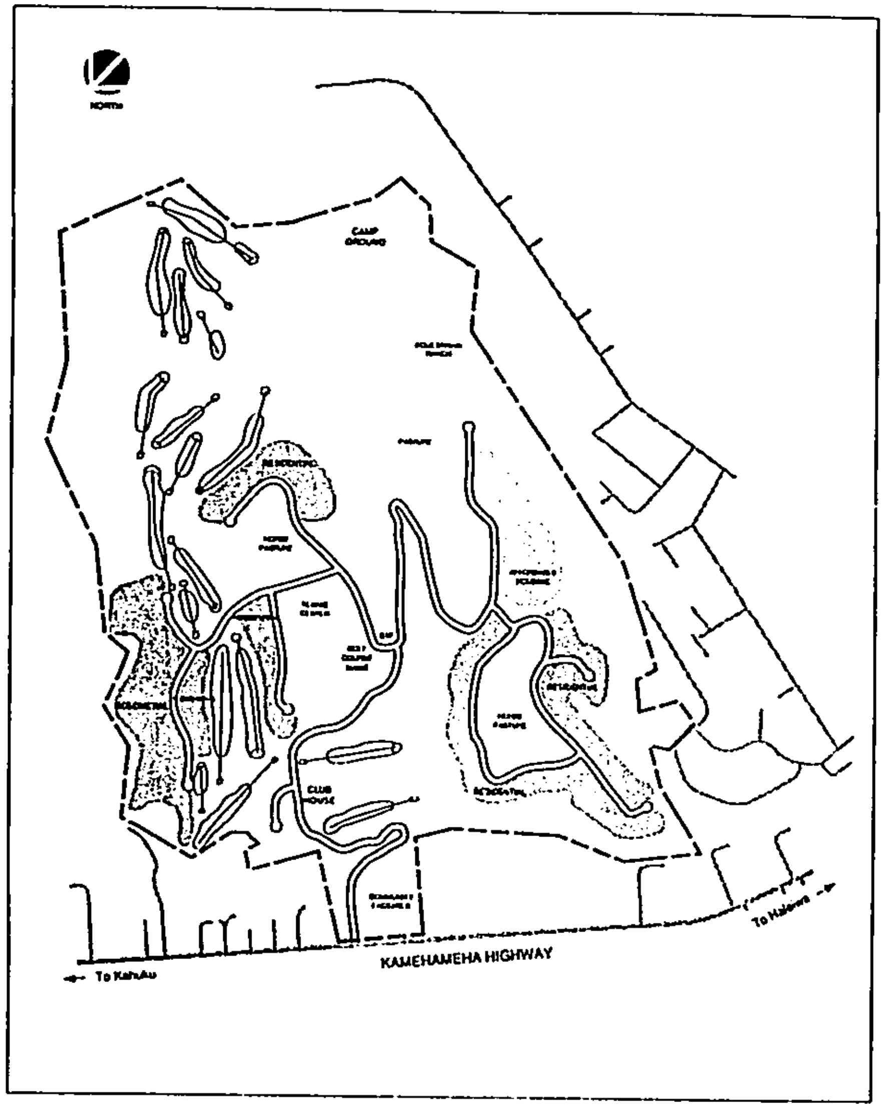

Figure 2. Project Site Plan

EXISTING CONDITIONS

An inventory of existing conditions was conducted to better understand the traffic impact of the proposed project. The review included the land uses in the area, roadway facilities, and existing traffic conditions.

Land Uses

The existing land uses surrounding the project site are generally residential, recreational and agricultural. Kamehameha Highway, Sunset Beach Elementary School and Neighborhood Park border the makai side of the project site, with residential housing and beach parks, including Ehukai Beach Park, located across (makai) the highway. Residential housing and the Comsat facility are located in the Kahuku direction. In the Haleiwa direction is residential housing.

The general area has many recreational areas. The North Shore of Oahu is known for its spectacular surf during the winter months and calm scenic beaches during the summer months. Haleiwa Town is a tourist attraction popular for its "plantation" appeal. North of the project are attractions such as the Polynesian Cultural Center in Laie, the Kahuku Sugar Mill, the Turtle Bay Resort Hotel, and Kuilima (East and West) Condominium developments.

Roadway Facilities

Major roadway facilities located in the area consist of one main highway connecting major population centers along the North Shore. Kamehameha Highway is the main arterial traveling along the coastline carrying through traffic.

Streets

Kamehameha Highway is a State-maintained highway with a 50 foot wide right-of-way and a 22-foot wide pavement. There is a 11 foot wide lane provided for vehicles travelling in each direction. The shoulders are grassed, and vehicles park along both sides of the road especially near beach parks. The posted speed limit along Kamehameha Highway is 45 miles per hour (mph) near the project site. In the vicinity of Sunset Beach Elementary School, the posted speed is 25 mph when indicated by flashing yellow lights.

Study Intersections

The intersection of Kamehameha Highway with Sunset Beach Elementary School driveway is approximately 900 feet from the project access road. The school's driveway is not marked, but is wide enough to permit both a left and right-turn lane onto Kamehameha Highway.

The intersection of Kamehameha Highway with Pupukea Road operates as a cross intersection with a beach park driveway providing the makai leg of the intersection. Pupukea Road has a exclusive left-turn lane and a through/right-turn lane on its approach to Kamehameha Highway at the intersection.

Traffic Conditions

A review 1989 State Department of Transportation (DOT) traffic count data indicated that the weekday commuter peak hours along Kamehameha Highway in the vicinity of the project generally occur between 7:00 to 8:00 in the morning and 3:30 to 4:30 in the afternoon. The weekend peak period was determined based upon discussions with community representatives, and generally occurs between 10:00 am to 3:00 pm on Sunday.

Manual traffic counts were taken at the following locations and intersections:

- Intersection of Kamehameha Highway with Sunset Beach Elementary School's Driveway
- Intersection of Kamehameha Highway with Pupukea Road
- Kamehameha Highway near Haleiwa Beach Park
- Kamehameha Highway near the Kahuku Sugar Mill

The traffic counts were taken on Thursday, November 15, 1990, during the morning and afternoon peak periods, and on Sunday, November 25, 1990 during the weekend peak period. During these counts the weather was sunny and clear, and waves along the north shore were high attracting many sightseers and surfers. Sunset Beach Elementary School was closed during the weekend. These counts were used as the baseline condition upon which future estimated traffic volumes were added.

Figures 3, 4, and 5 show the present volumes of traffic at the study intersections during the observed weekday and weekend peak hours. The manual traffic count data are summarized in Appendix B.

Observed Traffic Conditions

The following observations were made during the field surveys:

Along Kamehameha Highway between Haleiwa and Kahuku

During the weekend:

- Large numbers of cars parked along both shoulders of the highway at various surf spots such as Waimea Bay, Sunset Beach and Ehukai Beach Park.
- Bottlenecks occurred at surf spots due to parking maneuvers, and drivers slowing down to observe beach activities.

- A lack of a bus pull-out at bus stops along the highway created blockages resulting in queues of up to 15 to 20 cars behind the bus.
- A bottleneck of traffic occurred at Haleiwa due to the narrow bridge, commercial activities along the highway and tourist related traffic.

At the Pupukea Road and Kamehameha Highway Intersection:

During the afternoon and weekend:

- Drivers would drive along the shoulder to pass vehicles waiting to attempt left-turns from Kamehameha Highway into Pupukea Road.
- Drivers exiting Pupukea Road have limited sight distance due to a large tree on the mauka, Haleiwa bound corner of the intersection.
- Queues of cars would extend through the intersection due to bottlenecks along Kamehameha Highway at Waimea Bay.
- Queues of cars would extend through the intersection due to bus blockage in the Kahuku bound direction.

At the Sunset Beach Elementary Driveway and Kamehameha Highway Intersection:

During the weekday morning and afternoon:

- Several drivers drop-off and pick-up their children along Kamehameha Highway before and after school.
- Many cars park along the shoulders of the highway in the afternoon due to recreational activities at the beach park and at the school (Soccer practice).

During the weekend:

- Large number of cars park along the shoulder of the highway near the vicinity of the intersection.
- Drivers make U-turns into the school's driveway.

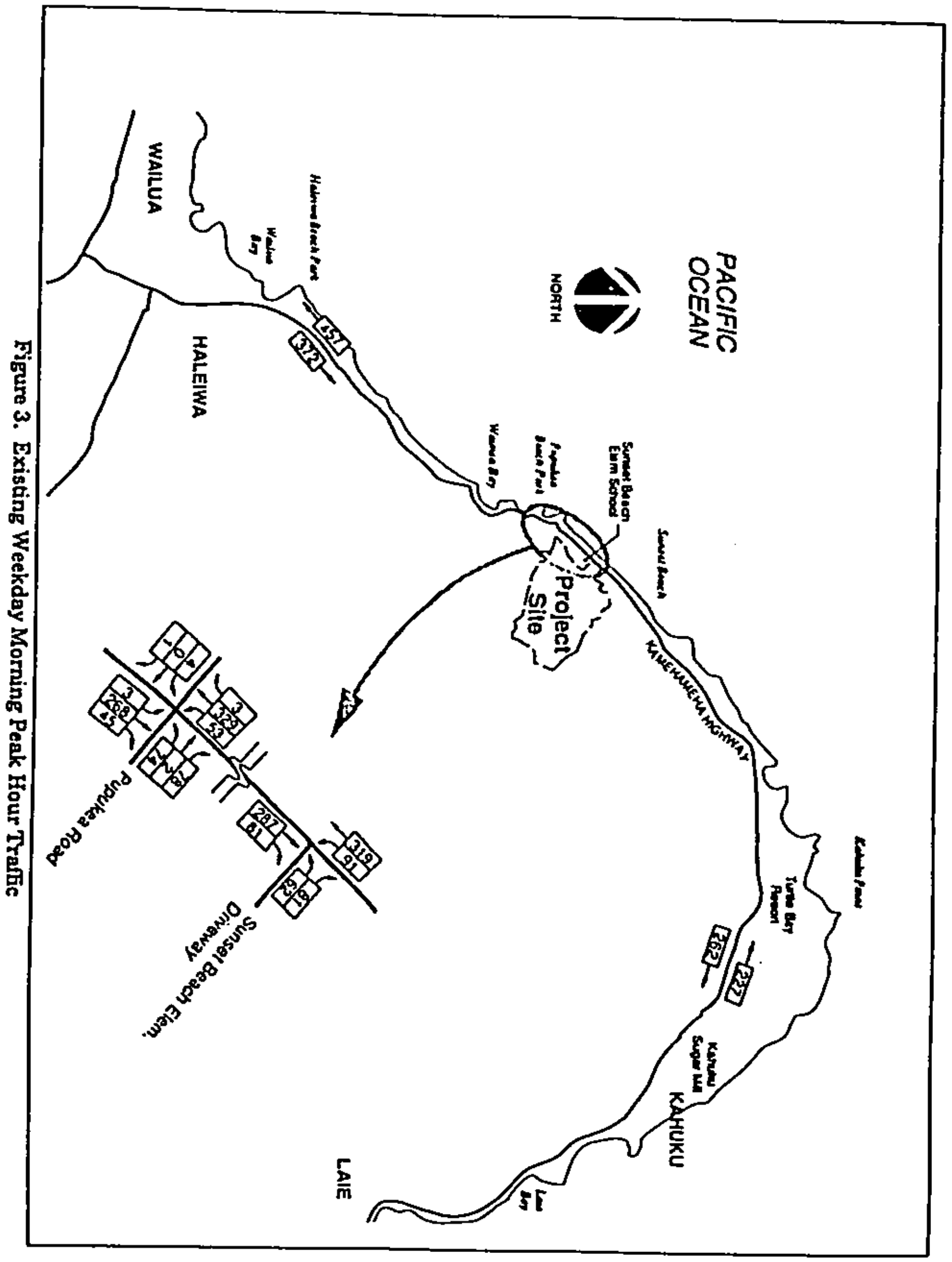

Figure 3. Existing Weekday Morning Peak Hour Traffic

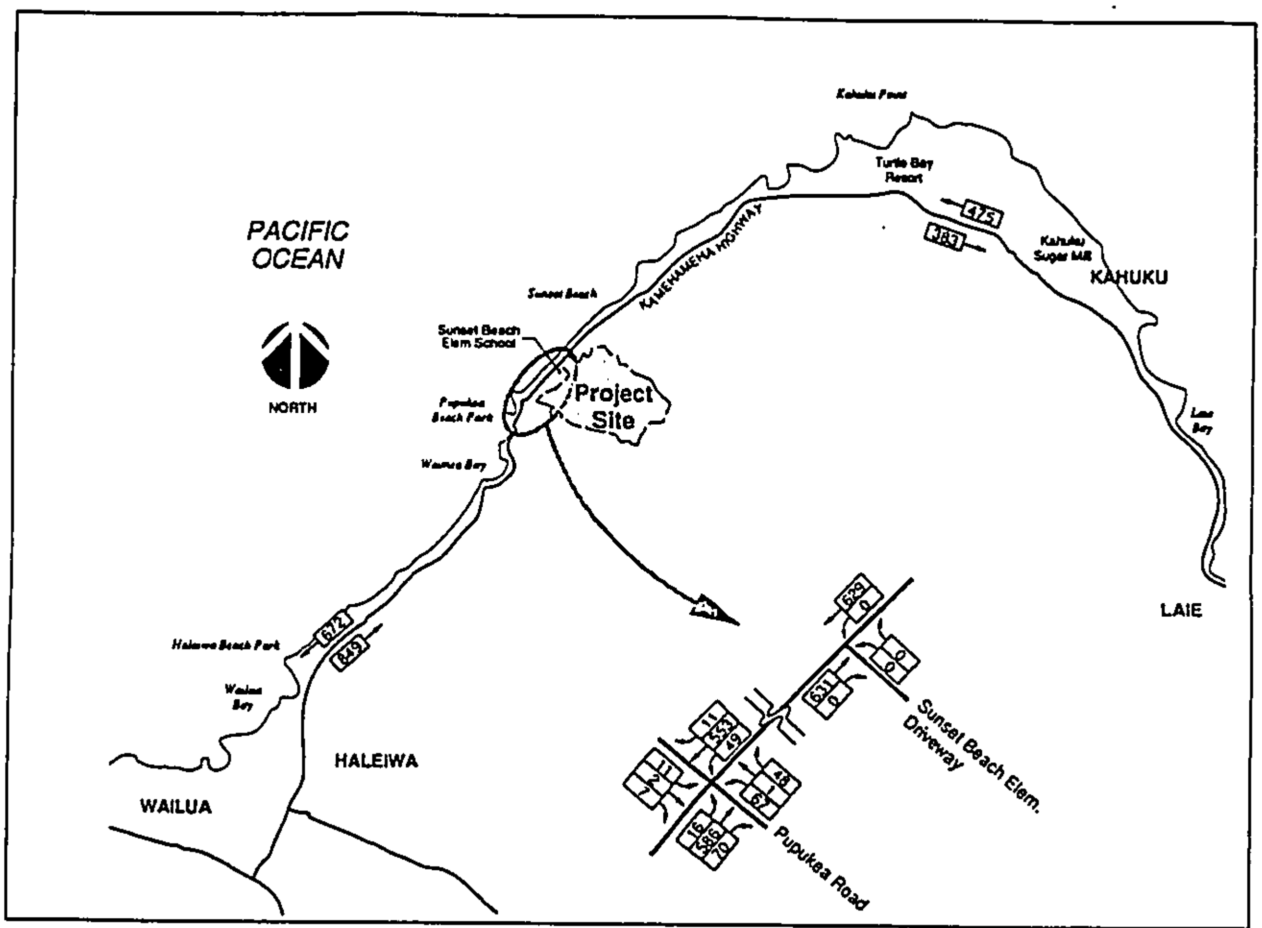

Figure 5. Existing Weekend Peak Hour Traffic

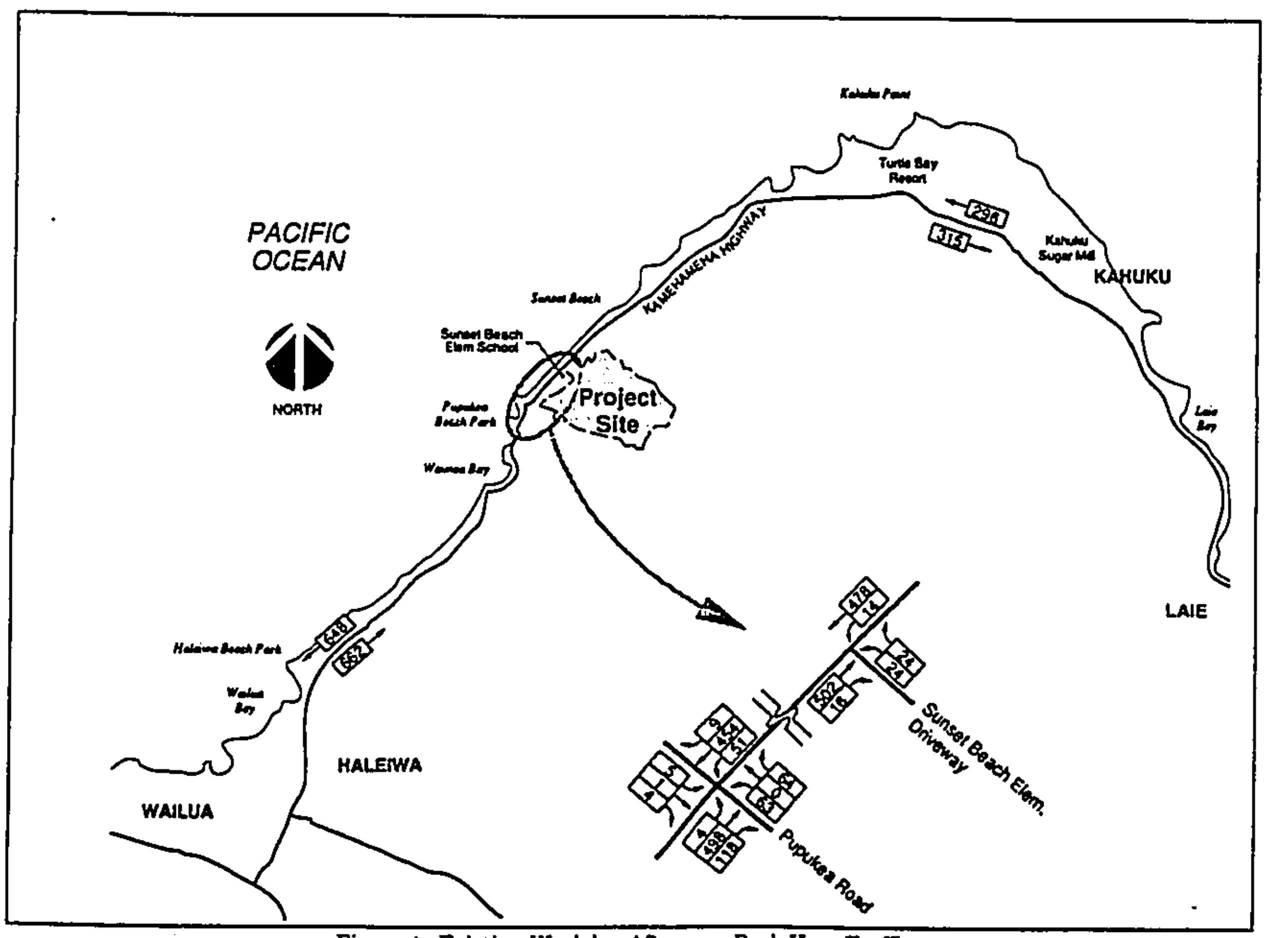

Figure 4. Existing Weekday Afternoon Peak Hour Traffic

FUTURE CONDITIONS

A research of approved planned developments and improvements to transportation facilities were conducted to estimate future traffic conditions at the study intersections.

Future Land Uses

Traffic generated by the following approved developments, as shown in Table 2, will impact the study intersections by the year 1997:

Table 2. Future Developments

Development	Land Use
Kuilima Resort Expansion	
Kuilima Hotel	2,183 rooms
Kuilima Resort Condominiums	300 units
Kuilima Shopping Center	40,000 square feet
Kuilima Golf Course	200 acres
Kahuku Villages	177 units
Kahuku Residential	87 units

Future Roadway Facilities

There are no roadway improvements planned in the study area for Kamehameha Highway, except for the Haleiwa Bypass which will provide an alternative route for drivers bypassing Haleiwa Town.

PROJECTED TRAFFIC CONDITIONS

Future traffic was forecast to determine traffic conditions without and with the Lihi Lani Recreational Community project. Traffic forecasts were estimated for the weekend peak hour, and weekday morning and afternoon peak hours for the year 1997 when the project is expected to be completed and occupied.

Future Traffic Without Project

Future traffic without the project was forecasted by adding the following: (1) existing peak hour traffic volumes; (2) the increase in through-traffic along Kamehameha Highway due to tourist and local traffic; and (3) traffic generated by other developments in the north shore are that will be completed by 1997.

Through-Traffic Growth along Kamehameha Highway

Through-traffic describes vehicular traffic without an origin or destination point near the project site such as tourist driving along the north shore sight seeing.

The growth in *through* traffic was forecasted based upon the growth trend of vehicular traffic along Kamehameha Highway. The North Shore is a strong recreational attraction for both tourists and locals due to the spectacular surf during the winter season. As a result, the increase in through traffic growth along Kamehameha Highway reflects increases in tourist traffic.

The growth in through-traffic was estimated using a linear regression analysis based upon historical data obtained from nearby DOT traffic count stations and projections of tourist and population growth. Based upon a review of the results of the analysis, it was estimated that daily traffic along Kamehameha Highway increasing about 3% annually. Therefore, existing through-traffic peak hour volumes along Kamehameha Highway were increased by 21% (3.0% for 7 years).

Traffic From Other Developments

A three-step procedure of trip generation, trip distribution and traffic assignment was used to forecast future peak hour traffic volumes generated from other proposed developments by 1997 in the North Shore area.

The trip generation step estimates the number of vehicle trips that would be generated by future developments based on the development's land use using data from the Institute of Transportation Engineers (ITE) Trip Generation Report (Fourth Edition, 1987). Table 3 shows the resulting trip generation for future developments listed in Table 2.

Trips generated by the Kuilima Resort's expansion during the weekday afternoon and weekend (Sunday) peak hours were based upon a traffic study prepared by Austin Tsutsumi and Associates (ATA)[1]. Trips generated during the weekday morning peak hour were determined based upon a comparison of 1989 DOT traffic volumes entering and exiting the resort (Station 28-A) with the resort's land uses.

Trips generated by the Kahuku Village and Kahuku Residential developments using the Trip Generation Report were compared with manual counts taken for the Pupukea Subdivision. The results of the

[1] Traffic Impact Report for the Proposed Turtle Bay Resort, by Austin, Tsutsumi & Associates, Inc., June 1985

comparison indicated that trips generated by single-family residential units located in non-urban areas were lower than those derived by the Trip Generation Report. As a result, trips generated by the Kahuku Village and Kahuku Residential developments were reduced by 35% during the weekday morning and weekend peak hours, and 25% during the weekday afternoon peak hour.

Table 3. Adjusted Trip Generation for Future Developments

Weekday Peak Hours

Land Use Description	Amount	Units	Morning Enter	Morning Exit	Afternoon Enter	Afternoon Exit
Kuilima Resort Expansion						
Hotel	2,183	rooms	386	304	243	263
Resort Condominiums	300	units	46	37	29	32
Shopping Center	40,000	GLA	28	12	76	79
Golf Course	200	acres	25	6	4	43
Kahuku Villages	177	units	24	65	88	52
Kahuku Residential	87	units	12	34	45	26

Weekend Peak Hour

Land Use Description	Amount	Units	Sunday Peak Hour Enter	Sunday Peak Hour Exit
Kuilima Resort Expansion				
Hotel	2,183	rooms	245	226
Resort Condominiums	300	units	30	27
Shopping Center	40,000	GLA	106	102
Golf Course	200	acres	29	29
Kahuku Villages	177	units	55	51
Kahuku Residential	87	units	31	28

The trip distribution step assigns trips to their predicted origins and destinations. Table 4 shows the general distribution percentages derived for each development. Trip distribution for the Kahuku Village and Kahuku Residential developments were generally based upon the distribution of employment on Oahu taking into account jobs within the district and Kuilima's expansion. The distribution for trips generated by the Kuilima Resort's expansion were generally based upon the existing distribution pattern obtained from manual counts and percentages used in the ATA traffic study.

The traffic assignment step assigns trips to a specific route on the roadway network that will take the driver from origins to destinations. Traffic was assigned based on the estimated shortest path or travel time between origins to destinations. Because Kamehameha Highway is the primary roadway providing vehicular access to these developments, all vehicle trips were assigned to the highway.

Table 4. Trip Distribution Percentages for Future Developments

Land Use Description	Entering: From Haleiwa	Entering: From To Laie	Exiting: To Haleiwa	Exiting: To Laie
Weekday Morning Peak Hour				
Kuilima Resort Expansion	65%	35%	65%	35%
Kahuku Villages	70%	30%	70%	30%
Kahuku Residential	70%	30%	70%	30%
Weekday Afternoon Peak Hour				
Kuilima Resort Expansion	55%	45%	55%	45%
Kahuku Villages	70%	30%	70%	30%
Kahuku Residential	70%	30%	70%	30%
Weekend (Sunday) Peak Hour				
Kuilima Resort Expansion	55%	45%	55%	45%
Kahuku Villages	60%	40%	60%	40%
Kahuku Residential	60%	40%	60%	40%

The resulting forecast traffic volumes without the project during the weekday morning and afternoon peak hours are shown in Figures 6 and 7. The resulting forecast traffic volumes without the project during the weekend peak hour is shown on Figure 8.

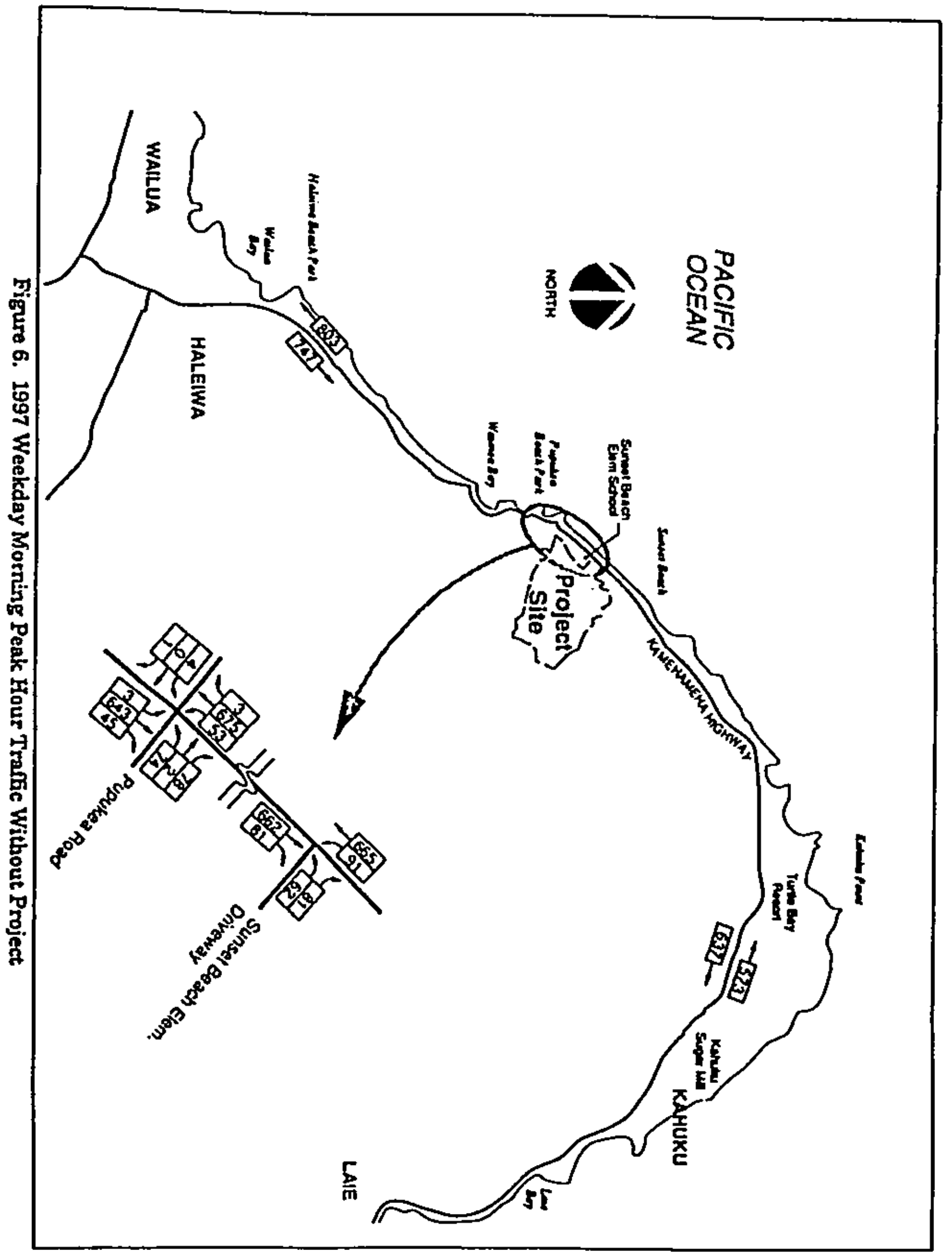

Figure 6. 1997 Weekday Morning Peak Hour Traffic Without Project

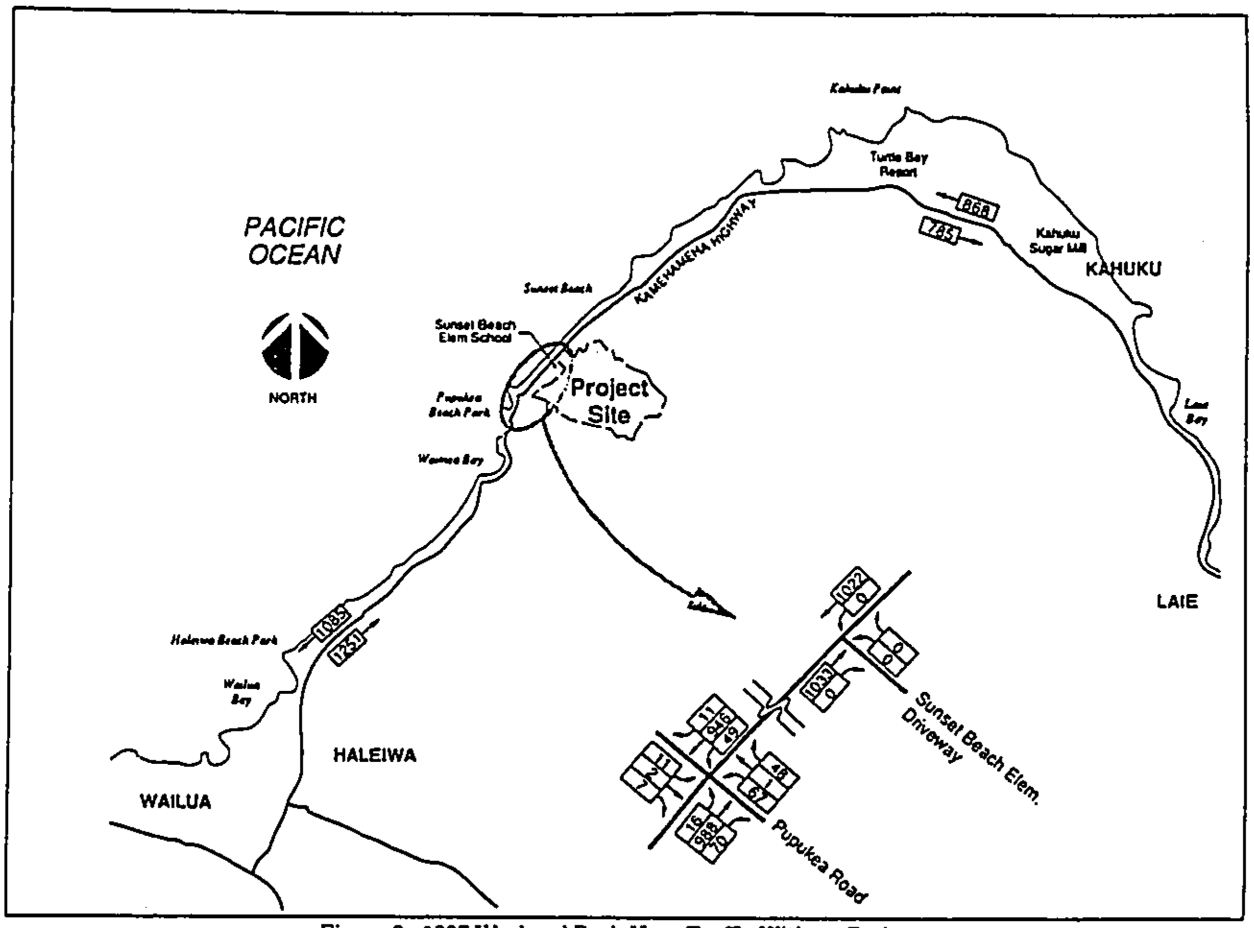

Figure 8. 1997 Weekend Peak Hour Traffic Without Project

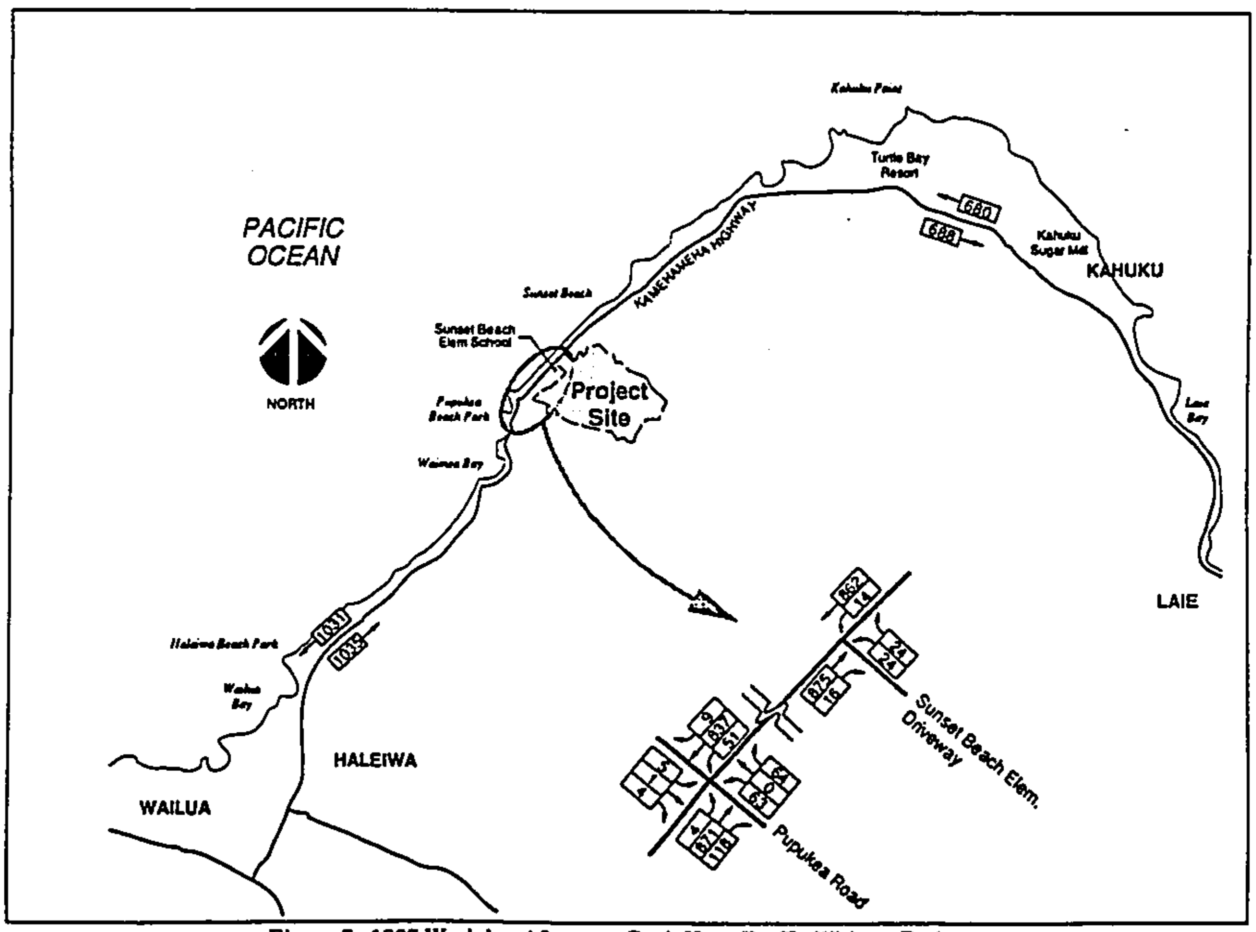

Figure 7. 1997 Weekday Afternoon Peak Hour Traffic Without Project

Future Traffic With Project

Future traffic with the project was forecasted by adding the traffic generated by the Lihi Lani Recreational Community project to the forecast traffic volumes without the project.

The three step procedure of trip generation, trip distribution, and traffic assignment was again used to forecast future traffic generated from the proposed project. The number of trips generated by the project were determined based upon the project's land uses and data from the ITE Trip Generation Report. Table 5 shows the trips generated by the project. The calculations for trip generation are shown in Appendix C.

It was assumed that 50% of the market homes would be used as recreational homes by part-time residents with the remaining 50% of the market homes occupied by full-time residents. Trips generated by the project's single-family affordable homes and market homes occupied by full-time residents were adjusted due to lower trips generated by homes located in rural areas. Trips generated during the weekday afternoon peak hour were reduced by 25%, and trips generated during the weekday morning and weekend peak hours were reduced by 35%.

Table 5. Adjusted Trip Generation for Project

Weekday Peak Hours

			Morning			Afternoon		
Land Use Description	Amount	Units	Enter	Exit	%	Enter	Exit	%
Full-Time Market Homes	60	units	9	24	14%	32	19	14%
Part-Time Market Homes	60	units	7	3	4%	7	9	5%
Affordable Homes	180	units	24	66	39%	89	53	39%
Community Facility	10	acres	17	7	10%	10	24	9%
Campground	15	acres	0	0	0%	0	0	0%
Golf Course	139	acres	30	7	16%	4	50	15%
Equestrian Ranch	100	stalls	18	7	11%	12	13	7%
Tennis Complex	12	courts	10	5	6%	16	25	11%
Total Trips			115	119	100%	170	193	100%

Weekend Peak Hour

			Sunday Peak Hour		
Land Use Description	Amount	Units	Enter	Exit	%
Full-Time Market Homes	60	units	23	21	11%
Part-Time Market Homes	60	units	19	23	11%
Affordable Homes	180	units	56	52	28%
Community Facility	10	acres	22	22	11%
Campground	15	acres	5	5	3%
Golf Course	139	acres	41	41	21%
Equestrian Ranch	100	stalls	12	12	6%
Tennis Complex	12	courts	16	16	8%
Total Trips			194	192	100%

Trip distribution for the project's traffic were based upon existing traffic patterns, and the distribution of population and employment on Oahu taking into account jobs within the district and Kuilima Resort's expansion. Table 6 shows the trip distribution used for each project's land use. Due to the project being a residential planned community having many recreational activities located within the project site, a portion of the trips generated by the project were captured within the development.

CORRECTION

THE PRECEDING DOCUMENT(S) HAS BEEN REPHOTOGRAPHED TO ASSURE LEGIBILITY
SEE FRAME(S)
IMMEDIATELY FOLLOWING

Future Traffic With Project

Future traffic with the project was forecasted by adding the traffic generated by the Lihi Lani Recreational Community project to the forecast traffic volumes without the project.

The three step procedure of trip generation, trip distribution, and traffic assignment was again used to forecast future traffic generated from the proposed project. The number of trips generated by the project were determined based upon the project's land uses and data from the ITE Trip Generation Report. Table 5 shows the trips generated by the project. The calculations for trip generation are shown in Appendix C.

It was assumed that 50% of the market homes would be used as recreational homes by part-time residents with the remaining 50% of the market homes occupied by full-time residents. Trips generated by the project's single-family affordable homes and market homes occupied by full-time residents were adjusted due to lower trips generated by homes located in rural areas. Trips generated during the weekday afternoon peak hour were reduced by 25%, and trips generated during the weekday morning and weekend peak hours were reduced by 35%.

Table 5. Adjusted Trip Generation for Project

Weekday Peak Hours

Land Use Description	Amount	Units	Morning Enter	Morning Exit	Morning %	Afternoon Enter	Afternoon Exit	Afternoon %
Full-Time Market Homes	60	units	9	24	14%	32	19	14%
Part-Time Market Homes	60	units	7	3	4%	7	9	5%
Affordable Homes	180	units	24	66	39%	89	53	39%
Community Facility	10	acres	17	7	10%	10	24	9%
Campground	15	acres	0	0	0%	0	0	0%
Golf Course	139	acres	30	7	16%	4	50	15%
Equestrian Ranch	100	stalls	18	7	11%	12	13	7%
Tennis Complex	12	courts	10	5	6%	16	25	11%
Total Trips			115	119	100%	170	193	100%

Weekend Peak Hour

Land Use Description	Amount	Units	Sunday Peak Hour Enter	Sunday Peak Hour Exit	Sunday Peak Hour %
Full-Time Market Homes	60	units	23	21	11%
Part-Time Market Homes	60	units	19	23	11%
Affordable Homes	180	units	56	52	28%
Community Facility	10	acres	22	22	11%
Campground	15	acres	5	5	3%
Golf Course	139	acres	41	41	21%
Equestrian Ranch	100	stalls	12	12	6%
Tennis Complex	12	courts	16	16	8%
Total Trips			194	192	100%

Trip distribution for the project's traffic were based upon existing traffic patterns, and the distribution of population and employment on Oahu taking into account jobs within the district and Kuilima Resort's expansion. Table 6 shows the trip distribution used for each project's land use. Due to the project being a residential planned community having many recreational activities located within the project site, a portion of the trips generated by the project were captured within the development.

Table 6. Trip Distribution Percentages for Project

To/From:	Morning	Afternoon	Sunday
Haleiwa	50%	50%	50%
Capture Within Project	15%	15%	25%
Laie	35%	35%	25%

Traffic generated by the project was assigned to Kamehameha Highway based on the estimated shortest distance or travel time between origin points and destinations. Tables 7, 8, and 9 show the resulting forecast volumes by turning movements in 1997 with and without the project along with the incremental increase in project related traffic. The resulting forecast traffic volumes with the project in 1997 for both weekday and weekend peak hours are shown on Figures 9, 10, and 11.

Table 7. 1997 Forecast Traffic Volumes
Morning Peak Hour

Intersection		1997 w/o Project	1997 w/ Project	Increase Traffic
Kamehameha Highway near Haleiwa Beach Park				
Northbound (to Laie)	TH	747	805	58
Southbound (to Haleiwa)	TH	803	864	61
Intersection of Kamehameha Highway with Pupukea Road				
Kamehameha Highway				
Northbound	LT	3	3	0
	TH	643	701	58
	RT	45	45	0
Southbound	LT	53	53	0
	TH	675	736	61
	RT	3	3	0
Pupukea Beach Park Driveway				
Eastbound (Mauka)	LT	4	4	0
	TH	0	0	0
	RT	1	1	0
Pupukea Road				
Westbound (Makai)	LT	74	74	0
	TH	2	2	0
	RT	78	78	0
Intersection of Kamehameha Highway with Sunset Beach Elementary School Driveway				
Kamehameha Highway				
Northbound	TH	662	720	58
	RT	81	81	0
Southbound	LT	91	91	0
	TH	665	726	61
Sunset Beach Elementary School Driveway				
Westbound (Makai)	LT	62	62	0
	RT	81	81	0
Intersection of Kamehameha Highway with Project Access Road				
Kamehameha Highway				
Northbound	TH	743	743	0
	RT	n/a	58	58
Southbound	LT	n/a	40	40
	TH	756	756	0
Project Access Road				
Westbound (Makai)	LT	n/a	61	61
	RT	n/a	41	41
Kamehameha Highway near Kahuku Sugar Mill				
Northbound (to Laie)	TH	637	678	41
Southbound (to Haleiwa)	TH	573	613	40

n/a - Not Applicable

Table 8. 1997 Forecast Traffic Volumes
Afternoon Peak Hour

Intersection		1997 w/o Project	1997 w/ Project	Incremental Increase
Kamehameha Highway near Haleiwa Beach Park				
Northbound (to Laie)	TH	1035	1119	84
Southbound (to Haleiwa)	TH	1031	1129	98
Intersection of Kamehameha Highway with Pupukea Road				
Kamehameha Highway				
Northbound	LT	4	4	0
	TH	871	955	84
	RT	118	118	0
Southbound	LT	51	51	0
	TH	837	935	98
	RT	9	9	0
Pupukea Beach Park Driveway				
Eastbound (Mauka)	LT	5	5	0
	TH	1	1	0
	RT	4	4	0
Pupukea Road				
Westbound (Makai)	LT	63	63	0
	TH	0	0	0
	RT	64	64	0
Intersection of Kamehameha Highway with Sunset Beach Elementary School Driveway				
Kamehameha Highway				
Northbound	TH	875	959	84
	RT	16	16	0
Southbound	LT	14	14	0
	TH	862	960	98
Sunset Beach Elementary School Driveway				
Westbound (Makai)	LT	24	24	0
	RT	24	24	0
Intersection of Kamehameha Highway with Project Access Road				
Kamehameha Highway				
Northbound	TH	899	899	0
	RT	n/a	84	84
Southbound	LT	n/a	57	57
	TH	876	876	0
Project Access Road				
Westbound (Makai)	LT	n/a	98	98
	RT	n/a	67	67
Kamehameha Highway near Kahuku Sugar Mill				
Northbound (to Laie)	TH	688	755	67
Southbound (to Haleiwa)	TH	680	737	57

n/a - Not Applicable

Table 9. 1997 Forecast Traffic Volumes
Weekend (Sunday) Peak Hour

Intersection		1997 w/o Project	1997 w/ Project	Incremental Increase
Kamehameha Highway near Haleiwa Beach Park				
Northbound (to Laie)	TH	1251	1354	103
Southbound (to Haleiwa)	TH	1085	1187	102
Intersection of Kamehameha Highway with Pupukea Road				
Kamehameha Highway				
Northbound	LT	16	16	0
	TH	988	1091	103
	RT	70	70	0
Southbound	LT	49	49	0
	TH	946	1048	102
	RT	11	11	0
Pupukea Beach Park Driveway				
Eastbound (Mauka)	LT	11	11	0
	TH	2	2	0
	RT	7	7	0
Pupukea Road				
Westbound (Makai)	LT	67	67	0
	TH	1	1	0
	RT	48	48	0
Intersection of Kamehameha Highway with Sunset Beach Elementary School Driveway				
Kamehameha Highway				
Northbound	TH	1033	1136	103
	RT	0	0	0
Southbound	LT	0	0	0
	TH	1022	1124	102
Sunset Beach Elementary School Driveway				
Westbound (Makai)	LT	0	0	0
	RT	0	0	0
Intersection of Kamehameha Highway with Project Access Road				
Kamehameha Highway				
Northbound	TH	1033	1033	0
	RT	n/a	91	91
Southbound	LT	n/a	55	55
	TH	1022	1022	0
Project Access Road				
Westbound (Makai)	LT	n/a	90	90
	RT	n/a	54	54
Kamehameha Highway near Kahuku Sugar Mill				
Northbound (to Laie)	TH	785	845	60
Southbound (to Haleiwa)	TH	868	929	61

n/a - Not Applicable

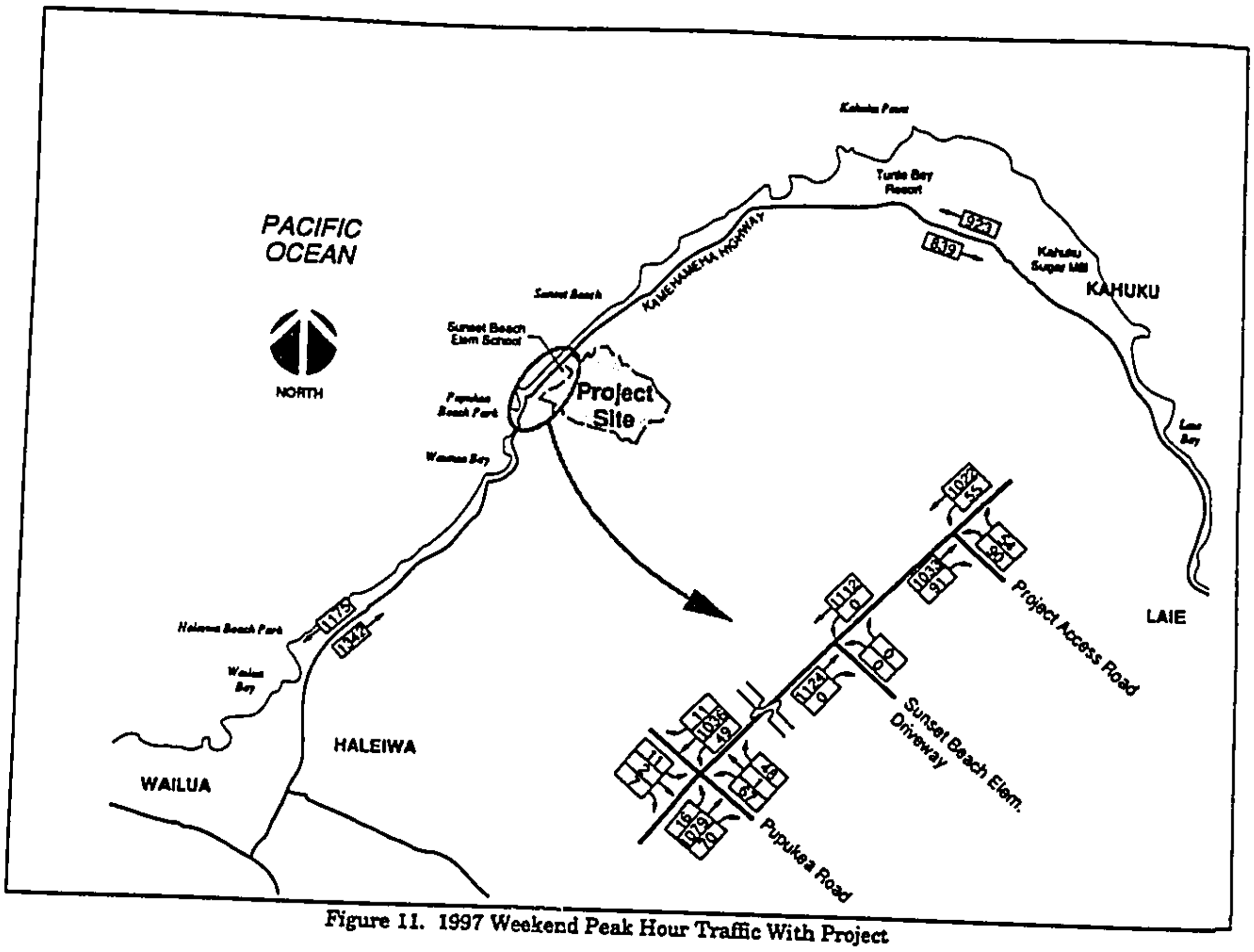

Figure 11. 1997 Weekend Peak Hour Traffic With Project

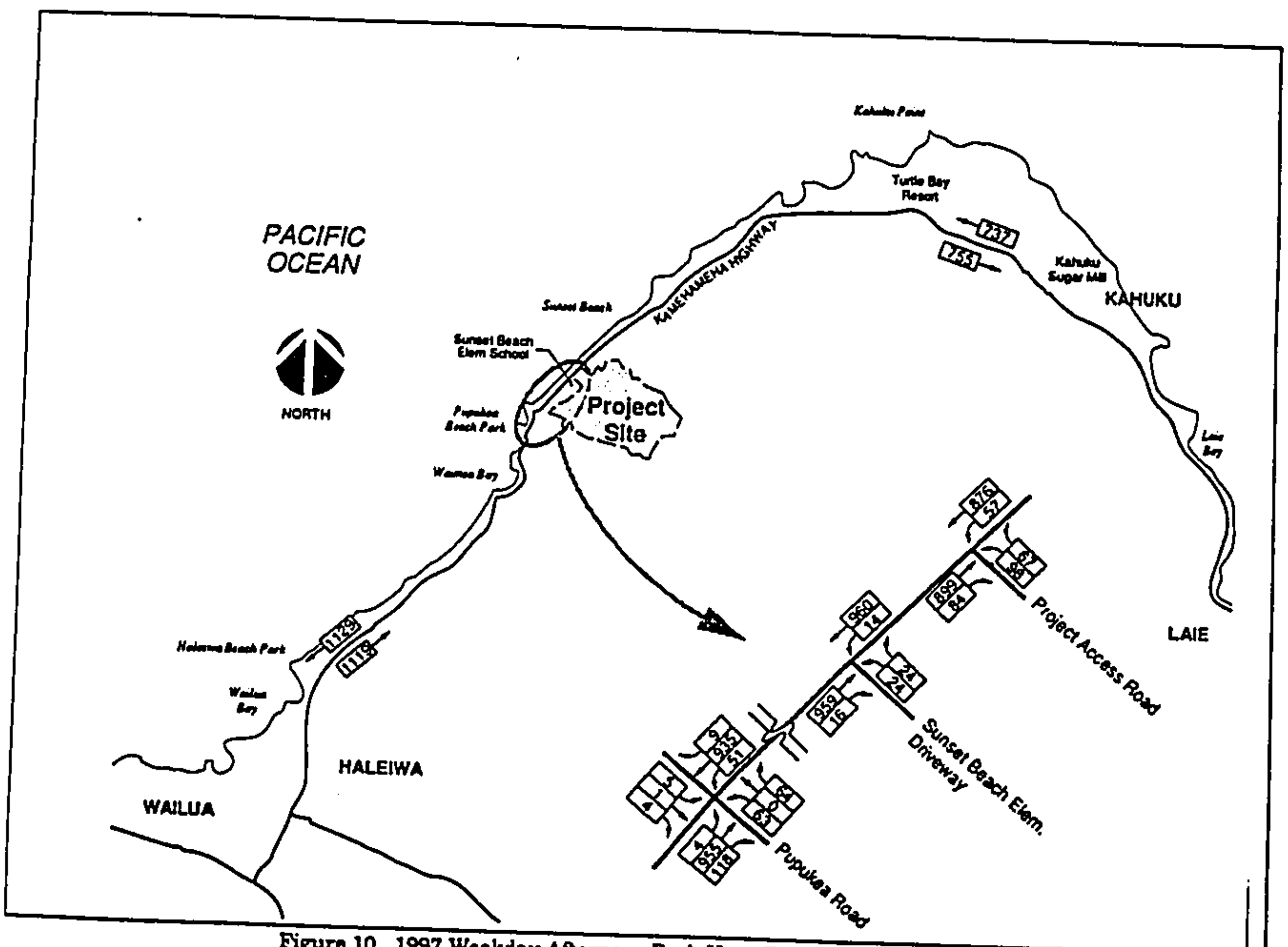

Figure 10. 1997 Weekday Afternoon Peak Hour Traffic With Project

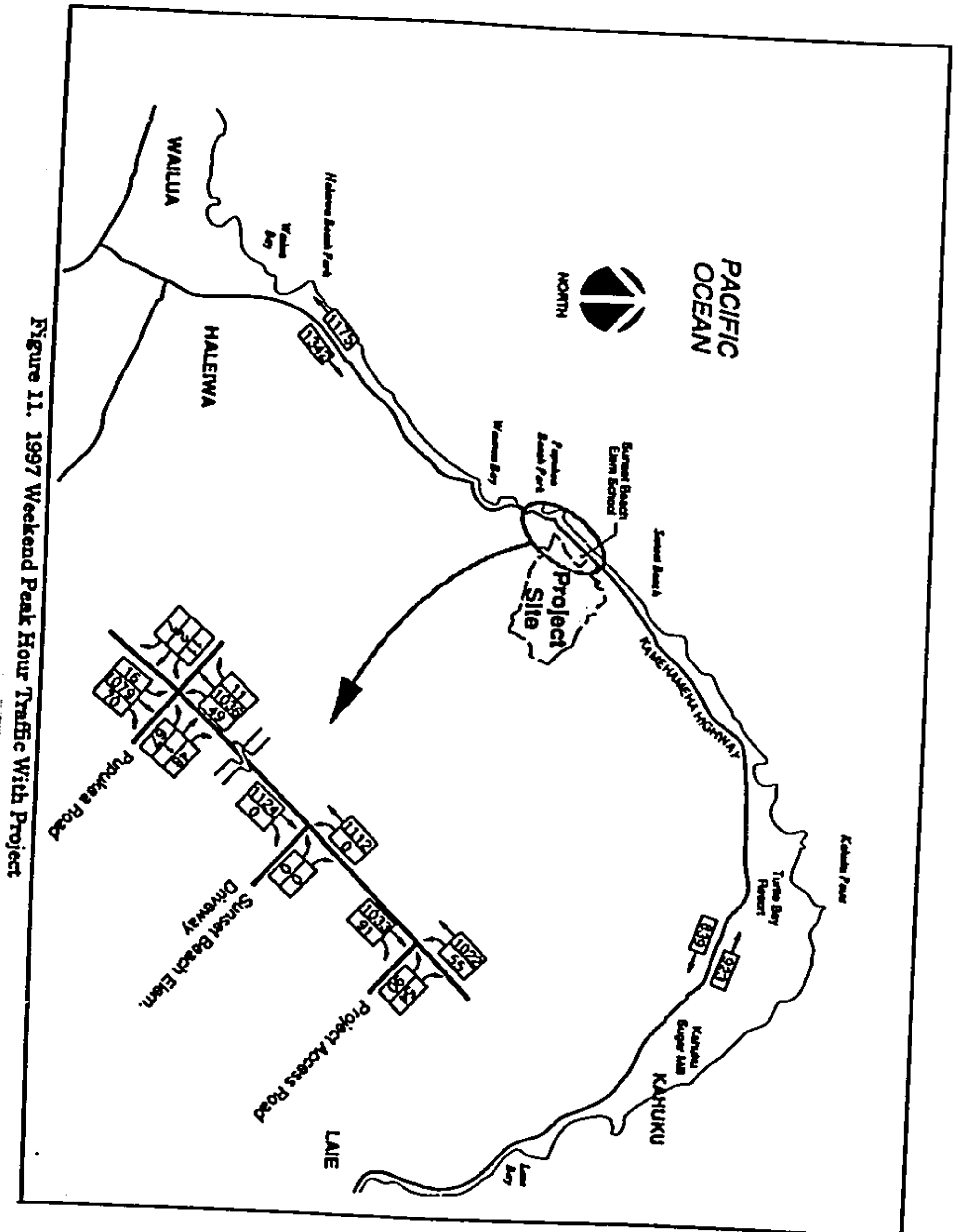

Figure 11. 1997 Weekend Peak Hour Traffic With Project

TRAFFIC IMPACTS

Analyses were conducted for the study intersections and segments of Kamehameha Highway to determine the relative impact of the proposed project on the local roadway system. The analysis of the study intersections and roadway segments were conducted for existing, 1997 forecasts without project, and 1997 forecasts with project. The analysis of forecasted traffic was based on the existing roadway network.

Analysis Methods

Kamehameha Highway and the study intersections were analyzed using methods from the Transportation Research Board (TRB) Highway Capacity Manual (HCM) Special Report 209, 1986.

Segments of Kamehameha Highway were analyzed using methods for analyzing two-lane rural highways. This method uses average travel speeds and ability to pass to measure traffic operational conditions on a section of highway. Slower speeds indicate poorer level-of-service (LOS).

The study intersections were analyzed using the Unsignalized Intersection Analysis. This analysis method is based on the estimated number of vehicle turning movements which could proceed through a conflicting traffic stream. The LOS is based on the capacity for a particular turning movement.

LOS is divided into six categories ranging from LOS A to LOS F. A detailed definition of LOS for rural highways and unsignalized intersections is given in Appendix B. LOS for rural highways and unsignalized intersections are not directly comparable.

Analysis Results

The results of the analysis for two-lane rural highway analysis are shown in Table 10. The results of the unsignalized intersection analysis are shown in Tables 11, 12, and 13.

Table 10. Level-of-Service for Two-Lane Rural Highway Along Kamehameha Highway

Highway Segment	1990 Existing	1997 Without Project	1997 With Project
Weekday Morning Peak Hour			
Near Haleiwa Beach Park	D	E	E
Near Pupukea Road	C	E	E
Near Sunset Beach Elementary School	D	E	E
Near Kahuku Sugar Mill	B	D	D
Weekday Afternoon Peak Hour			
Near Haleiwa Beach Park	D	E	E
Near Pupukea Road	D	E	E
Near Sunset Beach Elementary School	D	E	E
Near Kahuku Sugar Mill	C	D	D
Weekend (Sunday) Peak Hour			
Near Haleiwa Beach Park	E	E	F
Near Pupukea Road	D	E	E
Near Sunset Beach Elementary School	D	E	E
Near Kahuku Sugar Mill	C	E	E

Table 11. Level-of-Service for Unsignalized Intersections Morning Peak Hour

Intersection		1990 Existing	1997 Without Project	1997 With Project
Kamehameha Highway with Pupukea Road				
Kamehameha Highway				
Northbound (Makai)	LT	A	A	A
Southbound (Mauka)	LT	A	A	A
Pupukea Beach Park Driveway				
Eastbound (Mauka)	LT	B	D	E
	TH	B	D	E
	RT	B	D	E
Pupukea Road				
Westbound (Makai)	LT	C	E	E
	TH	A	B	B
	RT	A	B	B
Kamehameha Highway with Sunset Beach Elementary School Driveway				
Kamehameha Highway				
Southbound (Mauka)	LT	A	A	A
Sunset Beach Elementary School Driveway				
Westbound (Makai)	LT	B	E	E
	RT	B	E	E
Kamehameha Highway with Project Access Road				
Kamehameha Highway				
Southbound (Mauka)	LT	n/a	n/a	A
Project Access Road				
Westbound (Makai)	LT	n/a	n/a	E
	RT	n/a	n/a	E

n/a - Not Applicable

Table 12. Level-of-Service for Unsignalized Intersections
Afternoon Peak Hour

Intersection		1990 Existing	1997 Without Project	1997 With Project
Kamehameha Highway with Pupukea Road				
Kamehameha Highway				
Northbound (Makai)	LT	A	A	A
Southbound (Mauka)	LT	A	B	B
Pupukea Beach Park Driveway				
Eastbound (Mauka)	LT	C	E	F
	TH	C	E	F
	RT	C	E	F
Pupukea Road				
Westbound (Makai)	LT	D	F	F
	TH	A	C	C
	RT	A	C	C
Kamehameha Highway with Sunset Beach Elementary School Driveway				
Kamehameha Highway				
Southbound (Mauka)	LT	A	A	B
Sunset Beach Elementary School Driveway				
Westbound (Makai)	LT	C	E	E
	RT	C	E	E
Kamehameha Highway with Project Access Road				
Kamehameha Highway				
Southbound (Mauka)	LT	n/a	n/a	B
Project Access Road				
Westbound (Makai)	LT	n/a	n/a	F
	RT	n/a	n/a	F

n/a - Not Applicable

Table 13. Level-of-Service for Unsignalized Intersections
Weekend (Sunday) Peak Hour

Intersection		1990 Existing	1997 Without Project	1997 With Project
Kamehameha Highway with Pupukea Road				
Kamehameha Highway				
Northbound (Makai)	LT	A	B	B
Southbound (Mauka)	LT	A	B	C
Pupukea Beach Park Driveway				
Eastbound (Mauka)	LT	D	F	F
	TH	D	F	F
	RT	D	F	F
Pupukea Road				
Westbound (Makai)	LT	E	F	F
	TH	A	E	E
	RT	A	E	E
Kamehameha Highway with Project Access Road				
Kamehameha Highway				
Southbound (Mauka)	LT	n/a	n/a	C
Project Access Road				
Westbound (Makai)	LT	n/a	n/a	F
	RT	n/a	n/a	F

n/a - Not Applicable

Rural Highway Analysis for Segments of Kamehameha Highway

- *Presently*, segments of Kamehameha Highway operate at LOS D or better during the weekday and weekend, except at Haleiwa Beach Park which operates at LOS E during the weekend.

- *By 1997 without project*, the LOS of segments along Kamehameha Highway will drop to LOS E during both weekday and weekend peak hours. During the weekday peak hours, the LOS at Kahuku Sugar Mill will drop to LOS D.

- *By 1997 with project*, the LOS of segments along Kamehameha Highway will remain the same during both weekday peak hours. The LOS during the weekend peak hour will remain the same except at Haleiwa Beach Park which will drop from LOS E to LOS F.

Unsignalized Intersection Analysis for Study Intersections

Intersection of Kamehameha Highway with Pupukea Road

- *Presently*, drivers attempting turning movements from Pupukea Road onto Kamehameha Highway experience LOS D or better except for one movement. The left turn exiting Pupukea Road experiences LOS E during the weekend.

- *By 1997 without the project*, the LOS for turning movements during both weekday peak hours will drop LOS E or better except for left-turns from Pupukea Road during the afternoon peak hour which will drop to LOS F. During the weekend peak hour, the LOS for turning movements from Pupukea Road and the beach park driveway will generally drop to LOS F.

- *By 1997 with the project*, the LOS for turning movements during the weekday peak hours will remain the same except for turning movements from the beach park driveway which will drop to LOS E and F during the morning and afternoon peak hours respectively. During the weekend peak hour, the LOS will generally remain the same.

Intersection of Kamehameha Highway with Sunset Beach Elementary

- *Presently*, drivers exiting Sunset Beach Elementary School onto Kamehameha Highway experience LOS C or better during both weekday peak hours. Drivers attempting left-turns from Kamehameha Highway experience LOS A during both weekday peak hours.

- *By 1997 without project*, the LOS for vehicles exiting the school's driveway during both weekday peak hours will drop to LOS E while the LOS for the left-turns from Kamehameha Highway into the school will remain the same.

- *By 1997 with project*,the LOS for vehicles exiting the school during both weekday peak hours will remain the same. The LOS for left-turns from Kamehameha Highway into the school will operate at LOS B or better.

Intersection of Kamehameha Highway with Project Access Road

- *By 1997 with project*, turning movements from the project access road will operate at LOS E during the weekday morning peak hour, and LOS F during the weekday afternoon and weekend peak hours. The LOS for the left-turns from Kamehameha Highway into the project will operate at LOS C or better during both weekday and weekend peak hours.

CONCLUSIONS AND RECOMMENDATIONS

The proposed Lihi Lani Recreational Community project will have a slight impact on traffic flow along Kamehameha Highway and the study intersections when completed and fully occupied in 1997.

Presently, Kamehameha Highway is operating at LOS D or better except at Haleiwa Beach park during the weekend when it operates at LOS E. Traffic conditions were observed during November when the high surf attracts many tourists and spectators. During the weekend, congested conditions occurred at certain locations due to the following factors which contributed to the delays along Kamehameha Highway:

- Drivers parking along Kamehameha Highway at surfing locations causes traffic bottle necks due to parking maneuvers,
- Drivers slowing down to watch the surf, and
- City buses stopping at bus stops with no pull outs.

Even without the project by 1997, the level-of-service along Kamehameha Highway will decrease to LOS E. Vehicles exiting minor streets onto Kamehameha Highway at the study intersections will experience long traffic delays (LOS E or F). Drivers attempting left-turns from Kamehameha Highway into minor street will experience slight delays (LOS B or better).

Due to the expected delays for traffic exiting the minor streets, the study intersections should be studied in the future to determine if signalizing the intersections is warranted. This will minimize delays for vehicles exiting minor streets onto Kamehameha Highway.

With the project by 1997, the LOS at segments of Kamehameha Highway will remain the same as the without project case. The LOS for vehicles exiting minor streets onto Kamehameha Highway at the study intersections will remain the same as the without project case. Drivers attempting left-turns from Kamehameha Highway will experience slight to average delays (LOS B or C).

We recommend the following improvements at the Project Access Road:

- Provide a left-turn storage lane along Kamehameha Highway at its intersection with the project access road for southbound drivers attempting left-turns into the project. The left-turn storage lane should alleviate possible delays or back-ups along Kamehameha Highway caused by vehicles turning left into the project. This should also minimize rear-end collisions with vehicles slowing down or stopping to turn left into the project.

- Provide separate right and left-turn lanes at the project access road exiting the project site. This will permit left turning vehicles exiting the project to turn without creating unnecessary delays for drivers wanting to turn right onto Kamehameha Highway.

- In the future, study the possibility of signalizing the intersection of Kamehameha Highway with the Project Access Road.

The average percentage of total traffic along Kamehameha Highway in 1997 generated by future developments in the area are shown below in Table 14.

Table 14. Average Percentage of Total Traffic Along Kamehameha Highway

Development	Morning Peak Hour Percentage	Afternoon Peak Hour Percentage	Sunday Peak Hour Percentage
Kamehameha Hwy.	55%	65%	68%
Kahuku Villages	3%	4%	3%
Kahuku Residential	2%	1%	1%
Kuilima Resort Expansion	32%	21%	19%
Lihi Lani Community	8%	9%	9%
Total Percentage	100%	100%	100%

Construction-Related Traffic

An area of concern voiced by several people attending the project's Community Involvement Group meetings is the potential impact by project-generated construction vehicles on traffic along Kamehameha Highway. Our review of contemplated construction activities for the proposed project indicate that construction truck traffic will have minimal impact on traffic along Kamehameha Highway.

Trucks hauling construction materials such as cement, pipes, lumber, crushed rock, and asphalt concrete will average one or two trips per day initially. For a very short duration (two weeks), a maximum of 10 trucks per hour or 80 trucks per day hauling asphalt concrete to the job site. Traffic by construction workers will occur during the early morning hours and when workers leave the job site in the evening. An estimated 60 workers daily at the work site are expected to generate not more than 20 vehicles during the morning and afternoon peak hours. Most of the workers will be transported to the job site on company trucks from baseyards in Honolulu. Construction-related traffic entering and leaving the project will decrease beyond 1997 when the estimated work force is expected to drop to 10 to 30 workers daily.

Preliminary plans call for all earth moving operations to be confined to the project site, therefore, no trucks are expected to haul fill material onto the project or remove excess excavated material off the project site. This will further minimize truck traffic in and out of the project and along Kamehameha Highway.

APPENDIX A

LEVEL-OF-SERVICE DEFINITIONS
FOR
RURAL HIGHWAYS
AND
UNSIGNALIZED INTERSECTIONS

DEFINITION OF LEVEL-OF-SERVICE FOR UNSIGNALIZED INTERSECTIONS

For unsignalized intersections, the traffic most impacted will be the minor or cross-street with the stop or yield control. The major roadway will have the right-of-way. The level-of-service is the amount of delay expected for the average vehicle desiring to cross or enter the major road. The following gives a general description of the measure.

The concept of levels of service is defined as a qualitative measure describing operational conditions within a traffic stream, and their perception by motorists and/or passengers. A level of service definition generally describes these conditions in terms of such factors as speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience, and safety.

Six levels of service are defined for each type of facility for which analysis procedures are available. They are given letter designations, from A to F, with level-of-service A representing the best operating conditions and level-of-service F the worst.

Level-of-Service definitions--In general, the various levels of service are defined as follows for uninterrupted flow facilities:

Level-of-service A represents free flow. Individual users are virtually unaffected by the presence of others in the traffic stream. Freedom to select desired speeds and to maneuver within the traffic stream is extremely high. The general level of comfort and convenience provided to the motorist, passenger, or pedestrian is excellent.

Level-of-service B is in the range of stable flow, but the presence of other users in the traffic stream begins to be noticeable. Freedom to select desired speeds is relatively unaffected, but there is slight decline in the freedom to maneuver within the traffic stream from

LOS A. The level of comfort and convenience provided is somewhat less than at LOS A, because the presence of others in the traffic stream begins to affect individual behavior.

Level-of-service C is in the range of stable flow, but marks the beginning of the range of flow in which the operation of individual users becomes significantly affected by interactions with others in the traffic stream. The selection of speed is now affected by the presence of others, and maneuvering within the traffic stream requires substantial vigilance on the part of the user. The general level of comfort and convenience declines noticeably at this level.

Level-of-service D represents high-density, but stable, flow. Speed and freedom to maneuver are severely restricted, and the driver or pedestrian experiences a generally poor level of comfort and convenience. Small increases in traffic flow will generally cause operational problems at this level.

Level-of-service E represents operating conditions at or near the capacity level. All speeds are reduced to a low, but relatively uniform value. Freedom to maneuver within the traffic stream is extremely difficult, and it is generally accomplished by forcing a vehicle or pedestrian to "give way" to accommodate such maneuver. Comfort and convenience levels are extremely poor, and driver or pedestrian frustration is generally high. Operations at this level are usually unstable, because small increases in flow or minor perturbations within the traffic stream will cause breakdowns.

Level-of-service F is used to define forced or breakdown flow. This condition exists wherever the amount of traffic approaching a point exceeds the amount which can traverse the point. Queues form behind such locations. Operations within the queue are characterized by stop-and-go wave, and they are extremely unstable. Vehicles may progress at reasonable speeds for several hundred feet or more, then be required to stop in a cyclic fashion. Level-of-service F is used to describe the operating conditions within the queue, as well as the point of the breakdown. It should be noted, however, that in many cases operating conditions of the vehicles or pedestrians discharged from the queue may be quite good. Nevertheless, it is the point at which arrival flow exceeds discharge flow which causes the queue to form, and level-of-service F is an appropriate designation for such points.

These definitions are general and conceptual in nature, and they apply primarily to uninterrupted flow. Levels of service for interrupted flow facilities vary widely in terms of both the user's perception of service quality and the operational variables used to describe them.

REFERENCE: Highway Capacity Manual (Special Report 209, 1985)

DEFINITION OF LEVEL-OF-SERVICE
FOR
TWO-LANE RURAL HIGHWAYS

Level of service for two-lane rural highways addresses both mobility and accessibility concerns. The primary measure of service quality is percent time delay, with speed and capacity utilization used as secondary measures.

Level-of service A describes the highest quality of traffic service where motorists are able to drive at their desired speed. Without strict enforcement, this highest quality would result in average speeds approaching 60 mph on two-lane highways. The passing frequency required to maintain these speeds has not reached a demanding level. Passing demand is well below passing capacity, and almost no platoons of three or more vehicles are observed. Drivers would be delayed no more than 30% of the time by slow-moving vehicles.

Level-of-service B describes the region of traffic flow wherein speeds of 55 mph or slightly higher are expected on level terrain. Passing demand needed to maintain desired speeds becomes significant and approximately equals the passing capacity at the lower boundary of level-of-service B. Drivers are delayed up to 45% of the time.

Level-of-service C describes conditions where further increases in flow results in noticeable increases in platoon formation, platoon size, and frequency of passing impediment. Average speed still exceeds 52 mph on level terrain, even though unrestricted passing demand exceeds passing capacity. At higher volume levels, chaining of platoons and significant reductions in passing capacity begin to occur. While traffic flow is stable, it is becoming susceptible to congestion due to turning traffic and slow moving vehicles. Percent time delays are up to 60%.

Level-of-service D describes unstable traffic flow as two opposing traffic streams essentially begin to operate separately at higher volume levels, as passing becomes extremely difficult. Passing demand is very high, while passing capacity approaches zero. Mean platoon sizes of 5 to 10 vehicles are common, although speeds of 50 mph can still be maintained under ideal conditions. Turning vehicles and/or roadside distractions cause major shock-waves in the traffic stream. The percentage of time drivers are delayed approaches 75%.

Level-of-service E describes traffic flow conditions having a percent time delay of greater than 75 percent. Under ideal conditions, speeds will drop below 50 mph. Passing is virtually impossible and platooning becomes intense when slower vehicles or other interruptions are encountered.

Level-of-service F describes heavily congested flow with traffic demand exceeding capacity. Volumes are lower than capacity, and speeds are below capacity speed.

REFERENCE: Highway Capacity Manual (Special Report 209, 1985)

APPENDIX B

MANUAL TRAFFIC COUNT DATA

APPENDIX B

MANUAL TRAFFIC COUNT DATA

Kamehameha Highway at Pupukea Road

Thursday; November 15, 1990

	KAMEHAMEHA HIGHWAY						PUPUKEA ROAD					
	Haleiwa Bd			Laie Bd			Mauka Bd			Makai Bd		
TIME	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
0630-0645	1	58	11	0	55	12	0	0	0	24	0	6
0645-0700	3	59	0	0	52	8	0	0	0	23	0	10
0700-0715	8	72	0	0	43	11	0	1	0	27	1	14
0715-0730	5	80	0	0	43	19	0	0	0	30	0	15
0730-0745	12	70	1	1	62	4	1	0	0	21	0	31
0745-0800	15	92	0	2	78	13	1	0	1	11	2	23
0800-0815	14	87	1	0	67	15	1	0	0	23	0	16
0815-0830	12	80	1	0	61	13	1	0	0	19	0	8
Peak Hour Total												
0730-0830	53	329	3	3	268	45	4	0	1	74	2	78

	KAMEHAMEHA HIGHWAY						PUPUKEA ROAD					
	Haleiwa Bd			Laie Bd			Mauka Bd			Makai Bd		
TIME	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
1515-1530	12	116	2	0	99	25	0	0	1	13	1	10
1530-1545	10	114	2	2	116	29	0	0	2	21	0	19
1545-1600	17	113	3	1	109	21	0	1	1	18	0	16
1600-1615	12	103	2	0	137	34	2	0	1	8	0	10
1615-1630	12	124	2	1	136	34	3	0	0	16	0	19
1630-1645	14	123	3	0	102	24	2	0	1	12	0	19
1645-1700	11	118	0	2	112	28	3	2	1	10	1	19
Peak Hour Total												
1530-1630	51	454	9	4	498	118	5	1	4	63	0	64

Kamehameha Highway at Pupukea Road (continued)

Sunday, November 25, 1990

	KAMEHAMEHA HIGHWAY						PUPUKEA ROAD					
	Haleiwa Bd			Laie Bd			Mauka Bd			Makai Bd		
TIME	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
1100-1115	8	103	1	3	114	12	8	0	3	18	1	8
1115-1130	18	137	0	3	112	19	1	0	1	25	0	10
1130-1145	7	106	0	2	123	22	1	2	1	17	0	13
1145-1200	7	134	1	2	126	16	0	2	1	14	2	7
1200-1215	16	120	1	2	115	12	1	0	1	15	0	10
1215-1230	10	136	1	3	163	21	1	1	1	13	1	16
1230-1245	10	126	0	3	133	22	2	0	2	17	0	13
1245-1300	10	127	1	3	158	22	3	0	0	14	0	17
1300-1315	16	123	2	5	142	17	2	0	1	16	1	13
1315-1330	9	140	0	2	154	21	6	0	0	18	0	11
1330-1345	10	140	6	1	157	15	2	1	1	11	0	13
1345-1400	14	150	3	8	133	17	1	1	5	22	0	11
Peak Hour Total												
1300-1400	49	553	11	16	586	70	11	2	7	67	1	48

Kamehameha Highway at Sunset Beach Elementary School Driveway

Thursday, November 15, 1990

	KAMEHAMEHA HIGHWAY				SUNSET BEACH ELEMENTARY	
	Haleiwa Bound		Laie Bound		Makai Bound	
TIME	LT	TH	TH	RT	LT	RT
0630-0645	2	50	59	1	1	1
0645-0700	5	53	70	3	2	2
0700-0715	12	77	65	3	4	4
0715-0730	10	83	69	16	8	9
0730-0745	32	70	62	9	18	18
0745-0800	40	78	77	45	26	42
0800-0815	9	88	79	11	10	12
0815-0830	0	81	67	2	1	1
Peak Hour Total						
0715-0815	91	319	287	81	62	81

	KAMEHAMEHA HIGHWAY				SUNSET BEACH ELEMENTARY	
	Haleiwa Bound		Laie Bound		Makai Bound	
TIME	LT	TH	TH	RT	LT	RT
1350-1405	6	103	113	3	11	3
1405-1420	3	118	134	11	4	10
1420-1435	2	111	113	7	5	7
1435-1450	2	89	83	3	4	7
Peak Hour Total (for end of school)						
1350-1450	13	421	443	24	24	27

Kamehameha Highway at Sunset Beach Elementary School Driveway (continued)

Thursday, November 15, 1990

TIME	KAMEHAMEHA HIGHWAY Haleiwa Bound LT	KAMEHAMEHA HIGHWAY Haleiwa Bound TH	KAMEHAMEHA HIGHWAY Laie Bound TH	KAMEHAMEHA HIGHWAY Laie Bound RT	SUNSET BEACH ELEMENTARY Makai Bound LT	SUNSET BEACH ELEMENTARY Makai Bound RT
1515-1530	1	93	69	2	3	6
1530-1545	5	128	114	4	10	9
1545-1600	2	98	119	2	3	7
1600-1615	3	112	134	3	7	3
1615-1630	4	140	135	7	4	5
1630-1645	6	93	107	3	5	4
1645-1700	7	125	106	6	4	9
Peak Hour Total						
1530-1630	14	478	502	16	24	24

Kamehameha Highway at Sunset Beach Elementary School Driveway

Sunday, November 25, 1990

TIME	KAMEHAMEHA HIGHWAY Haleiwa Bound	KAMEHAMEHA HIGHWAY Laie Bound
1100-1115	131	130
1115-1130	129	140
1130-1145	132	109
1145-1200	109	138
1200-1215	135	137
1215-1230	157	158
1230-1245	149	139
1245-1300	154	130
1300-1315	173	159
1315-1330	158	160
1330-1345	157	167
1345-1400	141	145
Peak Hour Total		
1300-1400	629	631

Kamehameha Highway near Kahuku Sugar Mill
and
Kamehameha Highway near Haleiwa Beach Park

Thursday, November 15, 1990

TIME	NEAR KAHUKU SUGAR MILL Haleiwa Bd	NEAR KAHUKU SUGAR MILL Laie Bd	NEAR HALEIWA BEACH PARK Haleiwa Bd	NEAR HALEIWA BEACH PARK Laie Bd
0630-0645	43	16	85	66
0645-0700	45	40	103	50
0700-0715	50	55	114	66
0715-0730	61	66	132	56
0730-0745	55	63	111	113
0745-0800	61	78	94	89
0800-0815	40	65	120	114
0815-0830	32	42	105	79
Peak Hour Total	227	262	457	372

TIME	NEAR KAHUKU SUGAR MILL Haleiwa Bd	NEAR KAHUKU SUGAR MILL Laie Bd	NEAR HALEIWA BEACH PARK Haleiwa Bd	NEAR HALEIWA BEACH PARK Laie Bd
1515-1530			176	162
1530-1545	67	65	149	135
1545-1600	82	68	165	183
1600-1615	76	83	158	182
1615-1630	64	86	144	162
1630-1645	74	78	150	156
1645-1700	50	60	136	139
1700-1715			155	143
Peak Hour Total	296	315	648	662

Kamehameha Highway near Kahuku Sugar Mill
and
Kamehameha Highway near Haleiwa Beach Park

Sunday, November 25, 1990

TIME	NEAR KAHUKU SUGAR MILL Haleiwa Bd	NEAR KAHUKU SUGAR MILL Laie Bd	NEAR HALEIWA BEACH PARK Haleiwa Bd	NEAR HALEIWA BEACH PARK Laie Bd
1100-1115	75	63	141	132
1115-1130	76	83	137	186
1130-1145	66	77	178	171
1145-1200	71	111	151	187
1200-1215	69	83	180	214
1215-1230	97	85	136	233
1230-1245	88	92	187	224
1245-1300	83	91	169	178
1300-1315	125	105	152	199
1315-1330	122	95	179	188
1330-1345	66	103	197	236
1345-1400	162	80	174	187
Peak Hour Total	475	383	672	849

APPENDIX C

TRIP GENERATION CALCULATIONS

APPENDIX C

TRIP GENERATION EQUATIONS

Land Use	Ind Var		Total Number of Trips	Enter	Exit
Single Family	units	AM	T = exp(0.91xln(A)+0.2)	27%	73%
		PM	T = exp(0.94xln(A)+0.36)	63%	37%
		SUNDAY	T = exp(0.83xln(A)+0.8)	52%	48%
Recreational Homes	units	AM	T = 0.16xA	67%	33%
		PM	T = 0.262xA	41%	59%
		SUNDAY	T = 0.932xA	46%	54%
Golf Course	acres	AM	T = 0.266xA	80%	20%
		PM	T = 0.386xA	8%	92%
		SUNDAY	T = 0.867xA	50%	50%
Campground & Park	acres	AM	T = 2.431xA	50%	50%
		PM	T = 3.370xA	50%	50%
		SUNDAY	T = 4.420xA	50%	50%
Tennis Court	acres	AM	T = 1.286xA	60%	40%
		PM	T = 3.429xA	40%	60%
		SUNDAY	T = 2.643xA	50%	50%

T = Total number of trips
A = Quantity of independent variable

Note: A comparison of ITE trip generation rates for single-family homes with actual counts taken at Pupukea Road showed actual trips generated by homes in the area to be about 30% lower. As a result, trips generated by the single-family units were reduced by 25%.

APPENDIX P

D.L. ADAMS ASSOCIATES, LTD.
dba
DARBY & ASSOCIATES
ACOUSTICAL CONSULTANTS

J90-60
January 16, 1991

Group 70
924 Bethel Street
Honolulu, Hawaii 96813

Attention: Mr. Jeff Overton

Subject: Environmental Noise Impact Assessment, Lihi Lani Recreational Community, Pupukea, Oahu, Hawaii

Dear Mr. Overton:

A study has been performed to assess the noise impact due to the proposed project. The following is provided as a result of this study:

1. <u>SUMMARY</u>

1.1 The existing acoustical conditions in the vicinity of the section of the project site located near Kamehameha Highway are dominated by highway traffic noise, with a measured average level of 53 dBA (during a mid-day period at a distance of 170 feet from the highway). At the existing residential areas located on the mauka side of the highway away from the traffic noise, the current acoustical environment is dominated by natural sounds (the wind, birds, etc.) and general neighborhood noise. At these locations, the measured noise levels which were exceeded 50% of the time (L50) ranged from 38 to 40 dBA.

1.2 The existing residential areas located near Kamehameha Highway are estimated to be exposed to a current Day-Night Average Level (Ldn) of as high as 69 dB, due to traffic movements on the highway. It is estimated that the project-generated traffic will increase future (year 1997) traffic noise levels by less than 0.5 dB, and therefore, should not, by itself, cause any significant noise impact. The future Ldn levels are expected to increase up to about 72 to 73 dB at the homes closest to the highway, regardless of the project development. It is estimated that the traffic-generated 65 dB Ldn contour line will shift from its existing 75 feet distance (from the centerline of the highway) to 125 feet for the future case, again, regardless of the project development.

The future residential areas within the project should be exposed to Ldn's of less than 65 dB.

1.3 Noise due to the activities associated with the proposed golf course, such as clubhouse and ground maintenance operations, could potentially impact the nearby future single-family homes. However, provided that all necessary noise mitigation measures are implemented, noise generated by these activities will be in compliance with the appropriate regulations.

Due to relatively large distances involved (at least 1,200 feet), golf course operations are not expected to cause a significant noise impact at the existing homes.

1.4 Campground activities, such as groups of people singing during the nighttime, could cause a potential noise impact. The estimated noise generated by such singing would not normally raise the ambient level at the nearest existing homes (located 1,200 feet away). However, the noise may, at times, be audible at the homes and cause complaints, which could lead to State Department of Health (DOH) to enforce their noise regulations. Noise mitigation measures such as adequate setback distances and administrative controls will be needed in order to comply with the DOH regulations.

1.5 Noise generated by tennis match activities could exceed the DOH noise limits and cause annoyance to the residents of future homes located adjacent to or near the Tennis Center. Adequate setback distances and administrative control measures will be needed to comply with the DOH regulations.

1.6 Activities at the community facility could violate the DOH noise regulations and cause annoyance to the nearby residents, and if occurring during the school hours, the occupants of the adjacent school. Noise mitigation measures could be included in the building design as well as scheduling of events.

1.7 All necessary mitigation measures will be implemented such that noise from all stationary equipment will not exceed the allowable noise levels specified in DOH and City and County of Honolulu Land Use Ordinance (LUO) noise regulations. Administrative controls will be enforced to reduce the possibility of annoyance caused by other activities, such as trash pickup and delivery vehicles.

1.8 The various construction phases of a development project may generate significant amounts of noise; the actual amounts are dependent upon the methods employed during each stage of the process. Since it is anticipated that noise generated during construction will exceed allowable limits specified in DOH noise regulations, a permit will be obtained from DOH. All the required permit conditions for construction activities will be strictly observed. In addition, construction equipment and on-site vehicles or devices requiring an exhaust of gas or air must be equipped with mufflers. Also, construction vehicles using local roadways will satisfy the noise level requirements.

1.9 The design of all the facility will include noise mitigation measures, such that local noise regulations will be satisfied. Furthermore, strict administrative controls will be enforced to reduce the possibility of the facility-related activities creating annoyance to the existing and future residents nearby.

2. PROJECT DESCRIPTION

The project site is located at the north shore area of Oahu, on the mauka side of Kamehameha Highway across from the Sunset Beach Park. It consists of about 1,143 acres of land and will include the following (see Figure 1):

- an 18-hole golf course with a clubhouse, a driving range and a maintenance facility
- a tennis center
- an equestrian ranch and various patches of land for horse pasture
- a campground
- community facilities
- subdivision homes (120 lots)
- affordable housing
- sewage treatment plant
- related roadways and open spaces

3. NOISE STANDARDS

3.1 HUD Site Acceptability Standards -- The U.S. Department of Housing and Urban Development (HUD)'s Site Acceptability Standards specify an exterior Day-Night Average Sound Level (Ldn) of 65 dB as an acceptable level without any special noise mitigation measures

(Reference 1). Refer to Appendix I for an explanation of Ldn. For residential developments located within a 65 to 70 dB Ldn zone, the standards require the construction to provide a minimum of 5 dB attenuation in addition to "attenuation provided by buildings as commonly constructed in the area, and requiring open windows for ventilation." A minimum of 10 dB additional attenuation is required for residential projects exposed to an Ldn of 70 to 75 dB. The HUD document also states that the future noise level projections should be those considered "representative of conditions that are expected to exist at a time at least 10 years beyond the date of the project or action under review."

Although the HUD's Site Acceptability Standards are not applicable for existing homes, they can serve as guidelines in determining "acceptable" noise levels in residential areas.

3.2 State Department of Health and City and County of Honolulu Noise Regulations -- The State Department of Health (DOH) noise regulations specify allowable levels that shall not be exceeded for more than 10% of any 20-minute period (Reference 2). For the subject project, noise limits of 55 dBA for the daytime (7 am to 10 pm) and 45 dBA for the nighttime (10 pm to 7 am) will apply at the property lines of the areas containing any noise sources such as air conditioning equipment, motors, pumps, etc. The DOH allowable levels are summarized in Appendix II.

Section 3-100 of the City/County Building Department's Land Use Ordinance (LUO) sets forth the allowable noise limits presented in Appendix III (Reference 3). The LUO limits differ from those of the DOH in the that (a) they use octave-band levels, rather than the A-weighted levels; and (b) no temporal factor is involved. It should be noted that the DOH noise limits are more commonly enforced than those in the LUO.

4. EXISTING ACOUSTICAL ENVIRONMENT

On the morning of June 1, 1988, ambient noise level measurements were performed in order to assess the existing conditions. The measurements were made at Locations A through E shown in Figure 2.

The existing acoustical environment at locations near Kamehameha Highway is dominated by noise generated by highway traffic. A noise level measurement made at a distance of 170 feet from the center of the highway yielded an average level of 53 dBA over a 10-minute period.

Setback distances of residential structures located near the highway vary from about 40 to 200 feet. In order to estimate the existing noise levels at various distances from the highway, the above-mentioned noise measurement result at a distance of 170 feet was used to calibrate the Federal Highway Administration (FHWA) Highway Traffic Noise Prediction Model (Reference 4). Based on the field traffic data, the model calculated an hourly noise level (Leq[60 minutes]) of 52.8 dBA. The fact that the two values agree within 1 dBA is considered acceptable. Using this calibrated model along with the existing traffic data provided in Reference 5, noise exposure level estimates have been made at various distances from the highway, and the results are presented in Figure 3. As can be seen from the figure, the closest homes to the highway (at 40 feet distance from the centerline) are currently exposed to an estimated Ldn of about 69 dB. Homes located at a distance of 75 feet or greater are currently exposed to an estimated Ldn of 65 dB or less.

At the existing residential areas located on the mauka side of the highway away from the traffic noise (Locations A, B, and C), the current acoustical condition is dominated by natural sounds such as birds and wind in foliage, and neighborhood noise such as dogs barking, children playing, etc. The measured noise levels which were exceeded 50% of the time (L50) ranged from 38 to 40 dBA.

At Locations D and E, mauka of Kamehameha Highway, the L50 was about 45 dBA and dominated by highway traffic noise, but birds and wind in foliage were quite noticeable as well. At all sites, light aircraft or helicopter movements could occasionally be heard. The ambient sounds in homes right next to the beach are often dominated by surf noise.

5. <u>ASSESSMENT OF POTENTIAL NOISE IMPACT</u>

5.1 <u>Traffic Noise</u> -- Traffic noise calculations were performed using the previously mentioned calibrated traffic noise prediction model along with traffic data provided in Reference 5. The results of the calculations for the existing and future (1997) years with and without the project at various segments of Kamehameha Highway are summarized in Table 1. The levels are for an arbitrary distance of 100 feet from the centerline of the highway. As can be seen from the table, the increases in the future noise levels due to project-generated traffic are less than 0.5 dB. This is not considered a significant noise impact.

As stated earlier, the existing homes located directly adjacent to the highway (at a distance of about 40 feet) are currently exposed to an

Ldn of about 69 dB. The Ldn levels at these homes are estimated to increase to about 72 to 73 dB in the future (year 1997), regardless of the project development. The future 65 dB Ldn contour line is estimated to be at a distance of about 125 feet from the centerline of the highway, i.e., 50 feet further away from its existing location of 75 feet, again, regardless of the project development.

Traffic data for the interior roads are not available, except for the portion of the project access road where it intersects the highway. Assuming that the traffic volume is highest at the intersection, the proposed residences in the project are estimated to be exposed to Ldn's of well below HUD's 65 dB limit. Therefore, specifying setback distances for the housing should not be necessary. Note that traffic noise from Kamehameha Highway will not contribute significantly to the overall acoustical environment at any of the residences within the project.

5.2 <u>Golf Course Clubhouse Activity Noise</u> -- Noise sources associated with the clubhouse could include kitchen equipment, fans, air-conditioning equipment, refrigeration equipment, pool pumps, as well as sound systems for announcements and music. Noise from the clubhouse could potentially impact the nearby future single-family homes, which are to be located as close as 100 feet, just across the project access road from the clubhouse. Also, one of the lots near the clubhouse is located adjacent to the first-hole tee, which could house a public address (PA) sound system. If the appropriate measures are not taken in the design of these facilities, noise generated by the PA system and the above-mentioned noise sources may cause annoyance to the residents of the closest homes.

The sounds from the above sources should not cause any significant noise impact at the closest existing homes, which are located at a distance of about 1,200 feet. However, these sounds may occasionally be audible, depending on the sound propagation conditions, which depend largely on the topography, the amount and type of foliage involved, and the weather conditions.

5.3 <u>Golf Course Ground Maintenance Noise</u> -- Noise from equipment associated with ground maintenance activities, including lawn mowers and leaf blowers, could have an adverse impact on the proposed residential neighborhood particularly when the equipment is near the housing. However, noisy equipment is also incompatible and disruptive with golf play. Provided that all equipment powered by internal combustion engines is fitted with adequate exhaust mufflers, and that schedules are developed so noisier maintenance operations do not occur near the proposed residences before 7 a.m., the noise from ground maintenance operations will not cause "unreasonable" or "excessive" noise as defined in Reference 2.

5.4 Campground Activity Noise -- Noise levels generated by activities within the campground are expected to vary widely depending on the type of activities. For example, a group of 10 to 20 people singing around a campfire could generate noise levels as high as 54 to 63 dBA at a distance of 50 feet, compared to relatively quiet camping activities such as cooking, eating, sleeping, etc., which normally would not increase the ambient sound level significantly. The above estimates are based on vocal noise level data provided in Reference 6.

The closest noise sensitive positions to the campground are the existing homes along Pupukea Road, which are located at a distance of about 1,200 feet. Assuming a worst-case scenario (20 people singing during the worst-case sound transmission loss condition [6 dB per doubling of distance]), the noise level at the closest homes is estimated to be about 26 to 35 dBA, which is no greater than the measured ambient sound level. This analysis assumes that no sound amplification (i.e., boom boxes, PA sound system, etc.) will be used at the campground site. Therefore, although occasional campground activity noise may be audible at the homes, it should not have an adverse effect.

It should be noted, however, that if noisier activities such as a group of people singing around a campfire, occur near the property line of the project site, it would not be possible to comply with the DOH noise regulations. About the only practical measure to comply with the regulations is to keep such activities away from the closest noise sensitive areas, and possibly use the cabins or other structures as noise barriers.

5.5 Tennis Center Activity Noise -- The primary sources of noise from the Tennis Center, during a typical non-spectator tennis match, are racquet-to-ball impact, shoe screech, shouting and yelling. Noise generated by such activities may affect the proposed homes located adjacent to or near the Tennis Center. For example, based on our file noise data, a typical doubles tennis game could generate an L10 (10% exceedence level) level of about 58 dBA at the nearest property line of the tennis court. This exceeds both the DOH's daytime (7 am to 10 pm) and the nighttime (10 pm to 7 am) noise limit of 55 and 45 dBA, respectively. Adequate setback distances between the tennis courts and the common property line (between the tennis center and the adjacent homes) and strict administrative control measures will, therefore, be needed to comply with the DOH regulations.

It is our understanding that only a small number of bleachers will be provided at the center, and large crowds of spectators would not normally be expected. However, if tennis matches with large numbers of spectators are held, then the dominant sources of noise would be crowd cheering and PA sound system, and the DOH noise regulations will probably be exceeded.

5.6 Community Facility Activity Noise -- Activities at the community facility could include community gatherings, meetings, athletic events, and parties, which could have loud music or even live bands. Any events utilizing amplified sound systems could cause annoyance to the nearby residents, and if occurring during the school hours, the occupants of the adjacent school. Noise mitigation measures could be included in building design (i.e. adequate setback distances, sound insulation, etc.) as well as scheduling of events.

5.7 Stationary Equipment Noises -- Noise from air-conditioning equipment; pool pumps; exhaust fans; trash compactors; and any other stationary equipment at the Clubhouse, Tennis Center, sewage treatment plant and residential complexes will not exceed the allowable noise levels in References 2 and 3. Trash pickup and delivery vehicles will be operated and scheduled to cause minimum disturbance to neighboring residential units if complaints arise.

5.8 Construction Noise -- Development of the project site will involve grubbing, grading, and the construction of infrastructure and buildings. The various construction phases of a development project may generate significant amounts of noise; the actual amounts are dependent upon the methods employed during each stage of the process. Typical construction equipment noise ranges in dBA are shown in Figure 5. Earthmoving equipment such as bulldozers and diesel-powered trucks will probably be the loudest equipment used during construction for the majority of the project. However, the construction of the access road through the bluff will require rock removal which may involve rock hammers and drills as well as possible blasting. Equipment using impact to break rock is noisy (as seen in Figure 5, where 82 to 98 dBA at 50 feet is indicated as being typical of jack hammers and rock drills). The breaking of rock by explosion is usually accomplished by using numerous small charges detonated with small time delays. Also, the immediate blast area is covered by a blast mat with the purpose of (a) directing the explosive energy into the rock, (b) muffling the airborne pressure pulse, and (c) controlling flying debris. The actual blast would be perceived as a muffled "thump" sound and should cause minimal vibration through the ground to structures located below the bluff.

Since it is anticipated that noise generated during construction will exceed allowable limits in Reference 2, a permit will be obtained from DOH. DOH may grant permits to operate vehicles, construction equipment, power tools, etc. which emit noise levels in excess of the allowable limits. Required permit conditions for construction activities are:

> "No permit shall allow construction activities creating excessive noise...before 7:00 a.m. and after 6:00 p.m. of the same day."

> "No permit shall allow construction activities which emit noise in excess of ninety-five dB(A) ... except between 9:00 a.m. and 5:30 p.m. of the same day."

> "No permit shall allow construction activities which exceed the allowable noise levels on Sundays and on...[certain] holidays. Activities exceeding ninety-five dB(A) shall [also] be prohibited on Saturdays."

In addition, construction equipment and on-site vehicles or devices requiring an exhaust of gas or air must be equipped with mufflers. Also, construction vehicles using local roadways will satisfy the noise level requirements defined in Reference 7.

6. <u>NOISE MITIGATION MEASURES</u>

The design of the proposed Lihi Lani Recreational Community will include noise mitigation measures, including proper location, adequate setback distances, appropriate building design and orientation of the air-conditioning equipment, exhaust fans, pool pumps, amplified speaker sound systems, tennis courts, bleachers, etc., such that local noise regulations (References 2 and 3) will be satisfied. Furthermore, strict administrative controls will be enforced to reduce the possibility of the facility-related activities creating annoyance to the existing and future residents nearby. Such administrative controls could include the following:

- o no tennis games allowed after 10 pm or before 7 am at the courts located near the future homes.
- o no boisterous activities allowed on any portion of the campground

- o no amplified sound systems allowed on the campground (including auto stereo systems)

* * *

This concludes our noise impact assessment study of the project. Please feel free to call if you have any questions or if there are any changes to the project, which may cause affect our conclusions.

Sincerely,

Mike S. Lee
Senior Consultant

MSL:msl

REFERENCES:

1. "HUD Environmental Criteria and Standards, 24 CFR Part 51, "Federal Register, Volume 44, No. 135, July 12, 1979; amended 49 FR 880, January 6, 1984.

2. "Chapter 43 -- Community Noise Control for Oahu," Department of Health, State of Hawaii, Administrative Rules, Title 11, November 6, 1981.

3. "Section 3.100, Noise Regulations", Land Use Ordinance, City and County of Honolulu, October 22, 1986.

4. "FHWA Highway Traffic Noise Prediction Model", Federal Highway Administration, December 1978.

5. Traffic Data from Pacific Planning & Engineering, Inc., received December 7, 1990

6. "Chapter 14, Handbook of Noise Control," Cyril Harris, 1979

7. "Chapter 42 - Vehicular Noise Control for Oahu", Department of Health, State of Hawaii, Administrative Rules, Title 11, 1981.

TABLE 1

EXISTING AND FUTURE (1997) TRAFFIC NOISE LEVELS

AT SELECTED LOCATIONS

	Locations (see Figure 4)						
Condition	1	2	3	4	5	6	7
Existing a.m. Peak	62.6	62.7	62.8	63.0	63.0	--	52.1
Future a.m. Peak Without Project	65.7	65.7	65.7	65.8	65.8	--	52.1
Future a.m. Peak With Project	66.0	66.0	66.1	66.2	66.2	52.3	52.1
Increase in Future a.m. Peak Due to Project	0.3	0.3	0.4	0.4	0.4	--	0.0
Increase in a.m. Peak Due Project and Future Traffic Growth	3.4	3.3	3.3	3.2	3.2	--	0.0
Existing p.m. Peak	61.7	62.2	62.0	61.9	61.9	--	52.8
Future p.m. Peak Without Project	63.9	64.5	64.4	64.4	64.4	--	52.8
Future p.m. Peak With Project	64.3	64.9	64.8	64.8	64.7	54.2	52.8
Increase in Future p.m. Peak Due to Project	0.4	0.4	0.4	0.4	0.3	--	0.0
Increase in p.m. Peak Due Project and Future Traffic Growth	2.6	2.7	2.8	2.9	2.8	--	0.0
Existing Weekend Peak	62.2	62.9	62.9	62.9	62.9	--	52.8
Future Weekend Peak Without Project	64.3	65.0	65.0	65.0	65.0	--	52.8
Future Weekend Peak With Project	64.7	65.4	65.4	65.4	65.2	54.4	51.8
Increase in Future Weekend Peak Due to Project	0.4	0.4	0.4	0.4	0.2	--	0.0
Increase in Weekend Peak Due to Project and Future Traffic Growth	2.5	2.5	2.5	2.5	2.3	--	0.0

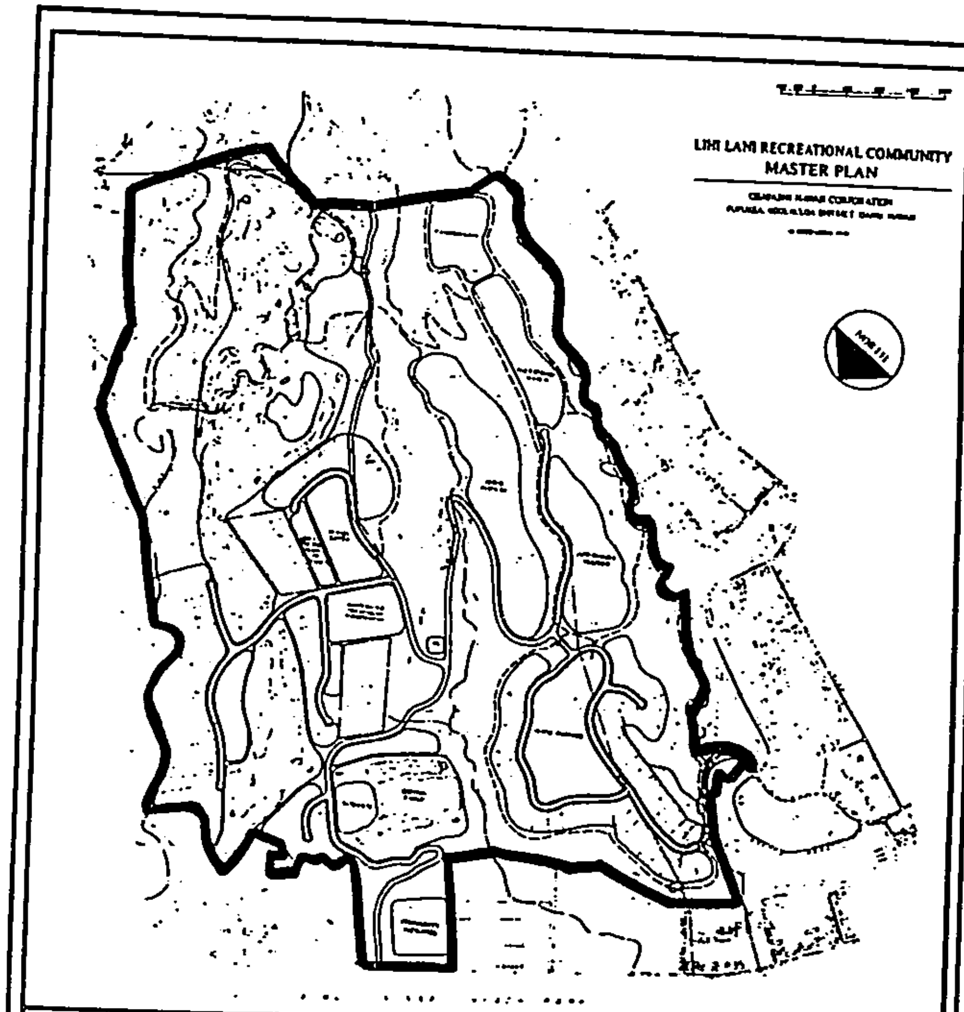

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FIGURE 1. PROJECT MASTER PLAN

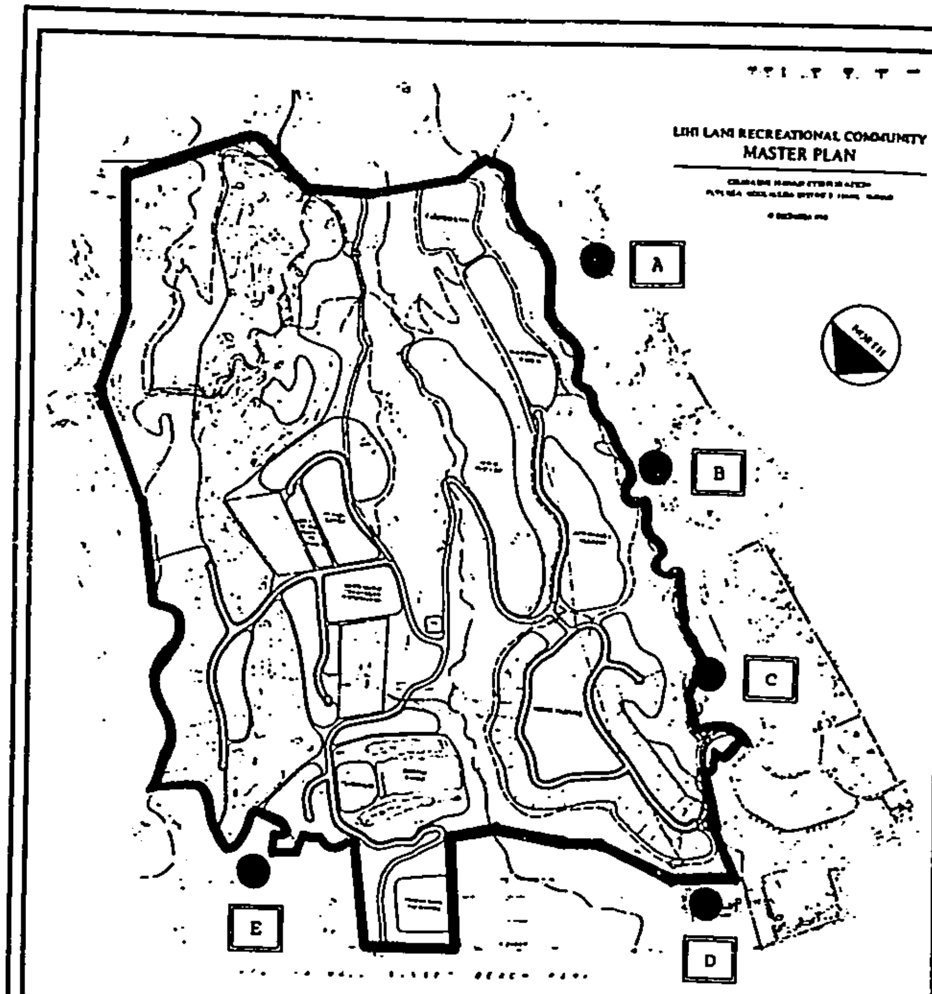

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FIGURE 2. NOISE MEASUREMENT LOCATIONS

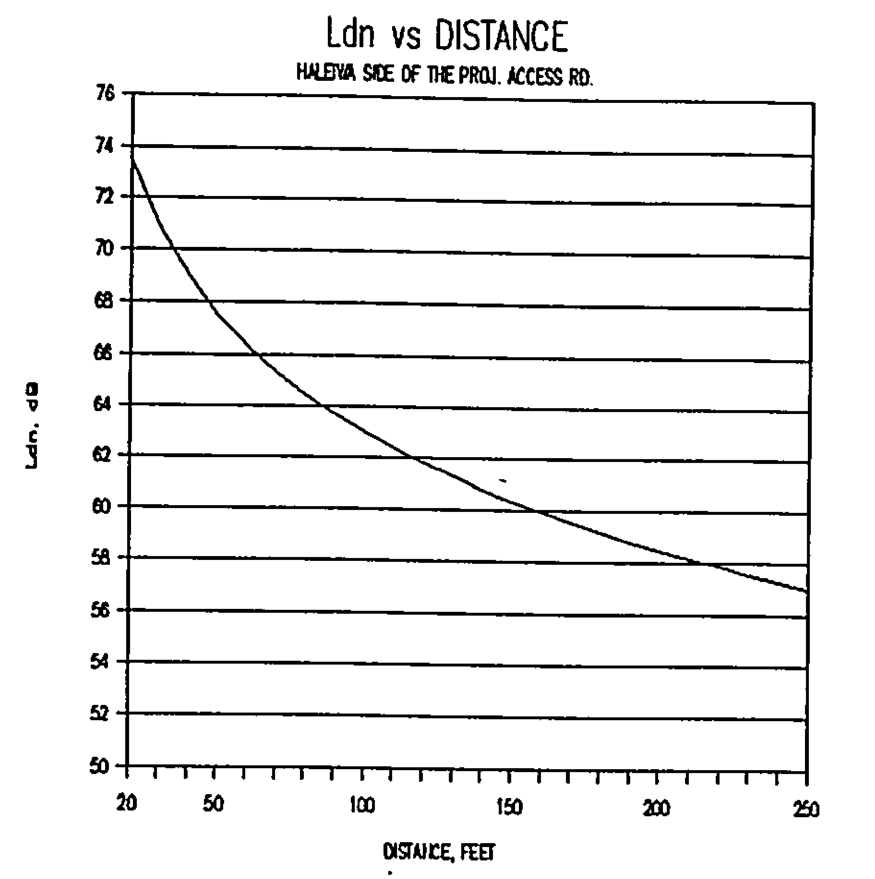

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FIGURE 3. Ldn LEVLES AT VARIOUS DISTANCES FROM THE CENTERLINE OF KAMEHAMEHA HIGHWAY; EXISTING CASE

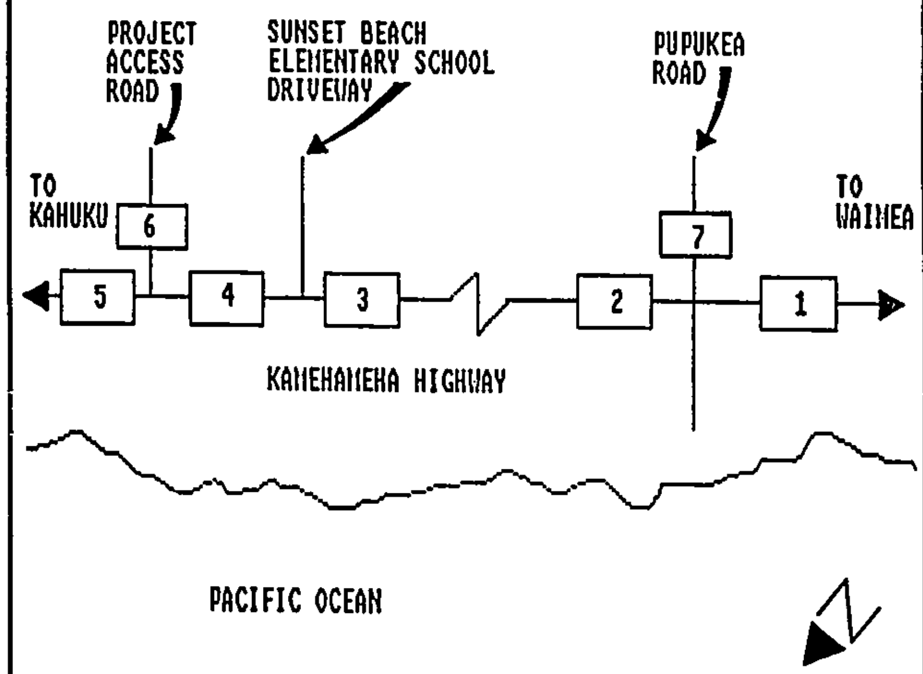

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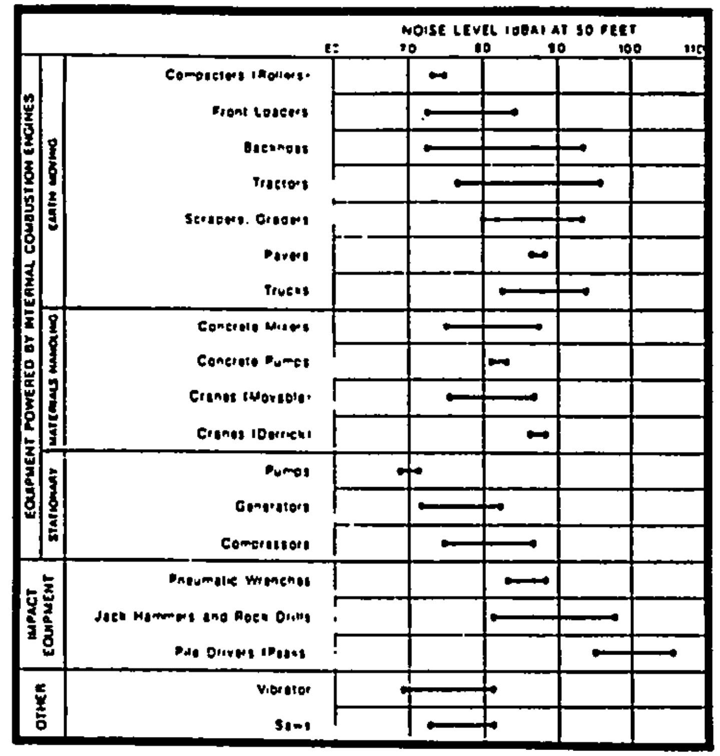
FIGURE 4 LOCATIONS OF THE SELECTED REACHES USED FOR THE TRAFFIC NOISE CALCULATIONS

'NO SCALE



Note: Based on Limited Available Data Samples

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FIGURE 5 NOISE LEVELS OF VARIOUS CONSTRUCTION EQUIPMENT

SOURCE: U.S. ENVIRONMENTAL PROTECTION AGENCY 1972

APPENDIX I

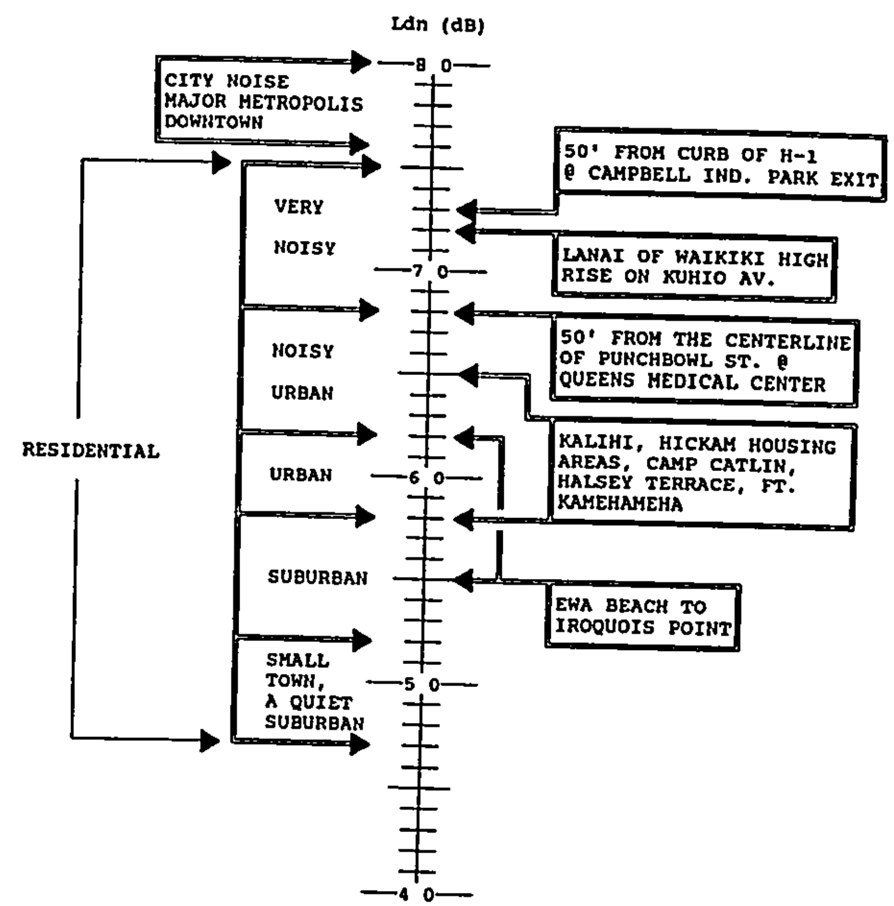
DAY NIGHT AVERAGE SOUND LEVEL, Ldn

The Day Night Average Sound Level, Ldn, is a commonly used noise metric in assessing land-use compatibility, and is used by federal and local agencies and standards organizations (U.S. Environmental Protection Agency, U.S. Department of Housing and Urban Development, Federal Aviation Administration, State Department of Transportation, American National Standards Institute, etc.).

The Ldn is an average of 24 consecutive A-weighted hourly average sound levels, with an exception of 10 dBA penalty for the nighttime and early morning hours (10 pm to 7 am), i.e. the measured or estimated levels during those hours are increased by 10 dBA before averaging. The 10 dBA penalty is due to the likely increase in annoyance to noise events occurring during those hours.

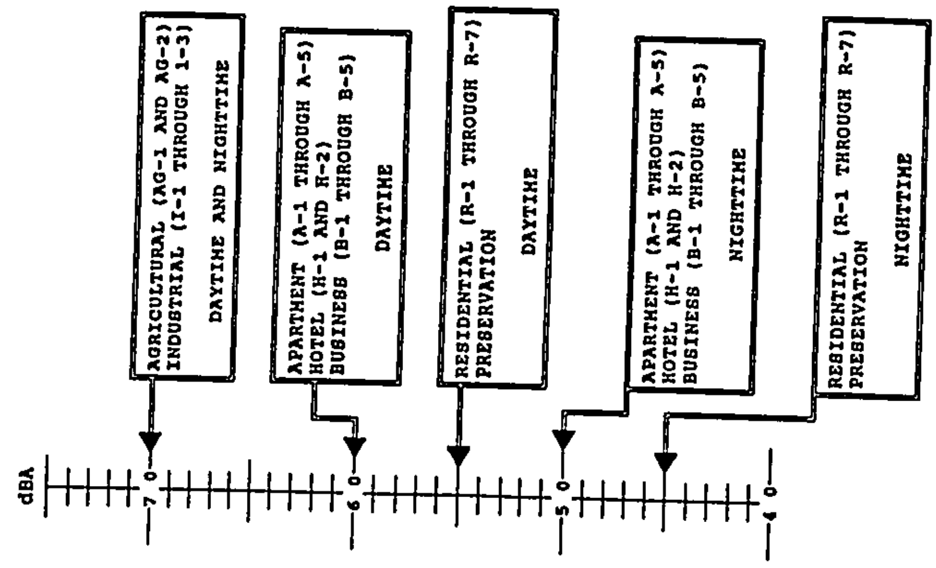
A comparative description of outdoor Ldn values is provided in Figure I-1.

TABLE I-1 QUALITATIVE DESCRIPTION OF THE AVERAGE DAY-NIGHT SOUND LEVEL (Ldn) AND SELECTED LOCATIONS ON OAHU EXPOSED TO THE INDICATED Ldn LEVEL



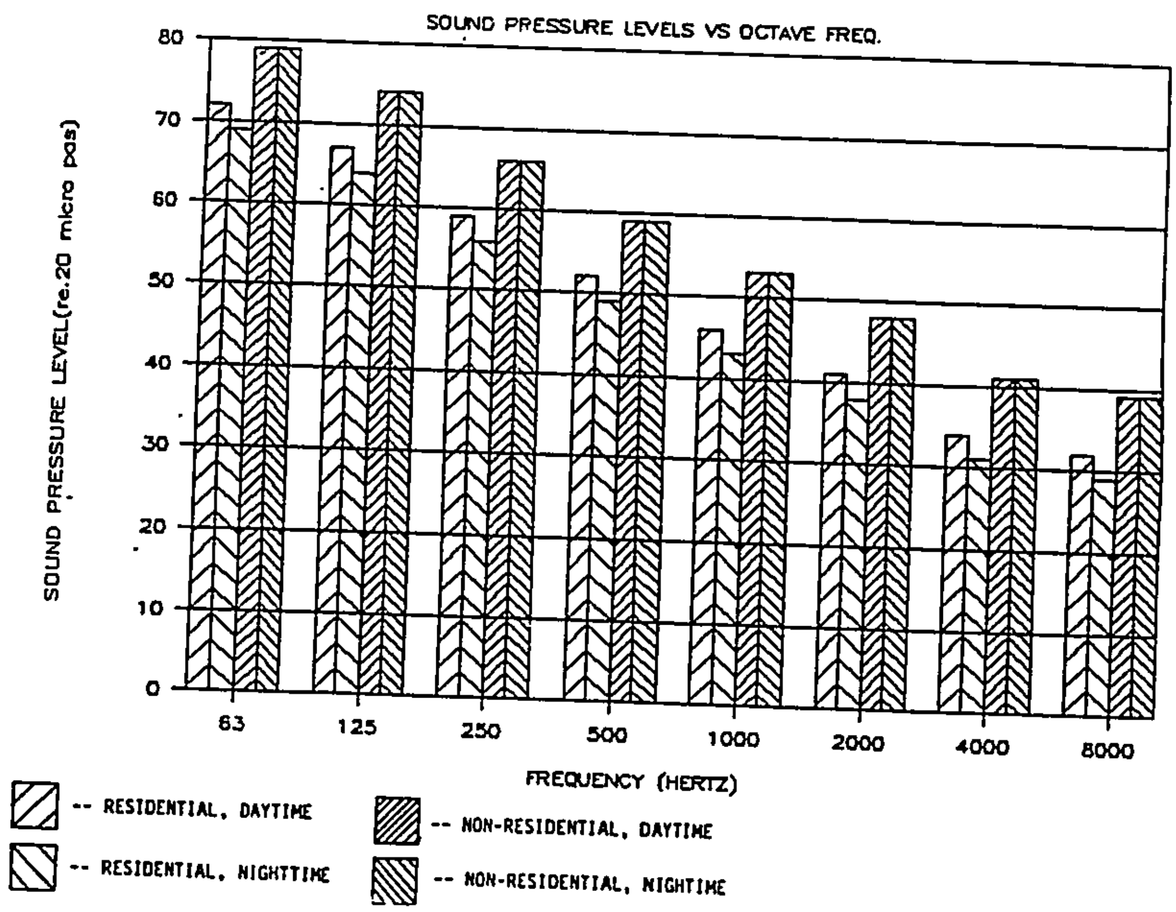
ALLOWABLE NOISE LEVELS FOR VARIOUS ZONING DISCTRICTS
COMMUNITY NOISE CONTROL FOR OAHU
STATE OF HAWAII, DEPARTMENT OF HEALTH

NOTE: THE REGULATION STATES THAT THE ALLOWABLE LEVELS SHALL NOT BE EXCEEDED FOR TEN PERCENT OF THE TIME WITHIN ANY TWENTY MINUTE PERIOD



APPENDIX III

MAXIMUM ALLOWABLE NOISE LEVELS vs OCTAVE BAND CENTER FREQUENCIES
CITY AND COUNTY OF HONOLULU LAND USE ORDINANCE



APPENDIX Q

AIR QUALITY STUDY
FOR THE PROPOSED
LIHI LANI RECREATIONAL COMMUNITY PROJECT

PUPUKEA, KOOLAULOA, OAHU

Prepared for:

Obayashi Hawaii Corporation

January 1991

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FIGURES

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1.0 INTRODUCTION AND PROJECT DESCRIPTION

Obayashi Hawaii Corporation is proposing for development the Lihi Lani Recreational Community Project at Pupukea, Oahu, Hawaii on approximately 1143 acres of land currently zoned for agricultural and residential use. As indicated in Figure 1, the project site is located north of Pupukea Road and mauka of Kamehameha Highway. Some of the major features of the project include: 120 one-acre residential lots, 180 affordable housing units, an 18-hole golf course, a driving range and clubhouse, an equestrian ranch and horse pastures, a tennis center, a campground and a community facilities complex. Construction of the proposed project is slated to begin in 1993. Completion of the golf course, ranch, tennis center, affordable housing and community facilities is expected to be achieved by 1996. Development of the market residential lots will occur between 1995 and 1997.

The purpose of this study is to describe existing air quality in the project area and to assess the potential short-term and long-term direct and indirect air quality impacts that could result from the development and subsequent use of the proposed facilities. Measures to mitigate potential impacts are suggested where possible and appropriate.

2.0 AMBIENT AIR QUALITY STANDARDS

Ambient concentrations of air pollution are regulated by both national and state ambient air quality standards (AAQS). National AAQS are specified in Section 40, Part 50 of the Code of Federal Regulations (CFR), while State of Hawaii AAQS are defined in Chapter 11-59 of the Hawaii Administrative Rules. Table 1 summarizes both the national and the state AAQS that are specified

in the cited documents. As indicated in the table, AAQS have been established for six air pollutants. These regulated air pollutants include: particulate matter, sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone and lead. National AAQS are stated in terms of primary and secondary standards. National primary standards are designed to protect the public health with an "adequate margin of safety". National secondary standards, on the other hand, define levels of air quality necessary to protect the public welfare from "any known or anticipated adverse effects of a pollutant". Secondary public welfare impacts may include such effects as decreased visibility, diminished comfort levels, or other potential injury to the natural or man-made environment, e.g., soiling of materials, damage to vegetation or other economic damage. In contrast to the national AAQS, Hawaii State AAQS are given in terms of a single standard that is designed "to protect public health and welfare and to prevent the significant deterioration of air quality".

Each regulated air pollutant has the potential to create or exacerbate some form of adverse health effect or to produce environmental degradation when present in sufficiently high concentration for prolonged periods of time. The AAQS specify a maximum allowable concentration for a given air pollutant for one or more averaging times to prevent harmful effects. Averaging times vary from one hour to one year depending on the pollutant and type of exposure necessary to cause adverse effects. In the case of the short-term (i.e., 1- to 24-hour) AAQS, both national and state standards allow one exceedance per year.

State of Hawaii AAQS are in some cases considerably more stringent than comparable national AAQS. In particular, the State of Hawaii

1-hour AAQS for carbon monoxide is four times more stringent than the comparable national limit.

Under the provisions of the Federal Clean Air Act [1], the U.S. Environmental Protection Agency (EPA) is required periodically to review and re-evaluate national AAQS in light of research findings more recent than those that were available at the time the standards were originally set. Occasionally new standards are created as well. Most recently, the national standards for particulate matter have been revised to include specific limits for particulate 10 microns or less in diameter (PM-10) [2]. The State of Hawaii has not explicitly addressed the question of whether to set limits for this category of air pollutant, but national AAQS prevail where states have not set their own more stringent levels.

Hawaii relaxed its AAQS for sulfur dioxide in 1986 to make them essentially the same as national limits. Various forums have proposed that the state also relax its carbon monoxide standards to the national levels, but at present there are no indications that such a change is being considered.

3.0 REGIONAL AND LOCAL CLIMATOLOGY

Regional and local climatology significantly affect the air quality of a given location. Wind, temperature, atmospheric turbulence, mixing height and rainfall all influence air quality. Although the climate of Hawaii is relatively moderate throughout most of the state and most of the year, significant differences in these parameters may occur from one location to another. Most differences in regional and local climates within the state are caused by the mountainous topography.

Hawaii lies well within the belt of northeasterly trade winds generated by the semi-permanent Pacific high pressure cell to the north and east. On the island of Oahu, the Koolau and Waianae Mountain Ranges are oriented almost perpendicular to the trade winds, which accounts for much of the variation in the local climatology of the island. Pupukea, the site of the proposed project, is located on the north shore of Oahu on the narrow western slope of the Koolau Mountains. The nearest wind data for this area of Oahu are collected at Dillingham Airfield located at Mokuleia. Winds at Dillingham Airfield are predominantly from the east or northeast [3]. Winds along the north shore of Oahu largely blow parallel to the coastline due to tradewind and orographic influences. Thus, the prevailing wind direction in the Pupukea area most probably is northeast. Winds from the south are infrequent occurring only a few days during the year and mostly in winter in association with Kona storms. Wind speeds along Oahu's northshore average about 10 to 15 mph and mostly vary between about 5 and 20 mph. Based on wind data from Dillingham Airfield, calms occur about 10 percent of the time.

Air pollution emissions from motor vehicles, the formation of photochemical smog and smoke plume rise all depend in part on air temperature. Colder temperatures tend to result in higher emissions of contaminants from automobiles but lower concentrations of photochemical smog and ground-level concentrations of air pollution from elevated plumes. In Hawaii, the annual and daily variation of temperature depend to a large degree on elevation above sea level, distance inland and exposure to the trade winds. Average temperatures at locations near sea level generally are warmer than those at higher elevations. Areas exposed to the trade wind tend to have the least temperature variation, while inland and leeward areas often have the most. Pupukea's northshore location results in a relatively moderate temperature profile compared to other locations around Oahu and the state. At nearby Wailua, average annual daily minimum and maximum temperatures are 64°F and 82°F, respectively [4]. The extreme minimum temperature at this location was 47°F, and the extreme maximum was 99°F. Maximum temperatures in the northshore area tend to be about the same on the average compared to Honolulu, while average minimum temperatures are about 5 degrees cooler.

Small scale, random motions in the atmosphere (turbulence) cause air pollutants to be dispersed as a function of distance or time from the point of emission. Turbulence is caused by both mechanical and thermal forces in the atmosphere. For air pollution assessments, turbulence is usually measured and described in terms of Pasquill-Gifford stability class. Stability class 1 is the most turbulent and class 6 the least. Thus, air pollution dissipates best during stability class 1 conditions and worst when stability class 6 prevails. In the Pupukea area, stability class 5 or 6 could occur during clear, calm nighttime or early morning hours when temperature inversions form either due to radiational cooling or to downslope winds that push warmer air aloft. Stability classes 1 through 4 should prevail during the daytime, depending mainly on the amount of cloud cover and incoming solar radiation and the onset and extent of sea breeze conditions.

Mixing height is defined as the height above the surface through which relatively vigorous vertical mixing occurs. Low mixing heights can result in high ground-level air pollution concentrations because contaminants emitted from or near the surface can become trapped within the mixing layer. In Hawaii, minimum mixing heights tend to be high because of mechanical mixing caused by the

trade winds and because of the temperature moderating effect of the surrounding ocean. Low mixing heights may sometimes occur, however, at inland locations and even at times along coastal areas early in the morning following a clear, cool, windless night. Coastal areas also may experience low mixing levels during sea breeze conditions when cooler ocean air rushes in over warmer land. Mixing heights in the state typically are above 3000 feet (1000 meters). Low mixing heights in the Pupukea area may occur on occasion either early in the morning during the breakup of nocturnally-formed temperature inversions or later in the day during seabreeze conditions.

Rainfall can have a beneficial effect on the air quality of an area in that it helps to suppress fugitive dust emissions, and it also may "washout" gaseous contaminants that are water soluble. Rainfall in Hawaii is highly variable depending on elevation and on location with respect to the trade wind. The north shore of Oahu experiences a moderately wet climate. At Waimea, about 1 mile south of the project site, average annual rainfall amounts to about 47 inches [4]. Annual rainfall may vary, however, from less than 30 inches during a dry year to more than 60 inches during a wet year. Monthly rainfall may vary from less than an inch during the summer to more than 20 inches during the winter.

4.0 PRESENT AIR QUALITY

Table 2 is an air pollutant emission summary for the City and County of Honolulu that was compiled in 1980. Although emissions are undoubtedly higher at this time, the major air pollution sources on the island are identified. Proportional relationships amongst the sources may continue to be about the same. The mineral products industry was the most significant source category for emissions of particulate matter. Sulfur dioxide emissions originated mainly from power plants, while motor vehicles accounted for much of the emissions of nitrogen oxides, carbon monoxide and hydrocarbons.

Present air quality in the project area could potentially be affected by air pollutants from natural, industrial, agricultural and/or vehicular sources. Natural sources of air pollution which could affect Pupukea include the ocean (sea spray), plants (aero-allergens), wind-blown dust, or perhaps distant volcanic emissions from the island of Hawaii.

Industrial and agricultural sources of air pollutants are located primarily on the leeward and central portions of Oahu. These sources are generally downwind from the project location. Upwind in the normal trade wind direction there are no industrial or agricultural air pollution sources for thousands of miles.

Kamehameha Highway, adjacent to the project site, is a major arterial roadway that often carries heavy motor vehicle traffic through the project area. Emissions from motor vehicles using this roadway, primarily nitrogen oxides and carbon monoxide, will tend to be carried away from the project site by the prevailing winds.

The State Department of Health operates a network of air quality monitoring stations at various locations on Oahu. Each station, however, typically does not monitor the full complement of air quality parameters. The only long-term State of Hawaii monitoring station on the windward side of Oahu is located at Waimanalo. This monitoring site was selected by the State to measure background

levels of particulate matter. None of the other regulated pollutants are measured at this location. Table 4 shows annual summaries of the data from the Waimanalo station for the period 1985 through 1989. During the five-year period, annual average total suspended particulate (TSP) concentrations ranged from 20 to 29 micrograms per cubic meter; 24-hour values ranged between 10 and 82 micrograms per cubic meter. These values are well within the State AAQS for suspended particulate and are probably typical of most locations on the windward coasts of Oahu.

Any air pollution currently affecting the project area is probably mainly from either natural or vehicular sources. Unfortunately, there are no nearby long-term measurements of vehicular-related pollutants (i.e., carbon monoxide, nitrogen oxides, ozone or lead) on the windward side of Oahu, so current levels of these pollutants are difficult to estimate very accurately. Lead, ozone and nitrogen dioxide typically are regional scale problems; concentrations of these contaminants generally have not been found to exceed AAQS elsewhere in the state. Carbon monoxide air pollution, on the other hand, typically is a microscale problem caused by congested motor vehicular traffic. In traffic congested areas such as urban Honolulu, carbon monoxide concentrations have been found to occasionally exceed the state AAQS. Present concentrations of carbon monoxide in the project area are estimated later in this study based on mathematical modeling of motor vehicle emissions.

5.0 SHORT-TERM IMPACTS OF PROJECT

Short-term direct and indirect impacts on air quality could potentially occur due to project construction. For a project of this nature, there are two potential types of air pollution emissions that could directly result in short-term air quality impacts during project construction: (1) fugitive dust from vehicle movement and soil excavation; and (2) exhaust emissions from on-site construction equipment. Indirectly, there also could be short-term impacts from slow-moving construction equipment traveling to and from the project site and from a temporary increase in local traffic caused by commuting construction workers.

Fugitive dust emissions may arise from the grading and dirt-moving activities associated with site preparation. The emission rate for fugitive dust emissions from construction activities is difficult to estimate accurately because of its elusive nature of emission and because the potential for its generation varies greatly depending upon the type of soil at the construction site, the amount and type of dirt-disturbing activity taking place, the moisture content of exposed soil in work areas, and the wind speed. The EPA [5] has provided a rough estimate for uncontrolled fugitive dust emissions from construction activity of 1.2 tons per acre per month under conditions of "medium" activity, moderate soil silt content (30%), and precipitation/evaporation (P/E) index of 50. Uncontrolled fugitive dust emissions in the project area would likely be somewhat lower because the PE index for the Pupukea area is probably greater than 50 due to the moderately wet climate. In any case, State of Hawaii Air Pollution Control Regulations [6] prohibit visible emissions of fugitive dust from construction activities at the property line. Thus, an effective dust control plan for the project construction phase is essential.

Adequate fugitive dust control can usually be accomplished by the establishment of a frequent watering program to keep bare-dirt surfaces in construction areas from becoming significant sources of dust. In dust-prone or dust-sensitive areas, other control measures such as limiting the area that can be disturbed at any

given time, applying chemical soil stabilizers and/or using wind screens may be necessary. Control regulations further stipulate that open-bodied trucks be covered at all times when in motion if they are transporting materials that could be blown away. Haul trucks tracking dirt onto paved streets from unpaved areas is oftentimes a significant source of dust in construction areas. Some means to alleviate this problem, such as road cleaning or tire washing, may be appropriate. Paving of parking areas and/or establishment of landscaping as early in the construction process as possible can also lower the potential for fugitive dust emissions.

On-site mobile and stationary construction equipment also will emit air pollutants from engine exhausts. The largest of this equipment is usually diesel-powered. Nitrogen oxides emissions from diesel engines can be relatively high compared to gasoline-powered equipment, but the standard for nitrogen dioxide is set on an annual basis and is not likely to be violated by short-term construction equipment emissions. Carbon monoxide emissions from diesel engines, on the other hand, are low and should be relatively insignificant compared to vehicular emissions on nearby roadways.

Indirectly, slow-moving construction vehicles on roadways leading to and from the project site could obstruct the normal flow of traffic to such an extent that overall vehicular emissions are increased, but this impact can be mitigated by moving heavy construction equipment during periods of low traffic volume. Likewise, the schedules of commuting construction workers can be adjusted to avoid peak hours in the project vicinity. Thus, most potential short-term air quality impacts from project construction can be mitigated.

6.0 LONG-TERM IMPACTS OF PROJECT

6.1 Roadway Traffic

By serving as an attraction for increased motor vehicle traffic on nearby roadways, the proposed project is considered to be an indirect air pollution source. Motor vehicles with gasoline-powered engines are significant sources of carbon monoxide. They also emit nitrogen oxides, and those burning leaded gasoline contribute lead to the atmosphere. The use of leaded gasoline in new automobiles is now prohibited. As older vehicles continue to disappear from the numbers of those currently operating on the state's roadways, lead emissions are approaching zero. Nationally, so few vehicles now require leaded gasoline that the EPA is proposing a total ban on leaded gasoline to take effect immediately. Even without such a ban, reported quarterly averages of lead in air samples collected in urban Honolulu have been near zero since early 1986. Thus, lead in the atmosphere is not considered a problem anywhere in the state.

Federal air pollution control regulations require that new motor vehicles be equipped with emission control devices that reduce emissions significantly compared to a few years ago. Although the recently adopted Clean Air Act of 1990 passed by Congress does not require further reductions in carbon monoxide emissions (except possibly in areas not currently meeting AAQS), the current emission standard for new vehicles will lower carbon monoxide emissions on a per vehicle basis by about 25 percent on the average by the year 1995 compared to the amounts now emitted due to the replacement of older vehicles with newer models. The new Clean Air Act of 1990 does, however, mandate that hydrocarbon emissions be cut by 40 percent and nitrogen oxides emissions be reduced by 60 percent over the amounts now permitted. Alternative-fueled cars and cleaner

burning blends of gasoline are also required by the new law in cities with chronic air pollution problems.

To evaluate the potential long-term indirect air quality impact of increased roadway traffic associated with a project such as this, computerized emission and atmospheric dispersion models can be used to estimate ambient carbon monoxide concentrations along roadways leading to and from the project. Carbon monoxide is selected for modeling because it is both the most stable and the most abundant of the pollutants generated by motor vehicles. Furthermore, carbon monoxide air pollution is generally considered a microscale problem, whereas nitrogen oxides air pollution most often is a regional issue. This is reflected in the fact that the AAQS for carbon monoxide are specified on a short-term basis (1-hour and 8-hour averaging times) while the AAQS for nitrogen dioxide are set on an annual basis.

For this project, three scenarios were selected for the carbon monoxide modeling study: year 1991 with present conditions, year 1997 without the project, and year 1997 assuming the project is built and complete. To begin the modeling study, critical receptor areas in the vicinity of the project were identified for analysis. Generally speaking, roadway intersections are the primary concern because of traffic congestion and because of the increase in vehicular emissions associated with traffic queuing. For this study, the three key intersections identified in the traffic study [7] were also selected for air quality analysis. These include: Kamehameha Highway at Pupukea Road, Kamehameha Highway at Sunset School and Kamehameha Highway at the project access road. The traffic impact assessment report for the project describes the present and future conditions and configurations of these intersections in detail. Briefly, Kamehameha Highway in this area of Oahu is presently a two-lane roadway with a narrow paved shoulder. Pupukea Road is channelized for left and right turn movements and stop-controlled at the intersection with Kamehameha Highway. The road into Sunset School is two lanes wide and also stop-controlled at Kamehameha Highway. With or without the project, these two intersections were assumed to remain the same in 1997. With the project in 1997, the project access road was assumed to form a t-intersection with Kamehameha Highway; it was further assumed that a left turn lane will be provided on Kamehameha Highway and that left and right turn lanes will be provided on the project access road.

The main objectives of the modeling study were to estimate both current and projected levels of maximum 1-hour average carbon monoxide concentrations that could then be directly compared to the national and state AAQS. The traffic impact assessment report indicates that traffic volumes generally are or will be higher during the afternoon peak hour than during the morning peak period during the week and that traffic volumes may be higher on a weekend than on a weekday. Worst-case emission and meteorological dispersion conditions typically occur during the morning hours at many locations. Thus, to ensure that worst-case concentrations were identified, weekday morning and afternoon peak traffic hours as well as weekend traffic periods were examined.

The EPA computer model MOBILE4 [8] was used to calculate vehicular carbon monoxide emissions for each year studied. One of the key inputs to MOBILE4 is vehicle mix. Based on recent vehicle registration figures, the present and projected vehicle mix in the project area is estimated to be 91.9% light-duty gasoline-powered vehicles, 5% light-duty gasoline-powered trucks and vans, 0.5% heavy-duty gasoline-powered vehicles, 0.6% light-duty diesel-

powered vehicles, 1% heavy-duty diesel-powered trucks and buses, and 1% motorcycles.

Other key inputs to the MOBILE4 emission model are the cold/hot start fractions. Motor vehicles operating in a cold- or hot-start mode emit excess air pollution. Typically, motor vehicles reach stabilized operating temperatures after about 4 miles of driving. For traffic operating within the project area, it was assumed that about 25 percent of all vehicles would be operating in the cold-start mode and that about 5 percent would be operating in the hot-start mode. These operational mode values were estimated based on a report from the California Department of Transportation [9] and taking into consideration the likely origins of traffic in the project area. MOBILE4 idle emissions were adjusted to account for excess cold/hot-start emissions per a recent U.S. EPA memorandum [10].

Ambient temperatures of 59 and 68 degrees F were used for morning and afternoon peak-hour emission computations, respectively. These are conservative assumptions since morning/afternoon ambient temperatures will generally be warmer than this and emission estimates given by MOBILE4 are inversely proportional to the ambient temperature.

After computing vehicular carbon monoxide emissions through the use of MOBILE4, these data were then input to the latest version of the computer model CALINE4 [11]. CALINE4 was developed by the California Transportation Department to simulate vehicular movement and atmospheric dispersion of vehicular emissions. It is designed to predict 1-hour average pollutant concentrations along roadways based on input traffic and emission data, roadway/receptor geometry and meteorological conditions.

Input peak-hour traffic data were obtained from the traffic study cited previously. The traffic volumes given in the traffic study for the future scenarios include project traffic as well as traffic from other growth that is expected to occur in the area by the year 1997. Traffic queuing estimates were made based on the project traffic study, Transportation Research Board procedures [12], U.S. EPA guidelines [13], and traffic observations at the subject intersections. For present and future without project scenarios, it was assumed that vehicles using Kamehameha Highway accelerated to 35 mph in the vicinity of Pupukea Road and 45 mph near Sunset School and the project access road. In the with project case, it was assumed that the speed limit on Kamehameha Highway will be reduced to 35 mph throughout the area. Vehicle speeds on the other roadways studied were assumed to be 25 mph. Deceleration and acceleration times of 10 and 12 seconds, respectively, were assumed for vehicles traveling at 25 mph, whereas values of 15 and 20 seconds were assumed for those traveling at 35 mph. For 45-mph traffic, a deceleration time of 20 seconds was used with an acceleration time of 25 seconds.

Model roadways were set up to reflect actual roadway geometry, physical dimensions and operating characteristics. There currently are no pedestrian walkways along Kamehameha Highway in the project area, but people frequently walk, jog and bicycle along the paved shoulder. Thus, model receptor sites were located approximately 3 meters (10 feet) from the edge of the roadways near the intersections studied. All receptor heights were placed at 1.5 meters above ground to simulate levels within the normal human breathing zone.

Input meteorological conditions for this study were defined to provide "worst-case" results. One of the key meteorological inputs is atmospheric stability category. For these analyses, atmospheric stability category 6 was assumed for morning scenarios and stability category 4 was assumed for afternoon cases. These are the most conservative stability categories that can be used for estimating pollutant dispersion at suburban or undeveloped locations. A surface roughness length of 100 cm was assumed with a mixing height of 300 meters. Worst-case wind conditions were defined as a wind speed of 1 meter per second with a wind direction resulting in the highest predicted concentration.

Existing background concentrations of carbon monoxide in the project vicinity are believed to be at relatively low levels. Hence, background contributions of carbon monoxide from sources or distant roadways not directly considered in the analysis were accounted for by adding a background concentration of 0.1 ppm to all predicted concentrations for both the 1991 and the 1997 scenarios.

Table 4 summarizes the results of the modeling study. Indicated in the table are the estimated worst-case 1-hour weekday (morning and afternoon) and weekend ambient carbon monoxide concentrations. These results can be compared directly to the state and the national AAQS. Estimated worst-case carbon monoxide concentrations are presented in the table for three scenarios: year 1991 with existing traffic, year 1997 without project traffic and year 1997 with project traffic. The locations of these estimated worst-case 1-hour concentrations all occurred at or very near the indicated intersections.

Insofar as present conditions are concerned, the highest worst-case 1-hour carbon monoxide concentration that was predicted in the vicinity of the project was 4.4 mg/m^3. This is predicted to occur along Kamehameha Highway near Sunset School during a weekday morning commute hour. Weekday morning/afternoon peak-hour concentrations at the other locations studied ranged from 1.0 mg/m^3 at the location of the future intersection of the project access road and Kamehameha Highway during the afternoon to 4.1 mg/m^3 at the Kamehameha Highway/Pupukea Road intersection during the morning. For the weekend afternoon case, the highest predicted 1-hour concentration (3.2 mg/m^3) was predicted to occur near the intersection of Kamehameha Highway and Pupukea Road. All estimated present 1-hour concentrations are within both state and national AAQS.

In the year 1997 without the proposed project, predicted worst-case 1-hour concentrations generally show an increase compared to 1991 levels due to the expected increase in traffic, particularly during the morning peak traffic period. Of the three locations studied, the highest concentration, 6.3 mg/m^3, was predicted to occur during a weekday morning near the Kamehameha Highway/Sunset School Road intersection. This is about 50 percent higher than the highest 1991 level in the project vicinity. Other predicted peak 1-hour concentrations varied from 1.3 mg/m^3 along through sections of Kamehameha Highway during the afternoon on a weekday to 4.7 mg/m^3 during the morning on a weekday along Kamehameha Highway near Pupukea Road. Based on these estimates, it appears that both state and national 1-hour AAQS for carbon monoxide would continue to be met in 1997 without the project.

For the 1997 with project scenario, estimated worst-case 1-hour weekday concentrations ranged from 2.1 mg/m^3 during the afternoon near Kamehameha Highway at Sunset School to 9.9 mg/m^3 during the afternoon near the intersection of Kamehameha Highway and the project access road. Worst-case weekend concentrations were higher at two of the three locations studied with a maximum of 13.2 mg/m^3 occurring near intersection of the project access road with Kamehameha Highway. Compared to the without project case, concentrations will be substantially higher at some locations, particularly near the area where the project access road will be constructed. As indicated in the table, it is predicted that worst-case 1-hour concentrations will exceed the state standard during weekend peak traffic periods, but concentrations will remain within the national AAQS.

Worst-case 8-hour carbon monoxide concentrations were estimated by multiplying the worst-case 1-hour values by a persistence factor of 0.5. This accounts for two factors: (1) traffic volumes averaged over eight hours are lower than peak 1-hour values, and (2) meteorological dispersion conditions are more variable (and hence more favorable) over an 8-hour period than they are for a single hour. Based on <u>monitoring</u> data, 1-hour to 8-hour persistence factors for most locations generally vary from 0.4 to 0.8 with 0.6 being the most typical. One recent study based on <u>modeling</u> [14] concluded that 1-hour to 8-hour persistence factors could typically be expected to range from 0.4 to 0.5. EPA guidelines [13] recommend using a value of 0.6 to 0.7 unless a locally derived persistence factor is available. Recent monitoring data for Honolulu reported by the Department of Health [15] suggests that this factor may range between about 0.35 and 0.55 depending on location and traffic variability. Considering the location of the project and the traffic pattern for the area, a 1-

hour to 8-hour persistence factor of 0.5 is probably most appropriate for this application.

The resulting estimated maximum 8-hour concentrations are indicated in Table 5. The highest estimated worst-case 8-hour carbon monoxide concentration for 1991 was 2.2 mg/m^3. This occurred on a weekday near the intersection of Kamehameha Highway and Sunset School Road. Estimated maximum 8-hour concentrations for 1991 at other locations and times varied from 0.6 mg/m^3 to 2.0 mg/m^3. In the year 1997 without project case, the predicted maximum 8-hour value was 3.2 mg/m^3. This would occur on a weekday at the Kamehameha Highway/Sunset School Road intersection. With the project in 1997, a maximum value of 6.6 mg/m^3 is estimated to occur near the intersection of the project access road and Kamehameha Highway during the weekend. With project concentrations will be higher than without the project, especially near the intersection of the project access road and Kamehameha Highway. Worst-case 8-hour concentrations should remain within the national standard but occasionally may exceed the more stringent state standard.

The results of this study reflect several assumptions that must be made concerning traffic movement and worst-case meteorological conditions. One such assumption concerning worst-case meteorological conditions is that a wind speed of 1 meter per second with a steady direction for 1 hour will occur. A steady wind of 1 meter per second blowing from a single direction for an hour is not very likely and may occur only once a year or less. With wind speeds of 2 meters per second, for example, computed carbon monoxide concentrations would be only about one-half the values given above.

6.2 Electrical Demand

The proposed project also will cause indirect air pollution emissions from power generating facilities as a consequence of electrical power usage. The annual electrical demand of the project when fully developed is not expected to exceed about 3 to 4 million kilowatt-hours. This power demand will most probably be provided mainly by oil-fired generating facilities located on Oahu. However, with H-Power now online and plans for a coal-fired power plant at Campbell Industrial Park in the near future, some of the project power could well come from sources burning other fuels. In order to meet the electrical power needs of the proposed project, power generating facilities will be required to burn more fuel and hence more air pollution will be emitted at these facilities. Given in Table 6 are estimates of the indirect air pollution emissions that would result from the project electrical demand assuming all power is provided by burning more fuel oil at Oahu's power plants. If power is supplied instead or in part by coal or solid waste burning facilities, emissions will likely be higher than the values given in the table.

6.3 Trash Disposal

Waste material generated by the project when fully completed is expected to amount to about 2 to 3 tons of refuse per day. Most if not all of this material will likely be hauled away in two to three truckloads per week and either landfilled or burned at another location. If all refuse is landfilled, the only air pollution emissions associated with solid waste disposal will be due to exhaust fumes and fugitive dust from the trucks and heavy equipment used to place the refuse in the landfill. If, on the other hand, all or part of the refuse is burned at a municipal incinerator or other facility (such as H-Power), disposal of solid waste from the project will also result in emissions of particulate, carbon monoxide and other contaminants from the incineration facility. Table 7 gives emission factors for municipal refuse incinerators (without controls) in terms of pounds of air pollution per ton of refuse material charged. Thus, uncontrolled air pollutant emission rates in terms of pounds per day, for example, can be estimated by multiplying the emission factors given in the table by the number of tons per day of refuse that is burned. Particulate emissions from the H-Power facility are much lower because emissions will be treated by a high-efficiency particulate control system. It should also be noted that if the project electrical demand derives all or in part from H-Power, this will help to offset emissions from burning oil or coal to produce power that might otherwise result.

6.4 Golf Course Pesticide Usage

Once the project is completed and the golf course is in use, it will be necessary to regularly apply various chemical pesticides to maintain grass quality. Herbicides are applied to greens, tees, fairways and perimeter areas, and insecticides and fungicides are used on greens and tees and for spot treatment of fairways. Golf course pesticides are applied with ground spray equipment. Typically, this includes tractor-mounted spray bars for fairways and perimeter areas and portable sprayer units for greens and tees and spot treatment of fairways. Pesticide chemicals are diluted with water in a mixing compartment, and the solutions are then applied under 20 to 40 pounds per square inch (psi) pressure to the target area by flat-fan type nozzles at about 1 to 3 feet above ground.

Murdoch and Green [16] have examined the potential impacts on air quality resulting from sprayer drift and have concluded that, if appropriate application techniques are used, there will be no significant adverse effects. Application during low wind speeds and using low nozzle heights, low spray pressures and coarse nozzle openings are recommended. Use of shrouded spray equipment will also reduce spray drift. Sufficient buffer space with tall vegetation between the golf course and housing sites and other facilities will further reduce the chance of exposure.

7.0 SUMMARY OF IMPACTS AND MITIGATIVE CONSIDERATIONS

7.1 Impacts Summary

The major short-term air quality impact will be the potential emission of significant quantities of fugitive dust during project construction. Uncontrolled fugitive dust emissions from construction activities are estimated to amount to about 1.2 tons per acre per month. During construction phases, emissions from engine exhausts (primarily consisting of carbon monoxide and nitrogen oxides) will also occur both from on-site construction equipment and from vehicles used by construction workers and from trucks traveling to and from the project.

The primary long-term air pollution impact from the project will arise from the increased motor vehicle traffic associated with the project. The proposed new facilities will generate more traffic entering/exiting the project area and on adjacent streets. Potential increased levels of carbon monoxide concentrations along roadways leading to and from the proposed development will be the primary concern. Based on mathematical modeling of projected vehicular traffic and on atmospheric dispersion estimates of vehicular emissions, it is predicted that with the proposed project worst-case carbon monoxide concentrations along roadways in the project vicinity will be higher near existing intersections compared to the without project case, but concentrations should remain within both the state and national AAQS. At the new intersection along Kamehameha Highway created by the project access road, air pollution concentrations will increase substantially; concentrations should remain within the national AAQS at this location but may occasionally exceed the state standards. It should be mentioned here, however, that the state standards are set so low that they are likely exceeded at many intersections in the state that have even moderate traffic volumes. It is also worth noting that, although the national AAQS allow higher levels of carbon monoxide, the national standards were developed after extensive research with the objective of defining levels of air quality that would protect the public health with an adequate margin of safety.

Some long-term impacts could also potentially occur due to indirect emissions from power generating facilities supplying the project with electricity and from the burning of waste materials generated by the project. Quantitative estimates of these impacts were not made, but it appears likely that any impacts will be relatively small since emissions from supplying the project with electrical power and solid waste disposal service will be much less than 1 percent of current Oahu emissions.

7.2 Mitigative Considerations

Strict compliance with State of Hawaii Air Pollution Control Regulations regarding establishment of a regular dust-watering program and covering of dirt-hauling trucks will be required to

effectively mitigate fugitive dust emissions from construction activities. Twice daily watering is estimated to reduce dust emissions by up to 50 percent. Use of wind screens, while generally less effective than watering, may further reduce dust. If dirt tracking onto paved roads by haul trucks is a problem, tire washing could help to reduce the resulting fugitive dust emissions. Paving of parking areas and establishment of landscaping early in the construction schedule will also help to control dust. Increased vehicular emissions due to disruption of traffic by construction equipment and/or commuting construction workers can be alleviated by moving equipment and personnel to the site during off-peak traffic hours.

Options available to mitigate traffic-related air pollution once the project is complete are to improve roadways, reduce traffic or reduce individual vehicular emissions. Predicted project air pollution impacts include the roadway improvements recommended by the traffic consultant. Installation of a traffic signal at some point in the future at the intersection of the project access road with Kamehameha Highway may be necessary to reduce delays for vehicles exiting the project. Signalization of the intersection would reduce vehicle delay times and thus reduce air quality impacts from the accumulation of vehicle idle emissions.

Reducing traffic can be accomplished by promoting mass transit, bus service and car pooling and/or by adjusting local school and business hours to begin and end during off-peak times. Reduction of emissions from individual vehicles is beyond the control of any single developer; however, due to the extended completion date for the project, it is conceivable that the efficiency of motor vehicle engines and/or emission control equipment will be improved or that vehicles will be developed which burn cleaner fuels before the project reaches full build-out. If this occurs, then impacts will be less than predicted. With regard to cleaner burning fuels, vehicles burning methanol or compressed natural gas or powered by electrical motors are some of the possibilities for technological development that are currently being contemplated. Lastly, even without technological breakthroughs, it is also possible that at some point in the future the state may decide to adopt either a motor vehicle inspection and maintenance program, which would ensure that emission control devices are properly maintained and thereby reduce emissions, or more restrictive emission control standards.

Indirect emissions from project electrical demand will be small but could be reduced somewhat by utilizing solar energy design features to the maximum extent possible. This might include installing solar water heaters, designing homes and other buildings so that window positions maximize indoor light without unduly increasing indoor heat, and using landscaping where feasible to provide afternoon shade to cut down on the use of air conditioning. Use of wind power generating units and other alternative energy sources by the utility instead of fuel-burning facilities also would lessen indirect emissions from project electrical demand.

Any air pollution impacts from burning solid waste from the project could be reduced substantially if the incinerator is fitted with pollution control equipment, i.e., electrostatic precipitators or fabric filters. Conservation and recycling programs could also reduce solid waste which would reduce any related air pollution emissions proportionately. Quite possibly, solid waste from the project will be processed by the H-Power garbage-to-energy facility which is fitted with fabric filters to control air pollution. Use of solid waste to generate power offsets emissions that would

otherwise occur from fossil-fueled power plants.

Compliance with application guidelines for the spraying of chemicals for golf course maintenance should mitigate potential air quality impacts from this activity. Measures available to mitigate impacts from pesticide drift include: spraying chemicals using coarse-droplet, low-pressure spray equipment; using shielded or shrouded sprayers; spraying from low heights during favorable wind conditions; maintaining a safe distance from sensitive receptor sites; and planting vegetation screens around the golf course boundary.

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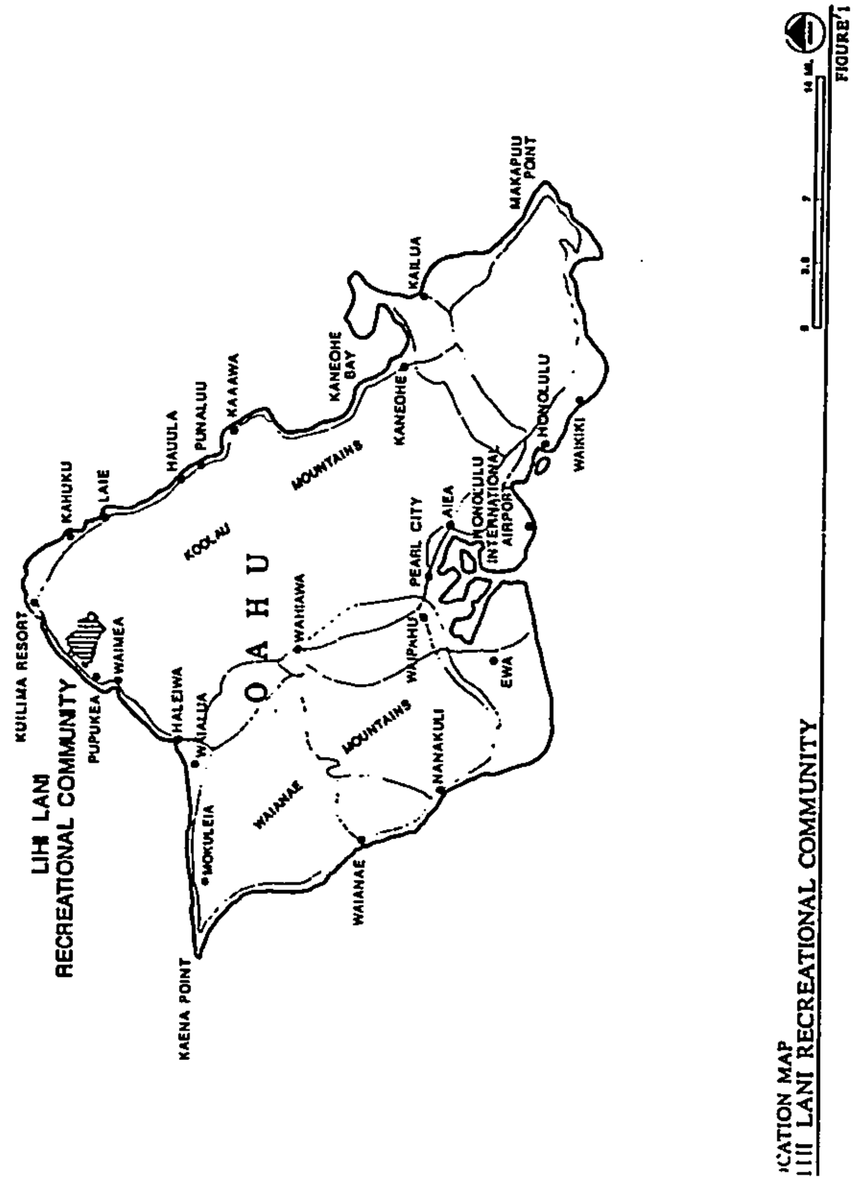

Table 1

SUMMARY OF STATE OF HAWAII AND NATIONAL AMBIENT AIR QUALITY STANDARDS

Pollutant	Units	Averaging Time	Maximum Allowable Concentration: National Primary	National Secondary	State of Hawaii
Suspended Particulate Matter	$\mu g/m^3$	Annual	-	-	60[a]
		24 Hours	-	-	150[b]
Particulate Matter[c]	$\mu g/m^3$	Annual	50	50	-
		24 Hours	150[b]	150[b]	-
Sulfur Dioxide	$\mu g/m^3$	Annual	80	-	80
		24 Hours	365[b]	-	365[b]
		3 Hours	-	1300[b]	1300[b]
Nitrogen Dioxide	$\mu g/m^3$	Annual	100	100	70
Carbon Monoxide	mg/m^3	8 Hours	10[b]	-	5[b]
		1 Hour	40[b]	-	10[b]
Ozone	$\mu g/m^3$	1 Hour	235[b]	235[b]	100[b]
Lead	$\mu g/m^3$	Calendar Quarter	1.5	1.5	1.5

[a]Geometric mean

[b]Not to be exceeded more than once per year

[c]Particles less than or equal to 10 microns aerodynamic diameter

Table 2

AIR POLLUTION EMISSIONS INVENTORY FOR CITY AND COUNTY OF HONOLULU, 1980

Source Category	Emissions (tons/year) Partic-ulate	Sulfur Oxides	Nitrogen Oxides	Carbon Monoxide	Hydro-carbons
Steam Electric Power Plants	2,092	36,736	12,455	1,065	184
Gas Utilities	14	0	199	0	0
Fuel Combustion in Agricultural Industry	1,088	579	358	0	31
Refinery Industry	622	7,096	2,149	266	2,584
Petroleum Storage	0	0	0	0	1,261
Metallurgical Industries	28	96	40	0	0
Mineral Products Industry	6,884	1,883	597	0	31
Municipal Incineration	42	145	2,029	0	184
Motor Vehicles	1,413	1,014	17,270	239,198	22,853
Construction, Farm and Industrial Vehicles	184	193	2,507	3,729	338
Aircraft	382	145	1,751	5,594	1,476
Vessels	42	386	438	533	123
Agricultural Field Burning	1,399	0	0	15,982	1,692
Total:	14,190	48,273	39,793	266,367	30,757

Source: State of Hawaii, Department of Health

Table 3

ANNUAL SUMMARIES OF AIR QUALITY MEASUREMENTS AT WAIMANALO MONITORING STATION

Parameter	1985	1986	1987	1988	1989
Particulate					
No. of 24-Hr Samples	57	59	54	60	56
Range of 24-Hr Values (µg/m3)	13-52	10-72	13-45	16-82	10-57
Average Daily Value (µg/m3)	26	28	25	29	20
No. of State AAQS Exceedances	0	0	0	0	0

Source: State of Hawaii Department of Health

Table 4

ESTIMATED WORST-CASE 1-HOUR CARBON MONOXIDE CONCENTRATIONS ALONG ROADWAYS NEAR LIHI LANI RECREATIONAL COMMUNITY PROJECT
(milligrams per cubic meter)

Roadway Intersection	Year/Scenario					
	1991/ Present		1997/ Without Project		1997/ With Project	
	AM	PM	AM	PM	AM	PM
Weekday:						
Kamehameha Highway at Pupukea Road	4.1	3.2	4.7	3.0	7.2	3.8
Kamehameha Highway at Sunset School	4.4	2.0	6.3	1.8	8.6	2.1
Kamehameha Highway at Project Access Road	1.5[a]	1.0[a]	1.8[a]	1.3[a]	3.4[b]	9.9[b]
Weekend:						
Kamehameha Highway at Pupukea Road	-	3.2	-	4.1	-	4.8
Kamehameha Highway at Sunset School	-	1.3	-	1.4	-	1.5
Kamehameha Highway at Project Access Road	-	1.3[a]	-	1.4[a]	-	13.2[b]

Hawaii State AAQS: 10
National AAQS: 40

[a]Assumes through traffic only on Kamehameha Highway.

[b]Assumes left turn lane provided both on Kamehameha Highway and on Project Access Road and speed limit on Kamehameha Highway reduced to 35 mph.

Table 5

ESTIMATED WORST-CASE 8-HOUR CARBON MONOXIDE CONCENTRATIONS ALONG ROADWAYS NEAR LIHI LANI RECREATIONAL COMMUNITY PROJECT
(milligrams per cubic meter)

Roadway Intersection	Year/Scenario		
	1991/ Present	1997/ Without Project	1997/ With Project
Weekday:			
Kamehameha Highway at Pupukea Road	2.0	2.4	3.6
Kamehameha Highway at Sunset School	2.2	3.2	4.3
Kamehameha Highway at Project Access Road	0.8[a]	0.9[a]	5.0[b]
Weekend:			
Kamehameha Highway at Pupukea Road	1.6	2.0	2.4
Kamehameha Highway at Sunset School	0.6	0.7	0.8
Kamehameha Highway at Project Access Road	0.6[a]	0.7[a]	6.6[b]

Hawaii State AAQS: 5
National AAQS: 10

[a]Assumes through traffic only on Kamehameha Highway.

[b]Assumes left turn lane provided both on Kamehameha Highway and on Project Access Road and speed limit on Kamehameha Highway reduced to 35 mph.

Table 6

ESTIMATED INDIRECT AIR POLLUTION EMISSIONS FROM LIHI LANI RECREATIONAL COMMUNITY PROJECT ELECTRICAL DEMAND[a]

Air Pollutant	Emission Rate (tons/year)
Particulate	<1
Sulfur Dioxide	10
Carbon Monoxide	<1
Volatile Organics	<1
Nitrogen Oxides	3

[a]Based on U.S. EPA emission factors for industrial boilers [5]. Assumes electrical demand of 4 million kw-hrs per year and low sulfur oil used to generate power.

Table 7

UNCONTROLLED AIR POLLUTION EMISSION FACTORS FOR MUNICIPAL REFUSE INCINERATORS (lb/ton)[a]

Air Pollutant	Emission Factor
Particulate	14[b]
Sulfur Oxides	2.5
Carbon Monoxide	35
Organics	1.5
Nitrogen Oxides	3

[a]Emission factors are given in terms of weight of material emitted per unit weight of refuse material charged.

[b]Assumes incinerator equipped with settling chamber and water spray.

Source: U.S. Environmental Protection Agency [5]

APPENDIX R

LANDSCAPE DESIGN CONCEPTS

FOR THE

PROPOSED ACCESS ROAD TO THE
PUPUKEA RECREATIONAL COMMUNITY

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July 12, 1988

INTRODUCTION

Landscape design concepts are presented below for the proposed access road to the Pupukea Recreational Community, planned for 1,130 acres in Pupukea on the north shore of Oahu. The access road will enter the property from Kamehameha Highway (elevation 25 ft. above mean sea level) and extend across a bluff to the upper elevations of the property (approximately 450 to 700 ft. above sea level).

The following text and graphics have been prepared to describe the existing visual setting along the bluff, including vegetation characteristics, and to detail the proposed modifications to the bluff to accommodate the access road. To mitigate the changes in views of the bluff caused by the access road construction, extensive landscape contouring and plantings are proposed which will effectively blend the access road into the existing visual setting. This report summarizes the various landscape measures planned to mitigate the visual impacts of the access road development.

0005U

I. EXISTING CONDITIONS

A. Exhibit L-1 illustrates the predominant natural vegetation typical of the Pupukea area, as it relates to topography. Classification of the major vegetation types is as follows:

Elevation	Land Form	Vegetation
100' - 200'	Bluff base	Kiawe (Prosopis pallida)
		Christmas Berry (Schinus terebinthifolius)
200' - 300'	Bluff face	Chinese Banyan (Ficus retusa)
300' - 400'+	Ridge line	Ironwood (Casuarina equisetifolia)

B. Exhibit L-2 indicates the general vegetation patterns existing within the area of the proposed Pupukea Bluff Access Road. These vegetation types and location reflect those of the region.

The planting concept for the access roadway should recognize and respond to the existing landscape, and should be characterized as a treatment complementing the natural environment.

II. VISUAL IMPACT AND RECOMMENDATIONS

Exhibit L-2 identifies four areas of varying roadway engineering requirements. Specific road sections with landscape concepts mitigating their visual impact are illustrated in Exhibits L-3 to L-10.

A. Section 1 (Exhibit L-3 and L-4)

1. Visual Impact: This "filled" roadway portion will be elevated 25 feet above the existing grade. A retaining wall with 20 feet of exposure will be required.
2. Recommendations:
   a. Existing Christmas Berry trees not impacted by construction should be maintained. Supplementary plantings of Christmas Berry trees should be added at the base of the wall to minimize the height of the wall.
   b. Cascading vines and shrubs should be planted along the top of the wall to further reduce and soften the wall's appearance.
   c. Christmas Berry or similar trees should be planted at the bottom of the filled slope to screen the view of the road. The planting at the top of the slope should be limited to ground cover and low shrubs to allow for optimum driver visibility at the hair pin corner and to allow panoramic views of the coastline.
   d. Fill slopes should be constructed and planted using erosion control netting and ground cover.
   e. Large canopy trees should be planted upslope at the road for shade.

f. Roadway design should make provisions for keeping the large existing Banyans.

B. <u>Section</u> 2 <u>(Exhibits L-5 and L-6)</u>

1. Visual Impact: This "cut" condition will create three 15 feet high terraces along the roadway's mauka edge. Because the makai portion will be depressed 7 feet below the existing grade, this portion of the roadway will not be visible from Kamehameha Highway.

2. Recommendations:

   a. Large canopy trees should be planted along the makai edge of the road for shade. Driver visibility will not be obstructed since the road is already depressed 7 feet.

   b. Ironwood trees should be planted on terraces to augment the existing forested ridge line and mask the terrace faces above.

   c. Shade tolerant ground cover should be planted under the Ironwood trees.

C. <u>Section</u> 3 <u>(Exhibits L-7 and L-8)</u>

1. Visual Impact: This "cut" condition is similar to Section 2, but to a lesser degree, having two cut terraces with the road depressed 4 feet.

2. Recommendations:

   a. The exisiting landscape of this section of roadway is comprised of random plantings of

Banyans along the bluff face. These Banyans should be maintained to preserve this character.

   b. The cut terraces should be planted with Banyans or trees of complementary nature. Existing Banyans upslope of the road should be maintained.

   c. The open grassed slopes at the ridge line should have minimal or no proposed major planting to maintain the coastal views from the proposed driving range above.

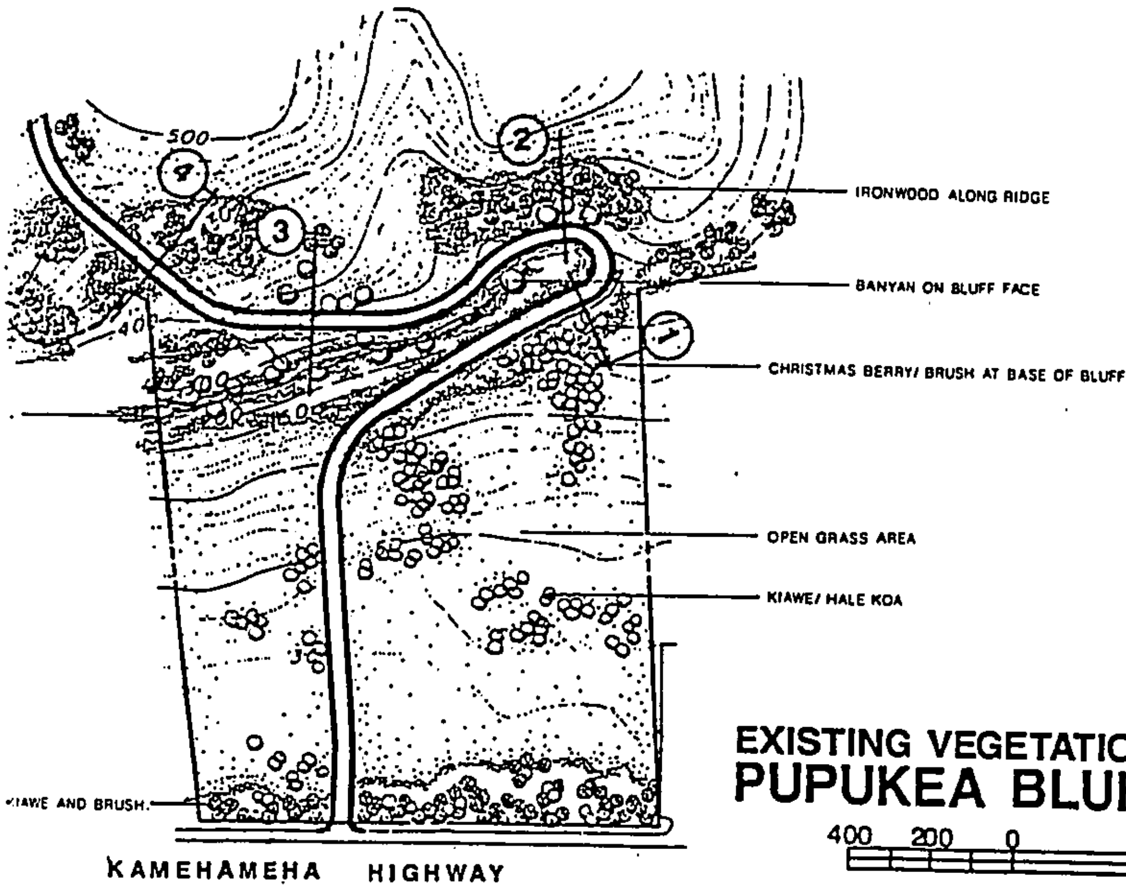
D. <u>Section</u> 4 <u>(Exhibits L-9 and L-10)</u>

1. Visual Impact: This "cut" portion will be depressed 30 feet below existing grade with three 15 feet high terraces on both sides, one along the makai side and two along the mauka side. The roadway alignment will be the most visible alignment viewed from the Sunset Beach Elementary School play fields.

2. Recommendations:

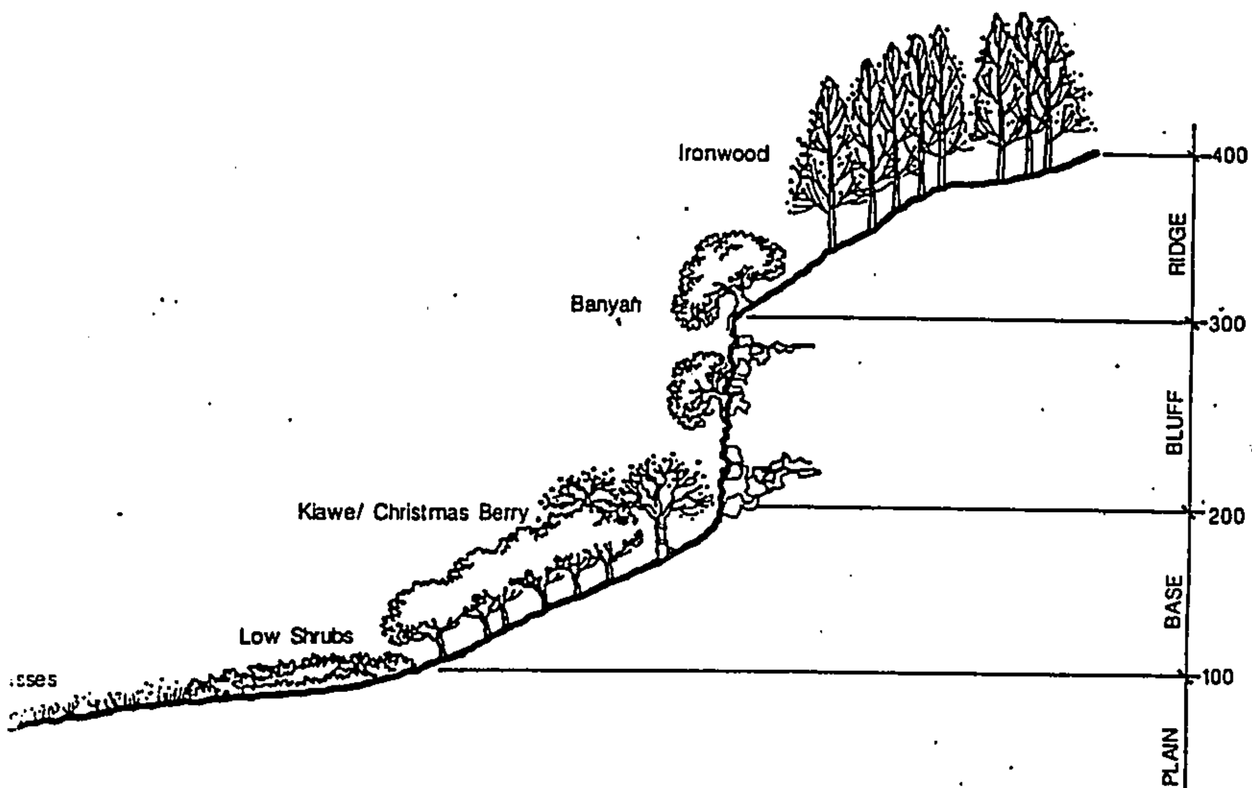
   a. The corridor of this section of road passes through an Ironwood forested ridge line. New plantings of Ironwood trees should be provided on terraces to restore and enhance the existing appearance.

b. Drought tolerant plantings compatible with a "rocky" environment, such as Sisal or Night Blooming Cereus, should be planted at the base of the first terrace face along both sides.



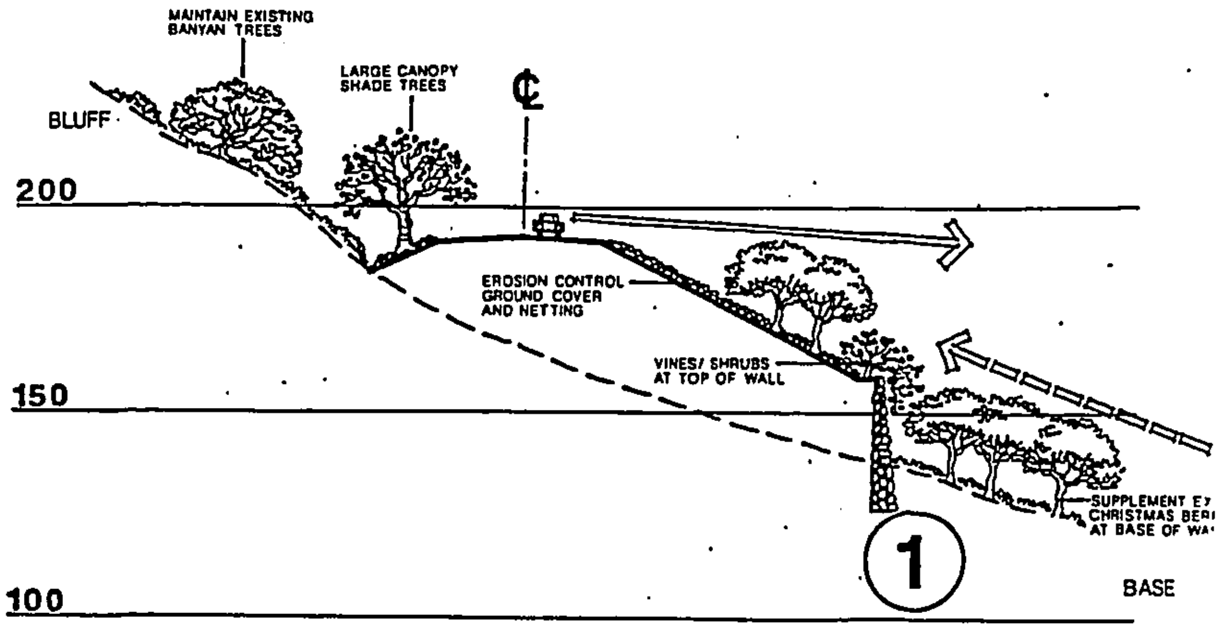
EXISTING VEGETATION
PUPUKEA BLUFF

EXHIBIT L-2



EXISTING VEGETATION SECTION
NO SCALE

EXHIBIT L-1



CONCEPTUAL LANDSCAPE TREATMENT
ALONG PUPUKEA BLUFF

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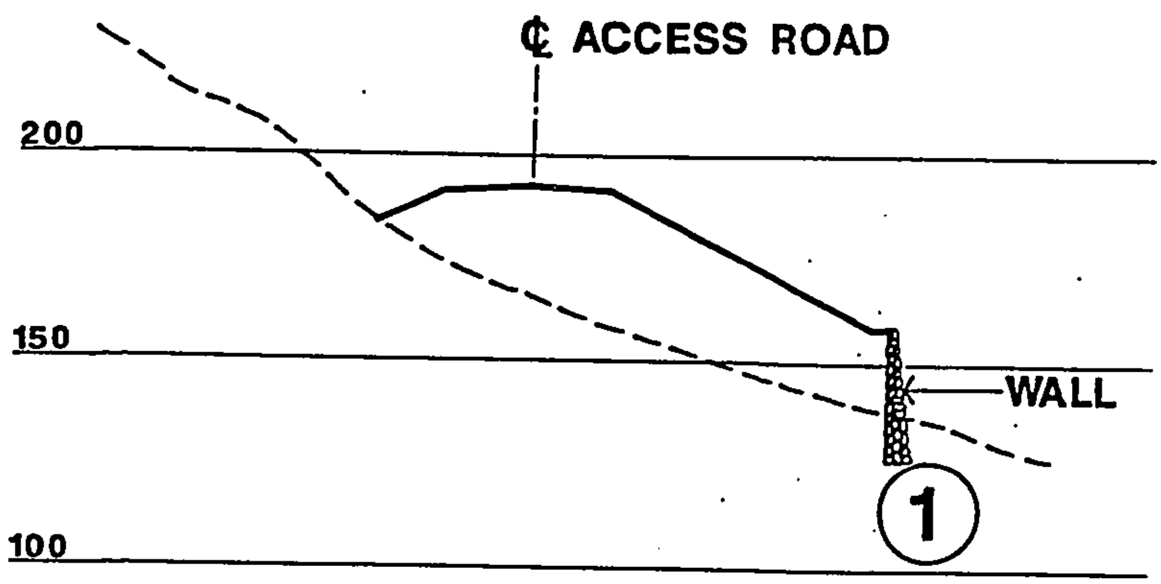
EXHIBIT L-4



ALONG PUPUKEA BLUFF

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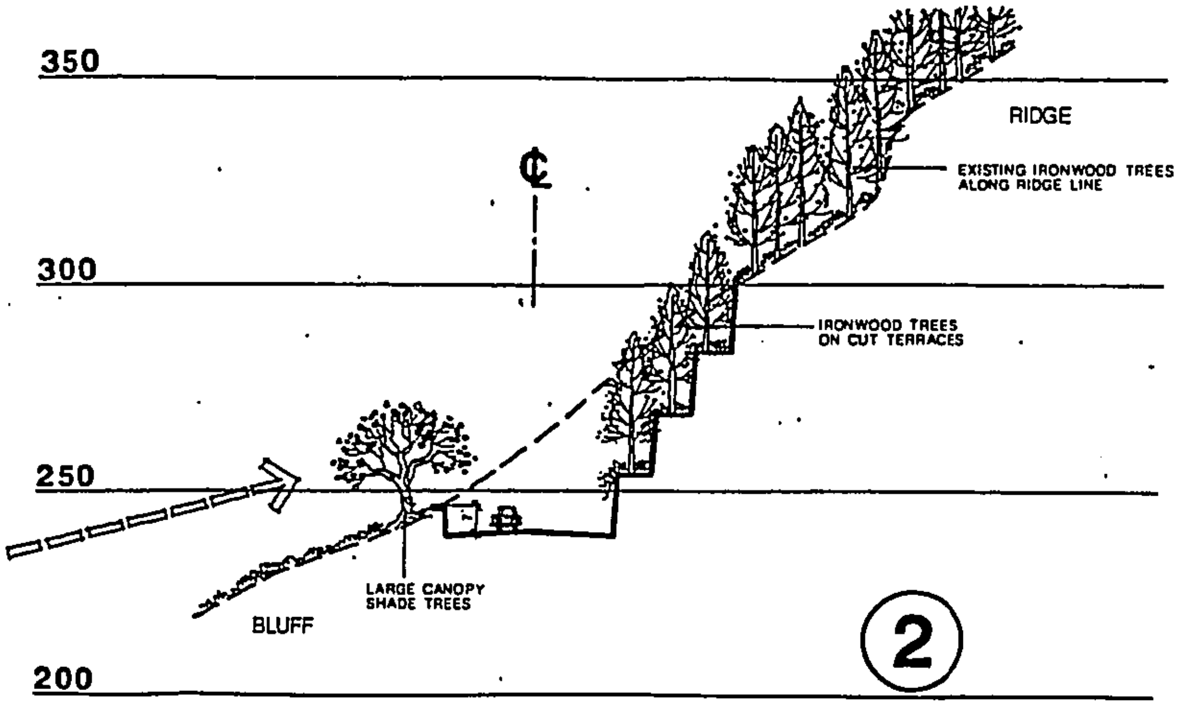
EXHIBIT L-3



CONCEPTUAL LANDSCAPE TREATMENT
ALONG PUPUKEA BLUFF

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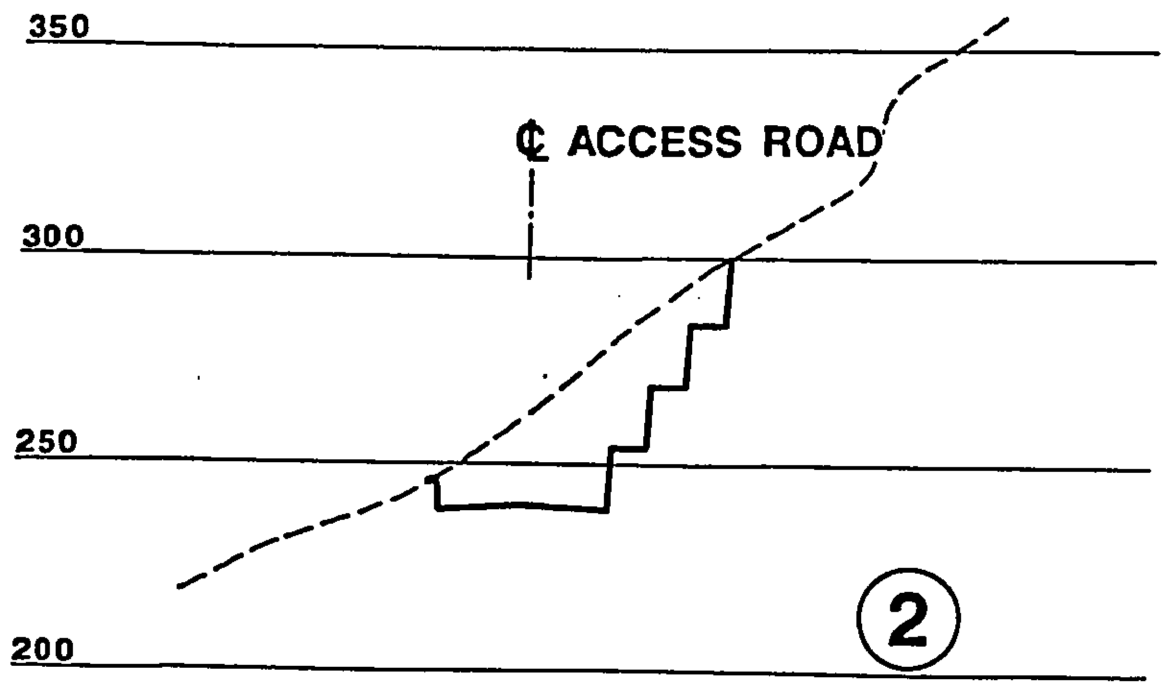

ALONG PUPUKEA BLUFF

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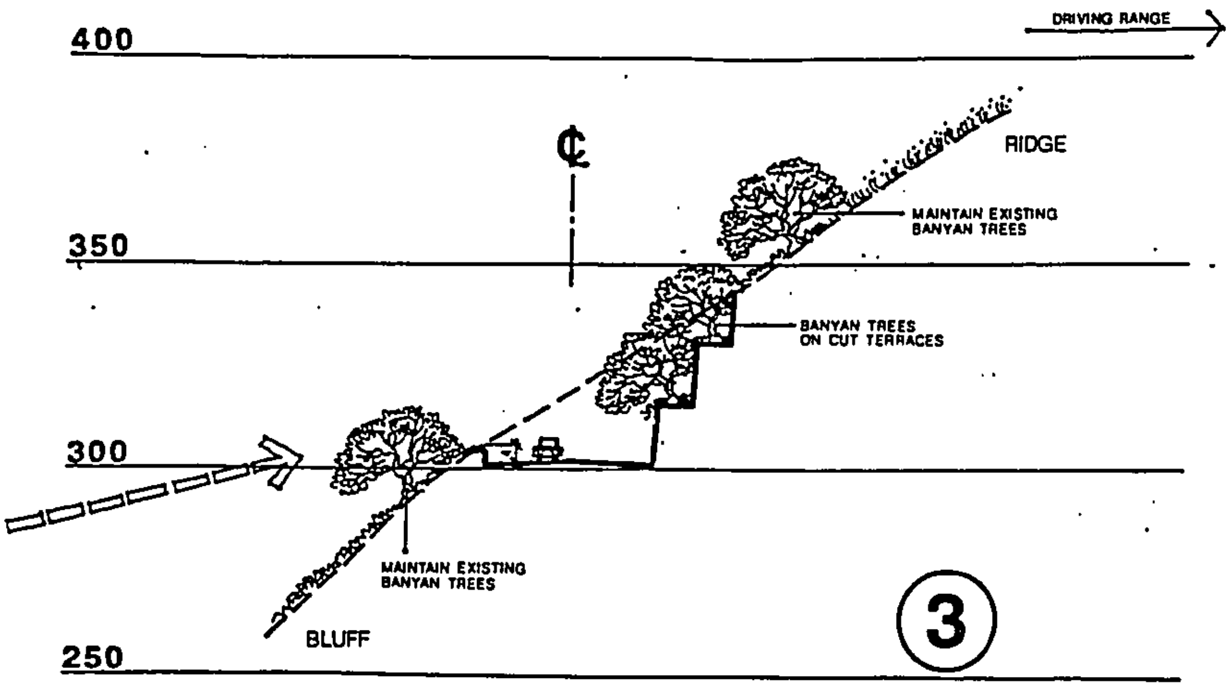

CONCEPTUAL LANDSCAPE TREATMENT

ALONG PUPUKEA BLUFF

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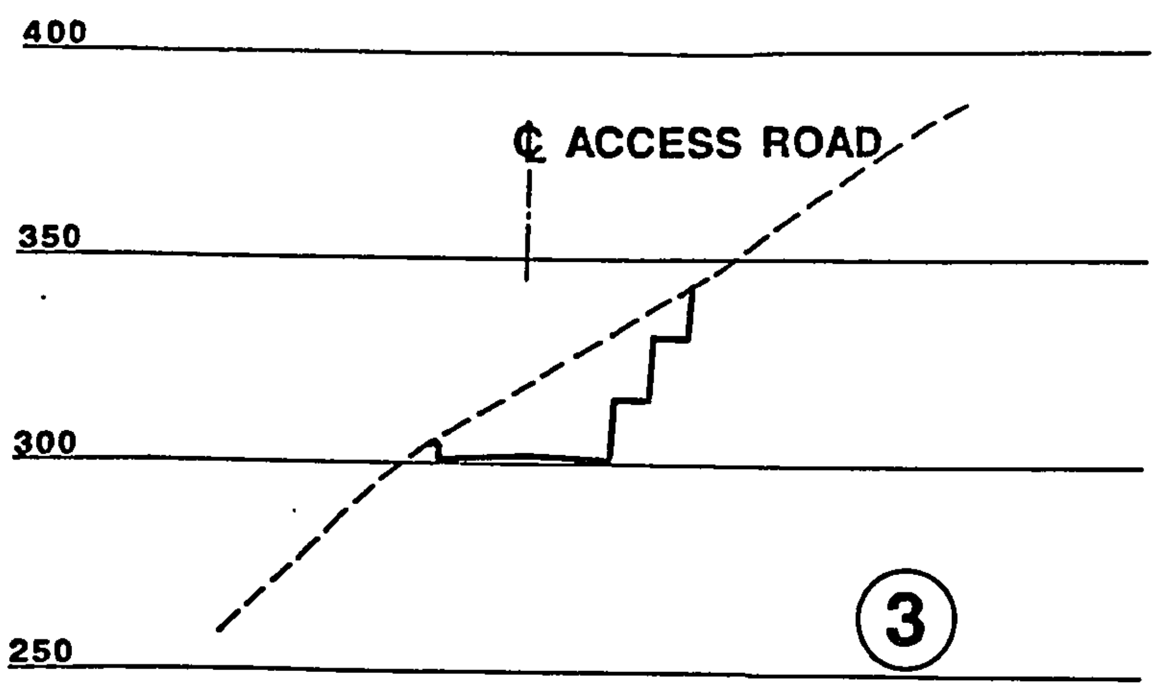

ALONG PUPUKEA BLUFF

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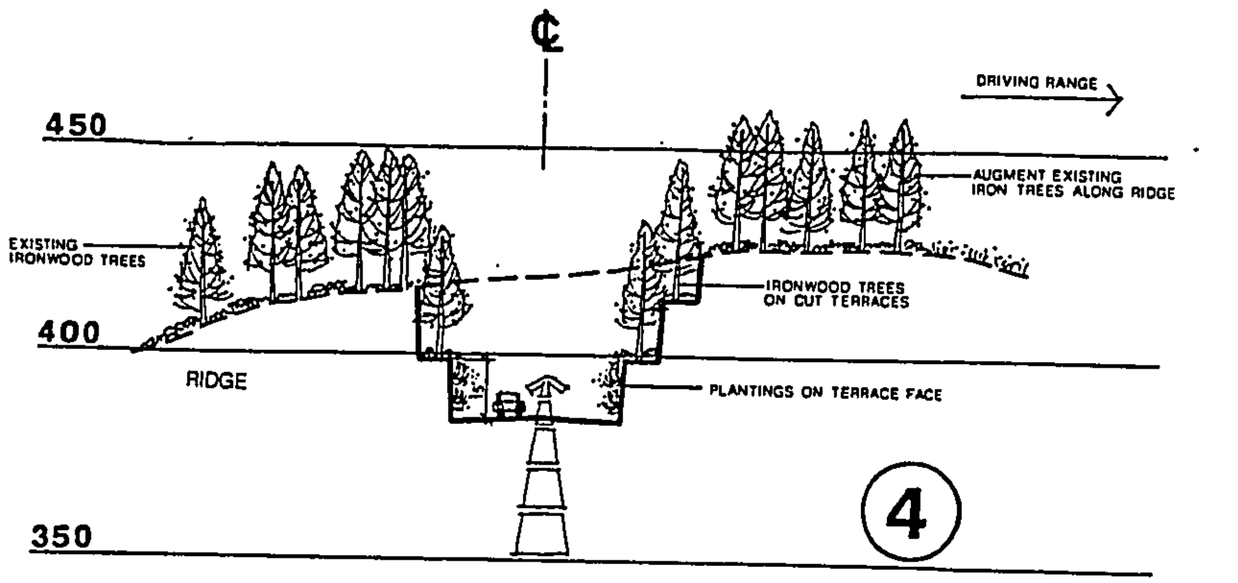

CONCEPTUAL LANDSCAPE TREATMENT
ALONG PUPUKEA BLUFF

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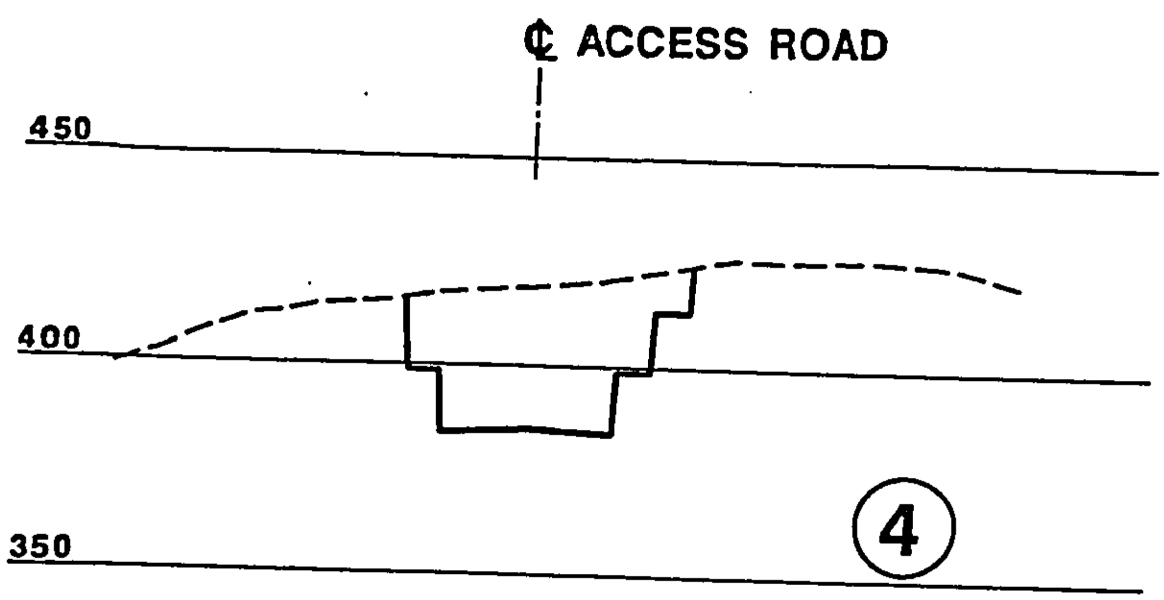

ALONG PUPUKEA BLUFF

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APPENDIX S

SOCIO-ECONOMIC IMPACT ASSESSMENT
OF THE PROPOSED
LIHI LANI RECREATIONAL COMMUNITY

January 1991

Prepared for

Obayashi Hawaii, Inc.

Prepared by

Community Resources, Inc.

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EXECUTIVE SUMMARY

Community Resources, Inc. (CRI) has prepared a Socio-Economic Assessment Impact for Obayashi Hawaii's proposed Lihi Lani Recreational Community.

Existing Conditions

The proposed project site is located on the plateau east of Pupukea Road and mauka of Kamehameha Highway's Sunset Beach section. The Primary Study Area affected by the proposed development would include the project site and the nearby communities of Pupukea, Sunset Beach, and Waimea. The total study area includes the City's North Shore Development Plan (DP) Area and the neighboring Koolauloa DP Area.

Population trends and socio-economic characteristics of the region include:

- The 1989 population of the study area stood at 26,396 persons, according to the City and County of Honolulu. The study area population has been somewhat younger than the islandwide average. In 1980, half the residents in the study area were Hawaii-born, and a third were Mainland-born. While Caucasians formed a majority of the ethnic make-up of the region in 1990, residents of Hawaiian, Filipino, and Japanese extraction were well represented. Polynesians other than Hawaiians were present in unusually high numbers compared to the rest of Oahu, especially in the Koolauloa town of Laie.
- In 1980, average study area incomes were well below the islandwide median. However, the Primary Study Area was a relatively affluent pocket within the larger region.
- Housing in the region is extremely limited. Even though prices have risen steadily over recent years, study area prices for single-family units remain less expensive than islandwide averages. A significant portion of the housing stock is rental housing held for short-term use. Household populations are generally larger than those for the rest of the island, with consequent overcrowding more frequent.
- Almost half the workforce commutes outside the study area for work. Surveys indicate that, in general, study area residents who commute further for work earn more. In 1990, high proportions of the labor force were involved in either professional or laboring jobs. The 1980 labor force participation was greater in the region than Oahu's, but unemployment was on par with the County rate.

Surveys conducted in the study area show that general community issues and concerns include:

- Maintaining a rural flavor to the region;
- The lack of roads and other infrastructure, the lack of nearby jobs, and the lack of recreational facilities;
- Availability of affordable housing;
- Worries shared with Oahu residents in general, such as education, traffic, drugs, and crime; and
- Anticipated impacts of golf courses on the environment, agriculture, and nearby communities.

Forces for Change Independent of the Project

Major developments planned for the study area are as follows:

- **Kuilima Expansion.** This project, which is ongoing, will have the most impact on the region. Current plans call for more than 3,500 new resort units, a new golf course, and a shopping village.
- **Haleiwa/Kawailoa.** Kamehameha Schools/Bishop Estate has offered a number of alternative uses for its land holdings in the study area. Some of the possible projects include housing, a dude ranch, a marine park, and a golf course.
- **Mokuleia.** Long-terms plans envision two golf courses, and a low-key lodge for golfer accommodation.

Other golf courses have been proposed for the region, at Malaekahana, Punamano, and Kaukonahua Road.

Community Issues and Concerns

There has been much dialogue between Obayashi Hawaii and study area residents since a recreational community was first proposed in 1987. Input and ideas provided by a variety of community groups -- especially the Joint Planning Committee (JPC), a group composed of concerned Primary Study Area residents and project representatives -- have considerably changed the nature of the proposal over the years.

Major areas of concern with regard to earlier plans have included:

- Environmental issues, such as possible groundwater contamination;

- Compatibility of the project with the general character of the Primary Study Area;
- Public access to the project;
- Affordable housing;
- Traffic;
- Foreign ownership;
- Employment;
- Recreational opportunities for study area residents; and
- Impacts on Sunset Beach Elementary School.

The developer has shaped the project design in the following major ways in response to community input:

- Inclusion of an affordable residential housing component;
- Extensive recreational facilities -- in addition to the golf course --including a hiking trail system, equestrian trails and stables, campgrounds, and a conservation park;
- A new wastewater management plan;
- Proposed community facilities, including a community center, a baseball/soccer field, an outdoor pavilion, a playground, a picnic and barbecue area, public parking, and a swimming pool;
- Additional community benefits, such as an education program, and a job training program; and
- Elimination of two major project components: a private 18-hole golf course and a helipad.

Socio-Economic Impacts and Mitigations

Direct project construction will result in employment at an estimated annual average of 204 person-years from 1993 to 1995, and an annual average of 79 person-years from 1996 to the year 2000. Indirect and induced employment in the State as a result of project construction would amount to an annual average of 163 person-years during the first period, and an annual average of 63 person-years during the second.

By 1995, operations on-site will provide 45 jobs. After buildout, operations will account for about 60 jobs. Indirect and induced jobs due to project operations will generate an estimated 42 statewide jobs by the year 2000.

The on-site population associated with the project at buildout will include an average of nearly 700 residents, and an average of 260 day visitors. Employees and their families are expected to account for around 60 new residents in the total study area by the year 2000. The total in-migrant population to Oahu, including new community residents and new employees, is estimated at less than 90 persons.

The project will add 300 units to the study area housing stock. However, some additional demand for housing is likely as an estimated 30 project employees and their families move into the study area. The housing impact of employee in-migration to the study area is likely to amount to between 10 and 25 housing units after buildout.

Since there are no project site residents, no displacement will occur. The present site tenant has run ranching activities for recreation and education, rather than as a commercial venture. This could continue, as the project site will include equestrian and pasture areas. Similarly, hiking and riding activities will continue, as trail facilities will be maintained.

Recreational benefits of the project include:

- 30% of golf tee times reserved for residents at reduced rates;
- A free junior golf program for study area students;
- Fund-raisers and support of local golf tournaments;
- Swimming facilities;
- Up to 30% of stable space for residents at a reduced rate;
- Support of a pa'u riding team;
- A baseball/soccer field;
- Making tennis facilities available to area residents;
- A community children's playground;
- Extra parking space for the community, and for Ehukai Beach Park patrons; and
- Dining and clubhouse facilities open to residents.

The project will have little impact on current uses of adjacent lands, since the site is separated from nearby residential areas by natural boundaries. Access to the Lihi Lani trail system will remain adequate.

Residents have expressed concern that the project's golf course will increase nearby land values and, hence, property

CONTENTS

(CONTINUED)

taxes, but Lihi Lani's course will not affect the short-term value of existing properties, since none gain either a physical improvement or clear market advantage from the course. Existing studies and assessment policy suggest that Lihi Lani will have minimal or no long-term impacts on nearby property values.

Occasional demand for police services for the de facto population of around 1,050 persons, and for large events staged at the golf course or equestrian facilities, will be mitigated by the developer's providing regular on-site security and additional private manpower during major events.

Needs for additional fire protection from the City will be mitigated by the developer's installation of water lines and storage with adequate fire fighting capacity. Buildings and on-site facilities will be designed with attention to fire safety.

The added enrollment at Sunset Beach Elementary school of students generated by the project would amount to about 20% of existing enrollment. This impact will likely necessitate additional facilities. However, the project will contribute new revenues to the State more than sufficient to cover this cost. Also, the developer intends to establish a trust fund for scholarships and other educational programs. Project residents are expected to constitute only about 3.5% of the existing enrollment at the nearest high school and intermediate school.

Economic development in the area is expected to bring: increased traffic; higher wages; new opportunities for small businesses; more tourists, and increased tourist visibility; and increased demand for housing. Many residents will likely find the character of the region to have changed, and may tend to concentrate interests in the vicinity of their respective communities where a sense of social continuity will be stronger. Lihi Lani, with its community facilities components, will likely become a focal point for its surrounding communities.

Other mitigating factors of the project include:

- Conformance with JPC guidelines, which require that the project will minimize any visual or aural intrusion, will maintain a rural atmosphere, and will respect the environment;
- Planning for low-density residential development;
- A commitment that project architecture will blend with the surrounding environment;
- A proposed community garden area and a child care facility; and
- Developer sponsorship of surf meets, golf tournaments, and community clean-up activities.

Contents (Cont.)

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Contents (Cont.)

FIGURES

TABLES

(CONTINUED)

Tables (Cont.)

1.0 INTRODUCTION

1.1 LIHI LANI RECREATIONAL COMMUNITY

Obayashi Hawaii, Inc. has owned approximately 1,143 acres of land on the North Shore of Oahu since 1974. Figure 1-1 indicates the project location. The owner developed preliminary plans for development of the property in 1988. These were presented to the community, and were changed in response to information and concerns from the community. The initial plan was withdrawn, and representatives of the owner have been working with residents of nearby areas to envision a plan that would address the needs of both existing and future residents.

The current proposed Lihi Lani development is a recreational community with several components, as shown in Figure 1-2:

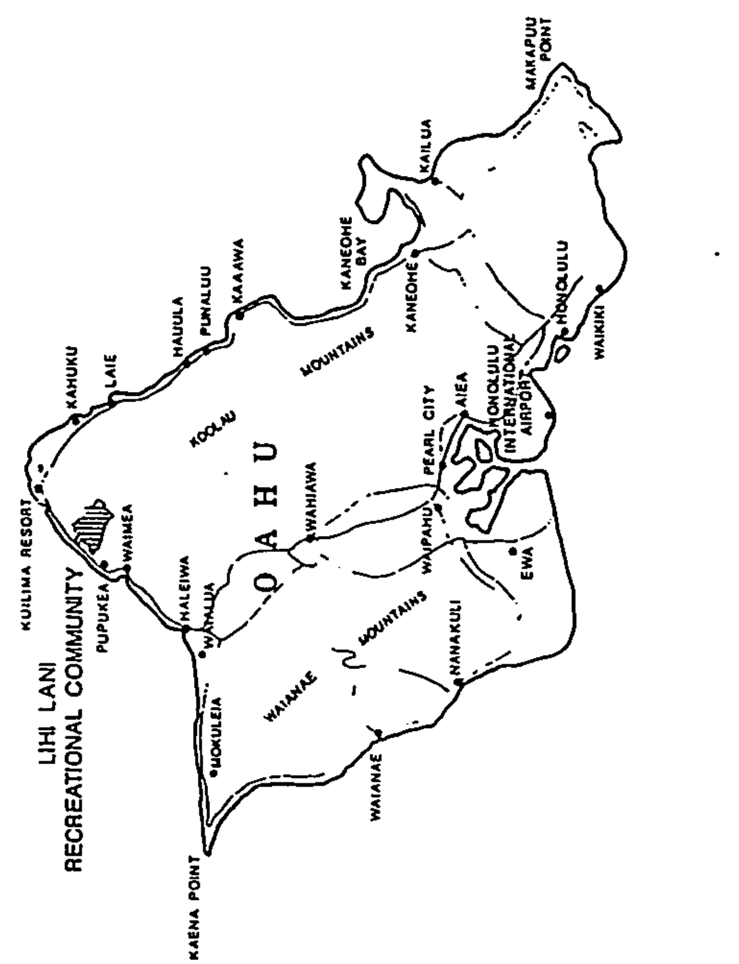
- 180 affordable housing units;
- 120 residential lots, each about an acre in size;
- An 18-hole semi-private golf course (with membership play along with tee times reserved for resident golfers at reduced rates), with a clubhouse and driving range;
- A tennis center;
- An equestrian ranch with additional areas for pasturage;
- Trails, open to the public, for riding and hiking;
- A campground intended for use by Oahu community groups; and
- An area set aside for community facilities.

The community facilities site has been identified -- it is adjacent to Sunset Beach Elementary School, and covers about 10 acres -- but the mix of facilities to be built is still under review. Possible facilities mentioned during the planning process include a field for baseball and soccer, a swimming pool, a playground, a pavilion, an area for picnics and barbecues, and parking. Obayashi Hawaii proposes to fund construction and maintenance of community facilities from golf revenues.

The project would have its own wastewater disposal system, using a series of ponds located near the center of the property.

Project construction is scheduled to begin in 1994. The affordable housing units, golf course, ranch, tennis center, and community facilities are expected to be open by 1997. Market residential lots would likely be developed over the next ten years, depending on lot absorption and buyers' schedules.

FIGURE 1-1: LOCATION MAP



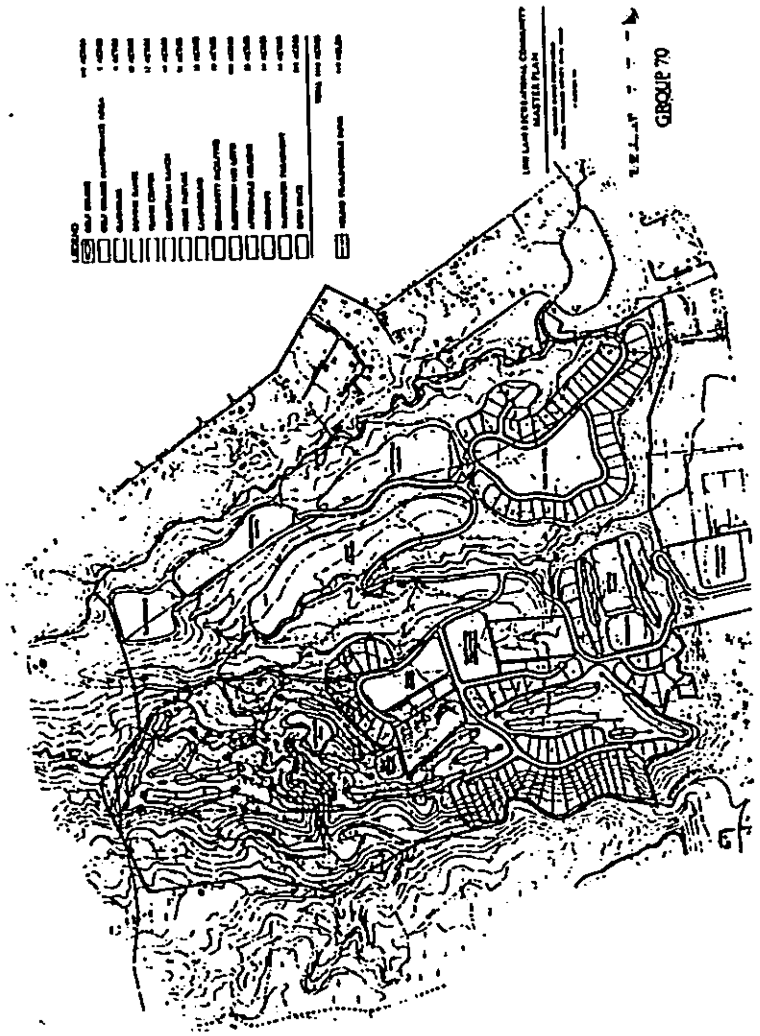


FIGURE 1-2: MASTER PLAN

1.2 PURPOSE AND SCOPE OF THIS REPORT

This report provides an independent consultant's assessment of the socio-economic impacts of the proposed Lihi Lani project. It has been prepared for Obayashi Hawaii, Inc., for eventual inclusion in the project Environmental Impact Statement being prepared by Group 70 Limited.

Social impact assessments are made in order to identify and disclose information of use to decision-makers and to the general public, as they consider the potential implications of future developments.

Impacts of a project are assessed in comparison to the situation that will exist at the time the project is expected to be built and operating. Hence those impacts are judged in relation to probable future conditions in the surrounding area, not just in relation to the situation existing at the time of writing. The project would be largely built by 1997, according to current plans, so current conditions and expected near-term developments form much of the context for assessment. The project will be built out in the decade after 1997, and it is expected to operate long after that period, so growth projections for the longer term are also considered in this report.

This report has five major sections:

- This section contains introductory material;
- The second section deals with existing conditions in the region surrounding the project site;
- The third section includes information about future conditions likely in the region;
- The fourth section identifies community issues and concerns with regard to the project, drawing on information about the community interaction process since 1988;
- The fifth section provides an assessment of anticipated social impacts and identifies community benefits and measures that could be taken, if appropriate, to mitigate anticipated adverse social impacts.

A separate description of economic and fiscal impacts of the project is being made by KPMG Peat Marwick. This report follows the quantitative analysis of project impacts contained in the Peat Marwick study, but goes on to deal with the more general social impacts of the employment, population, and housing effects of the project.

2.0 EXISTING CONDITIONS

This section reviews the existing socio-economic situation in the region surrounding the Lihi Lani site. It includes:

- A definition of the study area;
- An overview of the communities in the study area;
- More detailed information on socio-economic conditions (population and demographic trends, family and income data, housing conditions, and the economy);
- An account of study area lifestyles and values; and
- A review of major issues and concerns independent of the project expressed by residents of the region.

2.1 DEFINITION OF THE STUDY AREA

For the purpose of social impact analysis, two study areas have been designated:

- **The Primary Study Area** consists of the Sunset Beach/Pupukea/Waimea area immediately surrounding the project site. The part of this area which is now populated is identified by the United States Census as Tract 101, Block Group 2. (Figure 2-1 shows the Primary Study Area.)

- **The Secondary Study Area** consists of the rest of the North Shore/Koolaualoa region (Census Tracts 99.01, 99.02, 100, 101, 102.01, and 102.02). It extends from Kaena Point to Kaaawa.

  The boundary between the North Shore and Koolauloa sub-regions is situated differently by the State of Hawaii (and, along with the State, the U.S. Census), and the City and County of Honolulu. The State's Waialua District does not include the Primary Study Area, which is within the Koolauloa District. The City's North Shore Development Plan Area includes the Primary Study Area. The City's Koolauloa Development Plan Area includes the Kuilima area but not the Primary Study Area (as shown in Figure 2-2).

In this report, reference will be made to the "study area," "total study area," or the "North Shore region" -- meaning the Primary and Secondary Study Areas taken together.

This assessment focuses on the total study area. At times, the City and County of Honolulu will also be discussed to provide

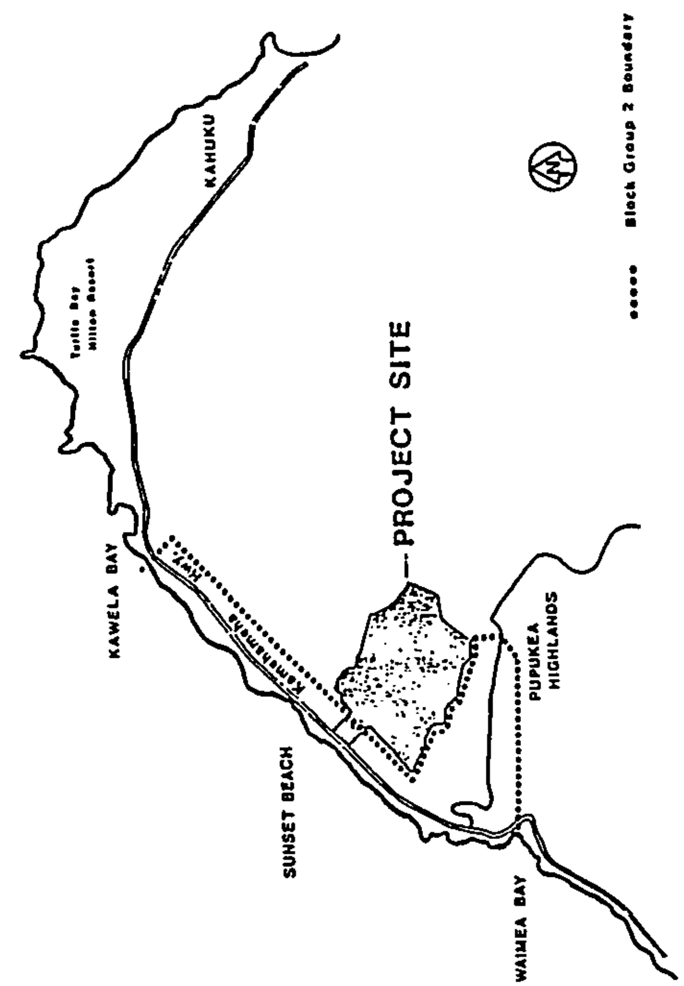


FIGURE 2-1: PRIMARY STUDY AREA

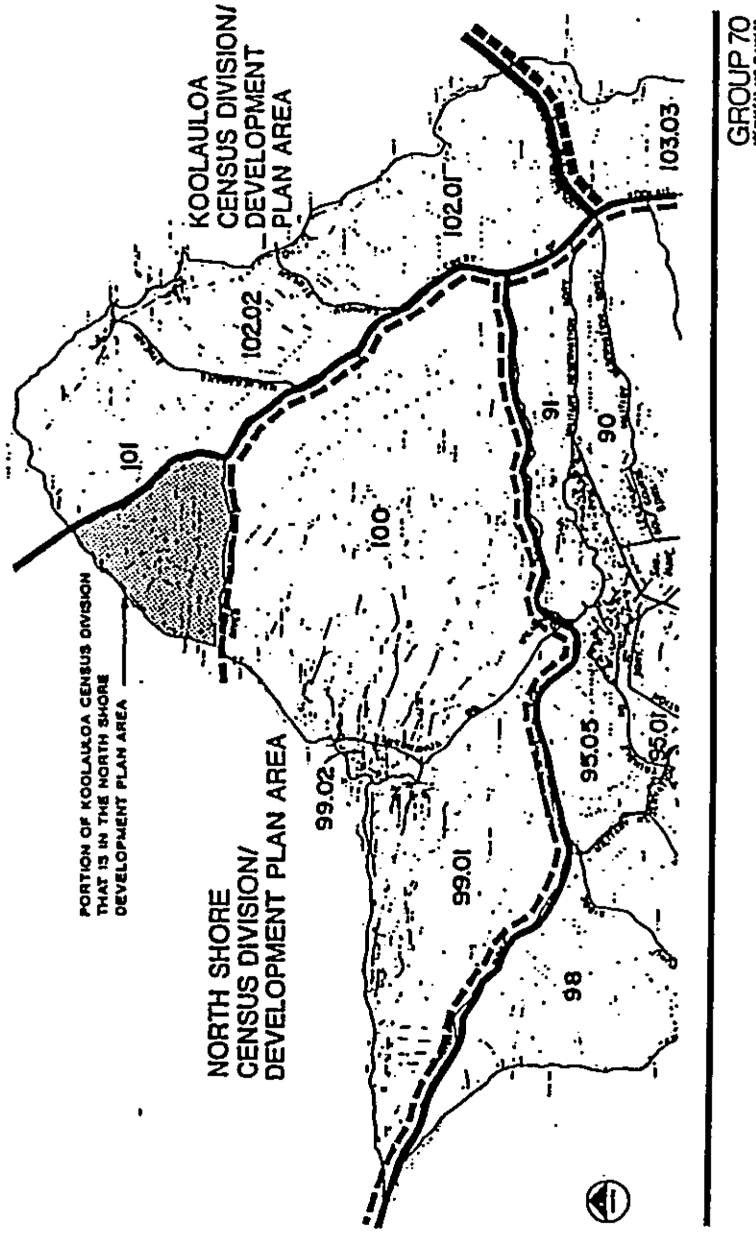


FIGURE 2-2: STUDY AREA CENSUS DIVISIONS VS. DEVELOPMENT PLAN AREAS

a general context in which information about the study area is analyzed. Also, viewpoints of study area residents are informed by debates at the City and State levels. Hence islandwide issues are reviewed at the end of this section.

2.2 OVERVIEW OF STUDY AREA COMMUNITIES

The study area contains several communities differing in size, density, and characteristics. This sub-section provides general descriptions of those communities and, as appropriate, geographic and historical data shaping them.

2.2.1 Primary Study Area

The Primary Study Area includes three distinctive zones. Along the coast, the magnificent waves of the area attract surfers, including many who rent housing for a short term.. Along Kamehameha Highway are also located the area's retail establishments. Much of the Pupukea Highlands is devoted to homes on large lots. The residents mostly commute to work elsewhere. Waimea Valley was once a center of habitation, but the valley is now an attraction for fee-paying visitors.

Sunset Beach. The Sunset Beach residential area -- a strip of homes along and mostly below the Kamehameha Highway -- begins about a mile southeast of Kuilima Resort. It continues for approximately three miles. The southerly portion of this strip is also known as "Waimea," and the hills above Waimea contain the rural one-acre lots comprising the Pupukea Highlands.

The Pupukea-Paumalu Beach Tract was subdivided and sold in 1919-20. It became known as the Sunset Tract since the sunsets were spectacular. Since then, the shore and the entire area along the coast have become known as Sunset Beach (Clark, 1977). Sunset Beach lots were first bought mainly as vacation or weekend homes by Honolulu residents.

The area became known to a few surfers in the 1950's, although it was not as prominent as Makaha. Today, the Banzai Pipeline and Waimea Bay, within two miles of the project site, are among the most famous surfing areas in the world. In December, surf meets involving international competitors are held at Ehukai Beach Park.

Oceanfront homes in the Sunset/Waimea area are often large and comfortable, although few are true mansions or estates. Houses closer to the highway are more modest, generally set on 5,000-square-foot lots. Many become surfer rentals during the winter.

The area is heavily Caucasian and strongly ocean-oriented in lifestyle. Many community leaders are former young surfers (now somewhat older surfers) who chose to settle and work in the area. However, given the lack of nearby professional jobs, the more affluent are either retired or willing to commute long distances to Honolulu.

Thus, values and lifestyles in this semi-"country" area are often characterized by a self-sufficient, pioneer ethic. The Sunset Beach community has historically been reluctant to support new growth in the area.

Pupukea is a more "local" and truly rural community set in the hills, with a number of small nursery and truck farms. The adjacent Sunset Hills subdivision is more affluent, containing several large cliffside homes with spectacular ocean views. Both communities recently activated their own community associations; prior to this, residents were either uninvolved or participated in community events through the Sunset Beach Community Association.

Early in this century, a large avocado farm was located in the Pupukea Highlands. The produce was hauled by wagon down to the railroad line, which had a stop near the present base of Pupukea Road. Libby, McNeil & Libby acquired the farm in 1912 and grew pineapples there. Pupukea pineapples were thought by some to be Oahu's best (Clark, 1977, pp. 124-25).

Pineapple cultivation was succeeded by ranching activities and, for a time, outdoor recreation -- polo and the shooting of game birds. Much of the Pupukea Highlands was divided into agricultural lots, and then sold between 1957 and 1965.

Waimea Bay was visited by the early British explorers Cook and Vancouver. Waimea had a large Hawaiian population until 1894, when many residents left the valley after a disastrous flood. Until then, the Waimea River had flowed into the ocean. The flood deposited silt that blocked the river, creating a barrier beach. Quarrying was carried on in Waimea while Kamehameha Highway was extended through the Primary Study Area in the early 1930's. Sand was removed from the beach until 1962 (Clark, 1977). The valley is now occupied by Waimea Falls Park, a commercial botanical and cultural attraction, while the entire beach area south of the Waimea River is now a beach park.

The project site is uninhabited. It consists of plateaus and gullies with a mixture of tree cover, scrub and grass. On the lowland parcel, cows are sometimes grazed. Attempts have been made to grow alfalfa and truck crops on the low-lying portion of the project site. A few horses and cattle are pastured on parts of the upland project area.

Some neighbors ride on or across the project site. Campers at the nearby Boy Scout camp have also hiked on-site.

While parts of the project site belonged to the Hawaiian Avocado Company and the Hawaiian Pineapple Company until the 1950's, no record shows the land being cultivated commercially for the last few decades. Conversations with area residents (by Agricultural Economist Frank S. Scott, Jr. and by members of the Community Resources, Inc. staff) have not yielded any account of economically viable agriculture on the land in the memory of adults living nearby.

The present owner acquired the project site in 1974. The site was then leased to a person conducting ranching operations. That lessee continues to pasture cattle and horses on the site. The ranching operation involves both cattle and horses in small numbers. It is not an intensive commercial use of the site. All livestock will be concentrated by early 1991 on the makai section of the property, because Ohbayashi Hawaii intends to start test plantings on the upland section.

The project site is shown on the 1967 Detailed Land Use Map (under Ordinance 2951 of March 16, 1967) as a mixture of Agricultural and Preservation land. (The plateaus are marked as Agricultural, while the more eroded areas are treated as Preservation land.) By 1970, the zoning of the site had been converted to Agricultural-1 (Zoning Map of June, 1970, under Ordinance 3234). The 1984 Zoning Map similarly shows the area as Agricultural. Under Ordinance 86-119 (October 22, 1986), the zoning of the project site was established as Agricultural-2. That zoning continues in force at present.

2.2.2 <u>The Rest of the North Shore Development Plan Area</u>

The City and County's North Shore Development Plan area begins about two miles to the west of the Kuilima Resort area and extends southwest to Haleiwa/Waialua, where the coast runs due west to Kaena Point. Much of the area is a coastal strip. The plain becomes wider west of the Sunset Beach area, and extends inland near Haleiwa. Fields planted in sugar and, at higher elevations, pineapple extend on both sides of Kamehameha Highway as it rises towards Wahiawa.

The North Shore's population is more spread out than is that of Koolauloa. Homes are found along the length of Kamehameha Highway, and, outside of Haleiwa/Waialua, retail centers consist of little more than a store or two. Haleiwa has become a center for surfers and visitors, and offers shopping for residents of the region as well as travellers. Waialua is the center of Waialua plantation, and is home to many of its employees. The plantation still operates, although its future is uncertain. Beyond Waialua is the beach area of Mokuleia, with scattered residences and second homes for Honolulu residents.

The North Shore's largest centralized communities (Haleiwa and Waialua) are about ten miles from the Kuilima Resort, and the North Shore areas nearest the Resort (Sunset Beach and environs) have more of a "country" character.

The North Shore has no visitor condominiums and only a few registered visitor units. (The Kuilima Resort is in Koolauloa.) Still, tourists are present in large numbers. An estimated 500,000 tourists visited the North Shore in 1989, of whom about 20% were Japanese (SMS Management Consulting, 1990). Most visitors pass through the region on circle island tours.

Additionally, the entire North Shore is heavily affected by an international surfing subculture (as well as other ocean sports such as windsurfing and diving). Each winter, hundreds and perhaps thousands of young people from around the nation and the world take temporary rentals in order to sample the North Shore's famed high surf. Consequently, there is a strong youth orientation -- and higher visibility of Mainlanders -- in this area than in much of Koolauloa.

North Shore communities to the south and west of the Primary Study Area are:

Kawailoa, a beachfront and highway residential strip, located just south of Sunset/Waimea (but separated by Waimea Bay). It is similar in character, lifestyle, and values to the other surfing-oriented communities, although it has fewer large houses and a slightly more "local" population.

Haleiwa is the North Shore's commercial, retail, and arts/crafts center. It has been experiencing rapid growth. The relatively small residential community, scattered in pockets in and around the town, is comprised of both established and transient residents.

Haleiwa was once the site of a major stop on the Oahu Railroad. The Haleiwa Hotel closed in 1928, and is now long gone. Still, residents are proud of the town's historic nature and lobbied for the Haleiwa Scenic District Design Ordinance to protect the area's character by controlling architectural design and signage.

The town's population has been estimated as growing from 2,620 in 1980 to 2,868 in 1989 (SMS Management Consulting, 1990). Household incomes are estimated as growing to a median of $30,300 in 1989. While this figure is in line with the estimate for the entire North Shore District, the rate of growth is high, and the median is higher than that of the Mililani/Wahiawa area of Central Oahu.

Waialua is Oahu's last functioning plantation town. The predominantly Filipino community leads a traditional Hawaii plantation lifestyle, in which the ILWU is a dominant political and social factor. Although the plantation's

owners have said they will keep it operating for the near future, uncertainties about the future mark community attitudes.

Mokuleia includes beach homes, many of which are occupied only part-time. It is the site of Dillingham Airfield, a military beach, and a field used for polo matches. These attract visitors from other parts of Oahu. The land between the end of the road and Kaena Point is used by motorcycle riders. Fishermen, hikers, and picnickers also visit the area. Part of Mokuleia Ranch is still a working ranch. Most of the Ranch's land is now little used, and slated for development by the owner (as discussed in Section 3).

2.2.3 The Koolauloa Development Plan Area

The Koolauloa area consists mainly of a strip of land bounded by mountains and the sea. A series of residential communities -- Kaaawa, Kahana, Punaluu, Hauula, Laie, and Kahuku --are spaced out along Kamehameha Highway, the region's single major roadway. Hauula, Laie, and Kahuku are the major population centers. Valleys are not densely populated. At the northern tip of Oahu, the coastal region becomes a broader plain, between Kuilima and Laie.

Earlier in this century, much land was planted in sugar. Sugar production in Koolauloa ended, however, in 1971. Major sources of employment and revenue now include tourism, aquaculture, and specialized agriculture. Major employers are the Kuilima Resort outside Kahuku and the Polynesian Cultural Center in Laie.

The Koolauloa labor force largely works within the region, unlike workers living in other rural areas of Oahu (Honolulu Department of General Planning, 1988, vol. I). (Employment is discussed further in Section 2.3.)

From north to south, Koolauloa population centers are:

The Kuilima Resort opened in 1972. It was originally developed as a joint venture by Prudential Insurance and the Del E. Webb Corporation. Prudential bought out its partner in 1976, and found a professional hotel operator -- the Hyatt Corporation, and subsequently Hilton Hotels -- to run the hotel. Prudential's interest was acquired in 1988 by Asahi Jyuken, which continues to retain Hilton as operator of the hotel now known as the Turtle Bay Hilton. The Hilton currently offers 486 hotel and cabana units.

The facilities at Kuilima also include two low-rise condominium complexes, a golf course and clubhouse, a riding stable, and tennis courts.

The mix of users and occupants in the condominiums has varied over time. In early 1989, property managers estimated that about 60% of the units are held by full-time owner-occupants, with the great majority being in the rental pool and/or held for part-time use by owners. Some rentals are to long-term residents -- primarily hotel mid-management personnel and professionals willing to commute to town.

For full-time and many part-time occupants, golf represents a central aspect of shared lifestyle.

Prudential developed plans for expansion of the Kuilima Resort in the late 1970's. Land use permits for expansion have been granted, and work has begun on the first phase. (See Section 3 for discussion of the expansion timetable.)

Bordering the Kuilima resort on the western side of Kawela Bay are approximately 26 units owned in fee simple (although many are now rented out).

Kahuku's history and social organization are particularly rooted in sugar. While the old Kahuku Sugar Plantation covered much of northern Koolauloa and employed residents of other towns, the mill and company headquarters were in Kahuku itself. Consequently, Kahuku is the site of many area services (e.g., police station, high school, hospital, etc.), despite a relatively small current population. Additionally, residents were accustomed to supporting decisions made first by the plantation management and, later, by union leaders.

When the plantation shut down in 1971, community leaders -- aided by the Campbell Estate and, initially, the ILWU -- fought to keep the community alive. They supported the new Kuilima hotel and a series of (not always successful) commercial ventures at the old mill, which area residents view as a prized symbol of the town's origin.

Perhaps most significantly, they formed a series of housing-related organizations to provide new and/or rehabilitated housing for original plantation camp residents. To a large extent, residents instrumental in forming and running these groups in the 1970's are still the community leaders in Kahuku today. This group has historically favored economic development in the area, so long as there are assurances that such development will actually benefit Kahuku residents.

However, Kahuku's tradition of community solidarity has recently begun to change. The City's 1982 housing project, originally initiated by the Kahuku Housing Corporation, turned out to provide homes for more newcomers than longtime residents, resulting in a substantial number of new residents who do not have any ties with "old" Kahuku. There have been controversies in recent years over the relation

between the Housing Corporation and residents. New construction is now being overseen by the Kahuku Village Association.

As a plantation town, Kahuku had almost no owner-occupied housing through 1980. Rents were low, but the housing stock was old. The Kahuku Housing Corporation began construction of a planned 289 housing units in 1987, and has completed over 100 of these (personal communication, Mei Maghanoy, Manager, Kahuku Village Association, December 12, 1990).

After the Kahuku Mill closed, a group of former sugar workers organized the Kahuku Farmers Association, a cooperative that has grown watermelons, papayas, corn and other produce.

Two other economic ventures in Kahuku involve developing technologies -- wind-generated electricity and aquaculture. Mauka of Kuilima are several windmills, operated by Hawaiian Electric. (Many of the mills have been taken out of service, because one mill's blade broke earlier this year.) On the makai side of Kamehameha Highway in the Kahuku Point area, shrimp are raised in ponds.

Kahuku Mill has become the site for a local shopping center. About 30,000 square feet of space has been developed and leased (Honolulu Advertiser, October 7, 1988, p. A-25).

Laie is Koolauloa's largest community. Its 1980 population was 4,600. The ahupuaa of Laie was purchased in 1865 by the Church of Jesus Christ of the Latter Day Saints to become a central settlement for members of the church in Hawaii and elsewhere in Polynesia. The Laie Temple was dedicated in 1919. Renovations of the Temple were recently completed.

Laie is not the gathering place for all of the Pacific area's Mormons that its leaders intended a century ago. However, it is a religious and educational center, with both the Temple and Brigham Young University - Hawaii. The Polynesian Cultural Center is closely related to the University, as it provides both jobs for students and income for the school.

Laie is still largely centered around the activities of the Mormon Church (or "Church of Jesus Christ of Latter-Day Saints") -- the Temple, Polynesian Cultural Center, and Brigham Young University - Hawaii campus. A survey sponsored by the land management arm of the church (Zions Securities Corp., 1981) found that nearly 70 percent of employed residents were working within Laie itself. Residents report a variety of socio-economic differences between the predominantly Mainland-originating college faculty and the largely Polynesian rank and file Laie working class.

The Mormon Church has historically encouraged community self-sufficiency, so that Laie residents in economic trouble tend to turn to family, neighbors, or the church rather than to public welfare agencies. People from neighboring communities have tended to view Laie as "self-contained" and having little contact with other towns (Community Resources, Inc., 1989a).

However, Laie residents may be growing both more independent of the church on land/economic issues and also more involved with nearby communities. The Laie Community Association has taken the initiative in expressing its preferences to Zions Securities Corp. for future community development. Persons associated with a community-based Hawaiian activist group have expressed anger and sorrow over dealings with Zions Securities (Koolauloa Neighborhood Board minutes, November 1990). A lack of new housing in Laie itself is resulting in many Mormons taking homes in Kahuku and Hauula.

A survey for Zions Securities and the community association (Community Resources, Inc., 1987) found widespread reported crowding of existing Laie housing units. Most Laie respondents said they care more about both new jobs and affordable housing than about keeping Laie "like it is now."

Laie has a large Polynesian community, with far higher concentrations of Samoans and Tongans than elsewhere on Oahu, as well as Hawaiians. Caucasians are also numerous in the community.

Hauula is a Hawaiian Homesteads community with high poverty rates and reported shortages of affordable housing. With a 1980 population of 3,000 people, it is more of a village-style "community" than the more "country"-like Kaaawa and Punaluu areas to the south. Hauula has a small shopping center and satellite City Hall. Its residents have historically been interested in new employment opportunities.

Punaluu is a generally rural, lightly-populated area in which beachfront homes tend to be second residences for Honolulu people. However, some actual farming and aquaculture activities take place in the valley. There is one major oceanfront condominium complex, Pat's at Punaluu, and a few other scattered stores and restaurants.

Kaaawa was historically a Hawaiian agricultural area (Clark, 1977). Today, it contains few urban amenities or employment opportunities, and many residents commute to more urban Oahu areas. Beachfront homes in Kaaawa are generally larger and more elegant than homes across the highway.

2.3 SOCIO-ECONOMIC CONDITIONS

The most precise indicators of conditions in the North Shore region are U. S. Census data. No final counts from the 1990 census are now available for the study area. Data from 1980 are cited here. More recent information derives from estimates and surveys, notably the August 1990 survey of study area household heads conducted for Kuilima Resort and the Kuilima/North Shore Strategy and Planning Committee (reported in Community Resources, Inc., 1990). Results of that survey are available for particular communities as well as the entire sample. Hence it provides information about the Primary Study Area, unlike other surveys and estimates since 1980.

Survey data can be compared with Census data only with caution. Survey samples include people who could be reached when called or visited. Large households and people who are not employed -- retirees, housewives, and the unemployed -- are hence often overrepresented in surveys. Still, the 1990 Kuilima survey sample was exceptionally large -- the study area sample was five times as large as the study area sample for the 1988 Tourism Impact Core Survey (Community Resources, Inc. 1989a).

2.3.1 Population Characteristics and Trends

Population Growth. In 1989, there were 26,396 people in the study area, according to City estimates (Honolulu Department of General Planning, 1990). This estimate indicates an annual growth rate of 1.0% since 1980. Table 2-1 shows long-term trends for the study area's two Census divisions. It shows that the rate of population increase for the entire study area has been declining, but that population growth has increased in the North Shore area to the south of the Primary Study Area.

Study area population figures for non-census years are estimates, based on data such as school enrollments, electrical hookups, and building permits. The State and the City and County have produced somewhat different estimates for recent study area population, yielding different growth rates for recent years. In this report, City and County estimates are recognized as official, but the actual population level and density may well be somewhat higher.

Population growth was more rapid in the Koolauloa side of the study area. The total study area is home to 3.2% of the Oahu population, while it covers about 31% of the island's land area (Honolulu Department of General Planning, 1990).

Population Characteristics. The total study area population was somewhat younger than the island average, according to U.S. Census data (in Table 2-2). Hawaii-born residents accounted for half the population, but a third were Mainland-born in 1980. About half of the residents had lived in the same house for five

TABLE 2-1: POPULATION TRENDS, CITY AND COUNTY OF HONOLULU AND STUDY AREA

Area Population —	April 1, 1950	April 1, 1960	April 1, 1970	April 1, 1980	July 1, 1989 (State Est.)	June 1989 (City Est.)
City and County of Honolulu	353,020	500,409	630,528	762,565	841,600	841,600
Koolauloa Division	5,223	8,043	10,562	14,195	17,200	
Koolauloa DP Area				11,123		12,388
North Shore Division	7,906	8,221	9,171	9,849	11,500	
North Shore DP Area				12,921		14,008
Total Study Area	13,129	16,264	19,733	24,044	28,700	26,396

Average Annual Rate of Growth —	1950-60	1960-70	1970-80	State 1980-1989	City 1980-1989
City and County of Honolulu	3.6%	2.3%	1.9%	1.1%	1.1%
Koolauloa Division	4.4%	2.8%	3.0%	2.1%	
Koolauloa DP Area					1.2%
North Shore Division	0.4%	1.1%	0.7%	1.7%	
North Shore DP Area					0.9%
Total Study Area	2.2%	2.0%	2.0%	1.9%	1.0%

SOURCES: U.S. Bureau of the Census, 1972 and 1981a, Hawaii State Department of Business and Economic Development, 1990; City and County of Honolulu, Department of General Planning, 1990.

TABLE 2-2: POPULATION AND DEMOGRAPHIC CHARACTERISTICS, CITY AND COUNTY OF HONOLULU, AND STUDY AREA, 1980

	CITY AND COUNTY OF HONOLULU 1980	TOTAL STUDY AREA 1980	KOOLAULOA DISTRICT 1980	NORTH SHORE DISTRICT 1980	PRIMARY STUDY AREA (PUPUKEA/SUNSET BEACH/WAIMEA) 1980
TOTAL POPULATION	762,565	24,044	14,195	9,849	3,212
Ethnicity					
Caucasian	33.1%	35.3%	38.2%	31.2%	60.6%
Japanese	24.9%	11.6%	7.4%	17.7%	7.3%
Chinese	6.9%	2.3%	3.2%	1.0%	1.6%
Filipino	12.8%	17.5%	7.1%	32.4%	13.0%
Hawaiian	10.5%	18.3%	22.9%	11.6%	11.6%
Other	11.8%	15.0%	21.2%	6.0%	5.9%
Age					
Less than 5 yr.	7.9%	10.5%	11.6%	9.0%	8.5%
5 to 17 yr.	20.2%	21.7%	22.8%	20.0%	16.5%
18 to 64 yr.	64.6%	60.4%	59.3%	61.9%	68.5%
65 or more yr.	7.3%	7.4%	6.3%	9.1%	6.5%
Median age (yrs.)	28.1	25.05	23.8	26.3	27.1
Place of Birth*					
Hawaii	55.1%	52.7%	50.9%	55.2%	43.5%
Other U.S.**	30.1%	29.6%	31.4%	27.0%	46.2%
Foreign	14.8%	17.7%	17.7%	17.8%	10.3%
Residence 5 Yrs. Before*					
(people aged 5 or more)					
Same house	48.2%	47.8%	46.0%	50.4%	40.9%
Same county	25.5%	26.6%	28.3%	24.2%	28.2%
Other county	1.3%	5.9%	0.8%	2.8%	1.9%
Other state	18.4%	16.5%	14.8%	18.9%	26.7%
Other country	6.6%	8.8%	10.0%	3.7%	2.3%
Education*					
(people aged 25 or more)					
0-11 years completed	24.4%	30.2%	24.7%	37.4%	16.8%
High School grad.	35.5%	31.9%	31.9%	32.0%	32.0%
Some post H.S.	18.3%	20.0%	23.3%	15.6%	26.8%
College, 4+ yr.	21.7%	17.9%	20.1%	15.0%	24.4%

NOTES: * Figures based on 15 percent sample; numbers hence represent estimates.
** Includes persons born in U.S. territories, or born abroad or at sea to U.S. parents.
"NC": 1970 categories not comparable to 1980 ones.
"N/A": Not Available.

SOURCES: U.S. Bureau of the Census, 1980 Summary Tape Files 1-A and 3-A (1981a, 1981b).

or more years, while a quarter had lived outside Hawaii five years before.

Census data from 1980 and 1990 survey data can be reviewed together to identify distinctive characteristics of the Primary and Secondary Study Areas:

<u>Primary Study Area</u>: Caucasians form a majority of the population in the Pupukea/Sunset Beach/Waimea area (as shown in Table 2-3, for 1990 survey results, and Table 2-2). Most are Mainland-born. The higher percentage of Caucasians in the 1990 survey sample, compared to the 1980 population, may reflect a change in composition of the population, lessening the "local" character of parts of the Primary Study Area. Nearly half the 1990 survey respondents from the Primary Study Area had lived in the same house for less than four years.

<u>Secondary Study Area</u>: Caucasians form the largest single group in the area, but people of Hawaiian, Filipino, and Japanese backgrounds are also well represented. "Other Polynesians" are present in unusually high numbers. Filipinos form a notably smaller percentage of those surveyed in 1990, as compared to their share of the 1980 population. The Hawaii-born slightly outnumber Mainland-born residents.

2.3.2 Family and Income Characteristics

Study area family characteristics evident in the 1980 Census were broadly similar to those of the overall Oahu population. (See Table 2-4.) Average study area incomes, however, were well below the islandwide median (except in the Primary Study Area).

If the relationship between family incomes in the study area and the Oahu median remains constant, 1990 family incomes should average slightly over $30,000:

	Median Family Income	
	1980	1990 (extrapolated)
Oahu	$23,554	$41,200
North Shore Development Plan Area (82% of Oahu median)	$19,270	$33,800
Koolauloa Development Plan Area (72% of Oahu median)	$17,005	$29,700

TABLE 2-3: DEMOGRAPHIC CHARACTERISTICS, STUDY AREA, 1990

	TOTAL STUDY AREA (%)	SECONDARY STUDY AREA (%)	PRIMARY STUDY AREA (%)
ETHNICITY			
Caucasian	42.6	37.4	67.4
Japanese	8.7	8.0	11.8
Filipino	10.7	11.2	8.3
Hawaiian	21.4	24.0	9.0
Other Polynesian	7.5	9.0	0.0
Mixed/Others	9.1	10.3	3.5
AGE			
Less than 25 years	9.9	10.3	7.6
25 to 34	26.0	26.6	22.9
35 to 44	23.2	22.3	27.8
45 to 54	14.1	14.3	13.2
55 or over	26.6	26.3	27.8
Refused	0.2	0.1	0.7
PLACE OF BIRTH			
Hawaii	42.4	43.9	34.7
Mainland U.S.A.	41.0	37.0	60.4
Pacific Islands	6.0	7.3	1.0
Philippines	6.1	6.8	2.8
Other Asian countries	2.0	2.3	0.7
Elsewhere	2.4	2.6	1.4
LENGTH OF RESIDENCE OF HEAD OF HOUSEHOLD IN THE SAME HOUSE			
Under 1 year	19.3	19.1	20.1
1-3 years	23.5	22.7	27.1
4-10 years	24.8	25.8	20.1
11-17 years	11.7	11.6	11.1
18 or more	20.7	20.5	21.5
Not sure/refused	0.1	0.1	0.0
EDUCATIONAL ATTAINMENT			
Some high school	13.2	14.3	8.3
High school graduate	30.1	30.7	27.1
Some college	34.3	33.0	40.3
College graduate	22.3	21.8	24.3
Not sure/refused	0.1	0.1	0.0
SAMPLE SIZE	831	687	144

SOURCE: Preliminary findings, from Community Resources, Inc., 1990.

TABLE 2-4: FAMILY CHARACTERISTICS AND INCOME LEVELS, CITY AND COUNTY OF HONOLULU, AND STUDY AREA,

	CITY AND COUNTY OF HONOLULU 1980	TOTAL STUDY AREA 1980	KOOLAULOA DISTRICT 1980	NORTH SHORE DISTRICT 1980	PRIMARY STUDY AREA (PUPUKEA/SUNSET BEACH/WAIMEA) 1990
POPULATION IN FAMILIES	653,118	20,158	11,687	8,471	2,509
as percentage of total population	85.6%	83.8%	82.3%	86.0%	78.1%
NUMBER OF FAMILIES	178,516	5,162	2,909	2,253	732
HEAD					
Husband/wife	82.8%	83.3%	83.7%	82.8%	74.6%
Male only	4.5%	5.2%	5.7%	4.6%	9.7%
Female only	12.7%	11.5%	10.6%	12.6%	11.6%
WITH OWN CHILDREN UNDER 18	54.9%	59.0%	62.0%	55.1%	60.1%
Female head	7.5%	7.9%	6.7%	9.5%	6.4%
BELOW POVERTY LEVEL	7.5%	11.5%	13.5%	9.0%	6.1%
MEDIAN FAMILY INCOME	$23,554	N/A	$19,566	$16,895	$24,451
NON-FAMILY HOUSEHOLDS	53,298	1,582	943	639	632
percentage below poverty level	15.7%	24.6%	25.3%	23.6%	14.4%

NOTES: All figures (except "Population in Families" and "Non-Family Households") based on 15 percent sample; hence, numbers represent estimates.
"N/A" = not available.
SOURCES: U.S. Bureau of the Census, 1980 Summary Tape Files 1-A and 3-A (1981a and 1981b).

Nearly all respondents to the 1990 survey lived in family households (as shown in Table 2-5). Most reported household incomes below $40,000. The estimated family income for FY1990 on Oahu is $41,200 (United States Department of Housing and Urban Development, 1990). Hence the survey strongly suggests that incomes remain low in the study area. The medians indicated by the survey are somewhat below the 1990 extrapolated medians shown above.

Primary Study Area: In 1980, the percentage of the population in family households was below the islandwide figure. Again, about a fifth of 1990 respondents indicated that they did not live in family households. Income levels reported in 1990 were low compared to estimated islandwide levels, with 59% reporting household incomes below $40,000. This is in contrast to 1980, when the median family income in the Primary Study Area was above the islandwide median.

Secondary Study Area. Incomes reported in 1990 were even lower than in the Primary Study Area. Again, a higher percentage of households was dependent on government welfare programs.

2.3.3 Housing Stock and Characteristics

Housing has long been widely recognized as among the most difficult issues facing many North Shore and Koolauloa residents. While the study area is distant from Honolulu, where Oahu's housing prices are highest, study area prices for single-family properties have climbed along with islandwide averages, as shown in Figures 2-3 and 2-4.) High prices and a lack of available units help to explain why there appears to be widespread overcrowding and housesharing in the area.

Over the period 1980 to 1989, the number of housing units in the Secondary Study Area grew at an average annual rate of 1.1%, well above Oahu's 0.7%. (Growth in the housing stock roughly kept pace with population growth.) The housing stock in the North Shore Development Plan Area (including the Primary Study Area) grew more slowly than in the Koolauloa Development Plan Area (Honolulu Deparment of General Planning, 1990):

Number of Housing Units
Not Including Resort Condo Units

	1980	1989	Annual Growth Rate
North Shore DP Area	4,787	5,191	0.9%
Koolauloa DP Area	3,347	3,789	1.4%
Total Study Area	8,134	8,980	1.1%
Oahu (total)	255,499	272,044	0.7%

TABLE 2-5: FAMILY CHARACTERISTICS AND INCOME LEVELS, STUDY AREA, 1990

	TOTAL STUDY AREA	SECONDARY STUDY AREA	PRIMARY STUDY AREA
	(%)	(%)	(%)
FAMILY HOUSEHOLDS as percentage of total sample	91.8	93.7	82.6
ANNUAL HOUSEHOLD INCOME			
To $10,000	9.5	9.6	9.0
To $20,000	14.9	16.7	6.3
To $30,000	23.0	22.4	25.7
To $40,000	17.0	16.7	18.1
To $50,000	11.2	10.8	13.2
To $60,000	6.7	6.2	9.0
Over $60,000	9.5	8.9	12.5
Not sure/refused	8.2	8.6	6.3
HOUSEHOLDS RECEIVING FOOD STAMPS AND PUBLIC WELFARE as percentage of total sample	9.5	10.2	6.3
SAMPLE SIZE	831	687	144

SOURCE: Preliminary findings, from Community Resources, Inc., 1990.

FIGURE 2-3:
OAHU AND NORTH SHORE/KOOLAULOA MEDIAN OFF-WATER SINGLE FAMILY RESALE PRICES

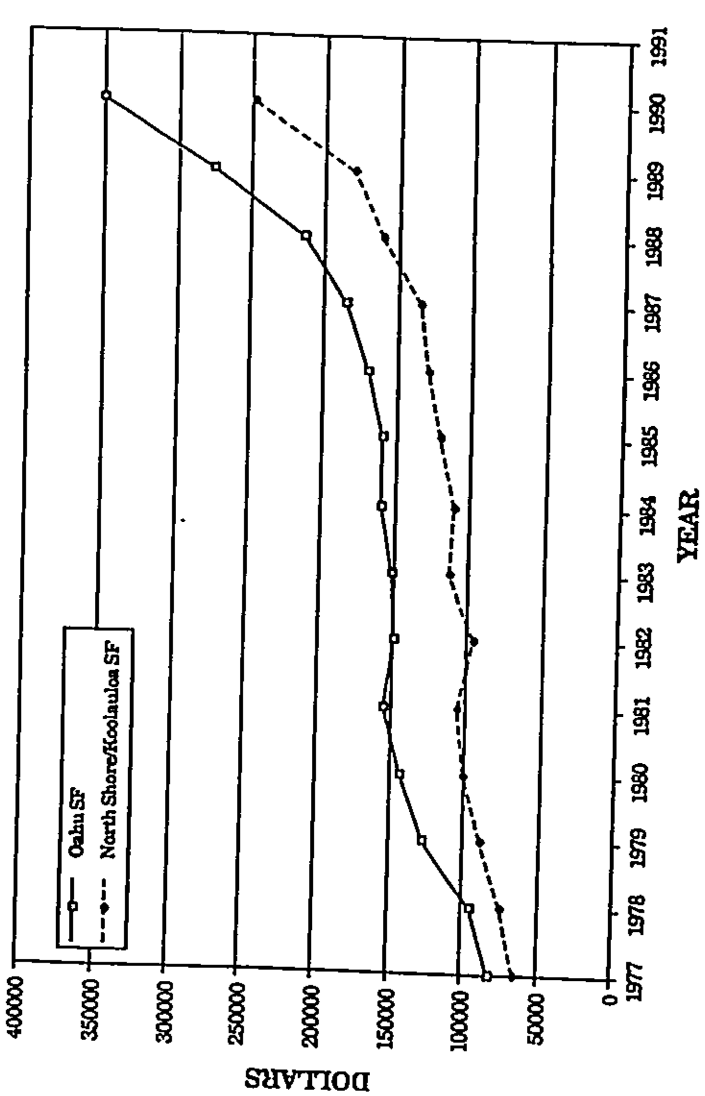
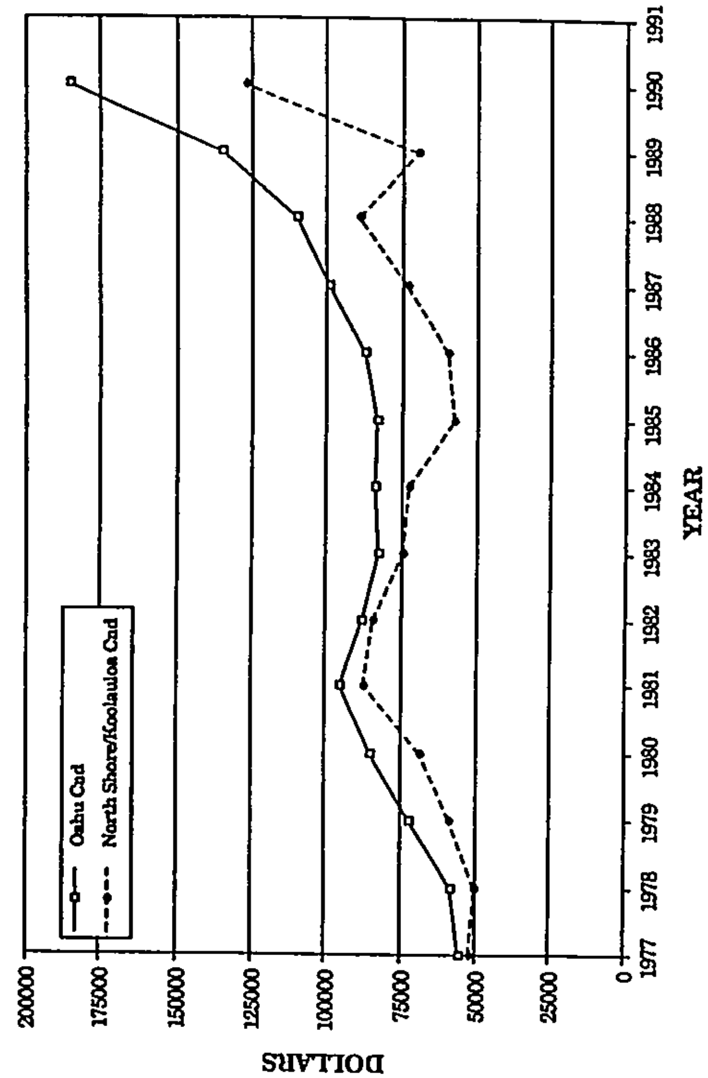


FIGURE 2-4:
OAHU AND NORTH SHORE/KOOLAULOA MEDIAN CONDOMINIUM RESALE PRICES



A significant portion of the study area housing stock is rental housing held for short-term use. No recent information is available regarding the number of vacation rental units.

In 1980, about 15% of the study area's housing stock was vacant at midyear. The estimated 1989 vacancy rate is about 3%, according to the City and County -- a rate lower than in some urban areas on Oahu (Honolulu Deparment of General Planning, 1990).

Estimates of household size other than Census data are open to question, so no definitive estimate of study area household sizes and crowding can be made. However, two trends stand out:

- Household size has likely decreased, in line with statewide trends; and
- Study area household populations are larger than the islandwide and statewide averages (Community Resources, Inc., 1989b, 1990 for survey data from 1988 and 1990).

Average study area household sizes were above the islandwide mean in 1980 (as shown in Table 2-6). The 1990 survey may indicate an important change within the study area, as North Shore respondents reported higher household sizes than Koolauloa respondents:

<u>Reported Household Size, 1990</u>

Primary Study Area	3.33
Rest of North Shore	5.25
Koolauloa DP Area	4.05
Total Study Area	3.67

(The absolute figures reported here could be inflated by the survey effects -- the numbers should be read comparatively.)

Over 40% of the 1990 survey respondents live in multi-family units, in houses with more than one unit in the house, or on properties with more than one house on-site. (See Table 2-7 for housing data from the Kuilima survey.) These responses suggest that many -- perhaps most -- people in the study area are in living situations different from the suburban norm of one family per household per lot.

Table 2-7 shows a higher proportion of owner-occupants in the study area than in 1980. This is likely an effect of sampling for this table, since second and third households on a property are not counted.

Primary Study Area: Little difference between reported 1990 housing conditions in the Primary and Secondary Study Areas is evident. However, reported housing costs are slightly higher on average in the Primary Study Area.

TABLE 2-6: HOUSING STOCK AND CHARACTERISTICS, CITY AND COUNTY OF HONOLULU, AND STUDY AREA, 1990

	CITY AND COUNTY OF HONOLULU 1980	TOTAL STUDY AREA 1980	KOOLAULOA DISTRICT 1980	NORTH SHORE DISTRICT 1980	PRIMARY STUDY AREA (PUPUKEA/SUNSET BEACH/WAIMEA) 1980
TOTAL YEAR-ROUND HOUSING UNITS	250,864	7,877	4,679	3,198	1,227
vacant (total)	8.2%	16.3%	20.0%	11.0%	14.0%
vacant for sale	0.5%	1.6%	0.8%	2.9%	0.7%
vacant for rent	3.6%	6.3%	9.3%	1.9%	3.9%
held for occas'l use	0.9%	5.3%	5.8%	4.7%	4.7%
other	3.2%	3.0%	4.1%	1.5%	4.7%
TOTAL YEAR-ROUND OCCUPIED UNITS	230,214	6,586	3,742	2,844	1,055
TENURE					
owner-occupied	49.9%	38.6%	37.7%	39.6%	43.1%
renter-occupied	50.1%	61.4%	62.3%	60.4%	56.9%
SELECTED CONDITIONS					
lacking some or all plumbing	1.5%	2.2%	2.4%	2.1%	2.0%
1.5 or more persons/room	7.4%	12.1%	16.0%	7.2%	5.7%
PERSONS PER HOUSEHOLD	3.15	3.45	3.55	3.35	2.97
MEDIAN CASH RENT (renter-occupied)	$279	N/A	$270	$257	$340
as % of median family income	16.2%	N/A	19.2%	15.8%	16.7%
MEDIAN VALUE* (owner-occupied)	$130,400	N/A	$96,500	$79,400	$145,600
MEDIAN MONTHLY MORTGAGE* (owner-occupied)**	$494	N/A	$462	$331	$515
as % of median family income	25.2%	28.2%	34.2%	20.3%	25.3%

NOTES: * For 1980, median values are for non-condominium housing units.
** Figures based on 15% sample; hence, numbers represent estimates.
"N/A": Not Available.
SOURCES: U.S. Bureau of the Census, 1980 Summary Tape Files 1-A and 3-A (1981a, 1981b).

TABLE 2-7: HOUSING CHARACTERISTICS, STUDY AREA, 1990

	TOTAL STUDY AREA	SECONDARY STUDY AREA	PRIMARY STUDY AREA
	(%)	(%)	(%)
TYPE OF HOUSING			
Multi-family	29.2	31.1	20.1
Undivided single-family with one unit in property	61.9	61.1	65.3
Undivided single-family with two or more units	6.4	5.5	10.4
Unattached small cottage	0.6	0.6	0.7
Attached small cottage	0.4	0.4	0.0
Divided house	1.4	1.0	3.5
Others	0.1	0.1	0.0
Refused	0.0	0.2	0.0
TENURE			
Owner-occupied	50.5	50.9	48.6
Rentre-occupied	46.2	45.6	49.3
Occupied without rent	2.5	2.6	2.1
Not sure/refused	0.7	0.9	0.0
HOUSING COST			
No $ cost	0.7	0.7	0.7
To $250	13.4	13.0	15.3
To $500	14.3	15.9	6.9
To $750	21.2	21.5	19.4
To $1,000	20.3	21.1	16.7
To $1,250	9.9	10.2	8.3
To $1,500	7.3	6.8	9.7
Over $1,500	8.8	6.8	18.1
Not sure/refused	4.1	3.9	4.9
SAMPLE SIZE	831	687	144

SOURCE: Preliminary data, from Community Resources, Inc., 1990.

In 1980, the mean household size in the Primary Study Area was slightly smaller than the island average, and much smaller than the average for the rest of the study area.

Secondary Study Area: Historically, the level of homeownership was low in the total study area. However, half the households surveyed in 1990 were owner-occupied. The similar responses from both the Primary and Secondary Study Areas suggest that homeownership has risen in the Secondary Study Area in the last decade.

2.3.4 Labor Force Characteristics

Although the North Shore and Koolauloa area are "country" in atmosphere, as much as half the workforce commutes outside the study area (as shown in Table 2-8). The 1990 survey indicates that, in general, study area residents who commute further for work earn more. Survey results also suggest the study area labor force includes high proportions of both professionals and general laborers. In 1980, the proportion of laborers in the North Shore District labor force was high compared to islandwide figures, while service workers were more numerous in Koolauloa District (as shown in Table 2-9).

In 1980, labor force participation was greater than the Oahu average in the North Shore District, and even higher in the Primary Study Area. In Koolauloa, the proportion of adults working for wages or looking for work was below the island average. Results of a 1988 survey (in Table 2-10) suggest that labor force participation in the study area has increased. That survey also showed that many in the study area work weekends or evenings -- a pattern characteristic of service sector jobs.

Recent State estimates show unemployment in the study area as low, in line with City and County trends (Table 2-11). However, Census Tract 101, including Kahuku and the Primary Study Area, has a somewhat higher level of unemployment.

Primary Study Area: Persons in managerial/professional occupations form nearly half the workforce, and salespersons are more numerous than in the rest of the study area, according to the 1990 Kuilima survey. More than half the Primary Study Area workforce commutes to job locations outside the study area.

Secondary Study Area: In light of the area's rural reputation, the high incidence of managers and professionals in the 1990 survey is striking.

TABLE 2-8: LABOR FORCE CHARACTERISTICS, STUDY AREA, 1990

	TOTAL STUDY AREA	SECONDARY STUDY AREA	PRIMARY STUDY AREA
	(%)	(%)	(%)
OCCUPATION			
Restaurant/cocktails	5.1	5.1	5.2
Housekeeping	1.5	1.8	0.0
Professional/managerial	39.4	38.3	45.5
Sales	9.6	8.6	14.3
Office/clerical	10.7	11.2	7.8
Farm/plantation	3.0	3.1	2.6
General labor	24.3	24.7	22.1
Other	6.2	6.9	2.6
Refused	0.2	0.2	0.0
JOB LOCATION			
Kuilima	4.7	5.1	2.6
Elsewhere on North Shore (Kaaawa to Wailua/Mokuleia)	44.6	44.9	42.9
Kahaluu to Kaneohe	5.3	6.1	1.3
Wahiawa	8.1	8.2	7.8
Elsewhere on Oahu	36.7	35.2	44.2
Not sure/refused	0.6	0.5	1.3
SAMPLE SIZE	469	392	77

SOURCE: Preliminary data, from Community Resources, Inc., 1990.

TABLE 2-9: LABOR FORCE SIZE AND CHARACTERISTICS, CITY AND COUNTY OF HONOLULU, AND STUDY AREA, 1980

	CITY AND COUNTY OF HONOLULU 1980	TOTAL STUDY AREA 1980	KOOLAULOA DISTRICT 1980	NORTH SHORE DISTRICT 1980	PRIMARY STUDY AREA (PUPUKEA/SUNSET BEACH/WAIMEA) 1980
POTENTIAL LABOR FORCE (AGED 25+)	574,903	17,207	9,833	7,374	2,484
not in labor force	30.8%	36.3%	36.4%	36.2%	30.7%
armed forces	10.1%	5.8%	1.4%	11.8%	3.0%
civil, labor force	59.1%	57.8%	62.2%	52.0%	66.3%
CIVILIAN LABOR FORCE	339,863	9,952	6,115	3,837	1,647
unemployed	4.6%	4.7%	4.9%	4.6%	8.4%
TOTAL EMPLOYED CIVIL. LABOR FORCE	324,113	9,472	5,812	3,660	1,509
OCCUPATION					
service	17.6%	23.3%	28.6%	15.1%	32.2%
manager./profes.	24.7%	20.6%	22.2%	18.1%	21.5%
technical, sales & adminis.	33.7%	22.6%	23.5%	21.2%	19.9%
farm/fish/forest	1.8%	7.5%	5.8%	10.4%	5.8%
precision, craft, repair	11.3%	12.4%	10.7%	15.1%	13.1%
operators, fabri- cators, laborers	10.9%	13.4%	9.2%	20.1%	7.4%
INDUSTRY (selected)					
agric., forest, fish, mining	1.7%	7.7%	5.1%	11.9%	5.7%
construction	6.6%	7.9%	8.3%	7.5%	12.8%
manufacturing	7.7%	7.6%	3.5%	14.1%	4.6%
retail trade	20.5%	13.9%	11.9%	17.1%	15.4%
financial, insur., real estate	8.1%	4.4%	4.9%	3.8%	8.2%
personal, entertain. & recreat. services	8.1%	16.1%	22.8%	5.7%	19.6%
health, educ., & professional	18.5%	21.3%	25.4%	15.0%	13.9%
public adminis.	10.9%	10.0%	8.7%	11.9%	11.1%
COMMUTE TO WORK					
45 minutes or more	11.9%	23.4%	21.1%	27.2%	37.9%
mean travel (min.)	22.9	25.5	25.1	25.9	34.0

NOTES: All figures based on 15% sample; hence, numbers represent estimates.
SOURCES: U.S. Bureau of the Census, 1980 Summary Tapes Files 1-A and 3-A, (1981a and 1981b).

TABLE 2-10: SELECTED LABOR FORCE CHARACTERISTICS, STATEWIDE TOURISM IMPACT CORE SURVEY, 1988

	STATE OF HAWAII	CITY AND COUNTY OF HONOLULU	STUDY AREA
Civilian labor force participation rate	69%	69%	68%
Workers with more than one full-time job	6%	6%	9%
Usually working 49 or more hours per week	22%	23%	19%
Usually working weekends	39%	38%	46%
Usually working evenings	29%	30%	34%
Usually working weekends & evenings	22%	22%	27%
Primary job is in visitor industry	24%	21%	26%
No member of household works a tourism job	66%	68%	63%
Very satisfied with primary job	57%	56%	52%
Usual travel time to work*			
20 minutes or less	58%	55%	46%
20 to 39 minutes	28%	29%	20%
40 minutes or more	13%	15%	29%
SAMPLE SIZE	(3,904)	(1,305)	(163)

NOTES:
* Percentages may not add to 100% due to some "no response" answers.

SOURCE: Based on 1988 Survey Data, Community Resources, Inc., 1989b.

TABLE 2-11: ESTIMATED STUDY AREA LABOR FORCE AND EMPLOYMENT

	1989 Average Labor Force and Employment		
	City and County of Honolulu	Total Study Area	Tract 101
Civilian labor force	384,500	11,249	2,392
Number employed	375,950	10,988	2,311
Number unemployed	8,550	261	81
Unemployment rate	2.2%	2.3%	3.4%

	October 1990 Labor Force and Employment		
	City and County of Honolulu	Total Study Area	Tract 101
Civilian labor force	395,991	11,585	2,468
Number employed	385,785	11,275	2,371
Number unemployed	10,206	310	97
Unemployment rate	2.6%	2.7%	3.9%

SOURCE: Personal communication, Manuel Fragante, Research Statistician, Hawaii Department of Labor and Industrial Resources, December 14, 1990

2.4 LIFESTYLE AND VALUES

A recurring theme in the North Shore region is the desire to "keep the country country". This slogan has become popular and increasingly important in the 1980s. However, different study area residents may emphasize different aspects and qualities of "country" life, while agreeing on the general aim.

Lifestyle and values are deeply rooted in an area's history, economy, and geography, along with the heritage of its peoples. While the study area is recognized as "country" by residents and government officials alike, "country" living involves community for some residents, and a more independent lifestyle for others. Nearly two-thirds of the study area population in 1980 lived in small towns with business centers and well-defined neighborhoods -- i.e., Waialua, Haleiwa, Kahuku, Laie, and Hauula. The remainder lived in more isolated settings or in strip-development neighborhoods such as Sunset Beach, Waimea, Punaluu, and Kaaawa.

The various communities differ from one another in many ways, as noted above in the overview of study area sites. However, "community" dwellers generally differ from the more rural "country" residents in that their homes are less isolated and they are more subject to small-town pressures for cooperation and social cohesiveness. Additionally, many of the communities are or were once "company towns," resulting in some clear lines of social organization.

Ethnic factors also contribute to the country/community differences. According to the 1980 Census, the majority of Caucasians in the study area lived in "country" locales, while Filipinos tended to be concentrated in Kahuku and Waialua. People from South Pacific backgrounds were concentrated in Laie while Hawaiians and part-Hawaiians were numerous in Hauula, although present in other parts of the study area.

The country/community distinction is not absolute. Community residents value their country surroundings, and people living in the "country" areas report a sense of community, too. However, communities in the study area were founded on various economic activities, and there is a history of third- and fourth-generation families seeking preservation of their particular community as a home for the next generation. The more rural "country" areas, by contrast, have a higher proportion of first-generation residents attracted by recreational opportunities and/or the absence of nearby large-scale economic activity.

Thus, large-scale economic activity and centralized employment centers are (to a point) historically compatible with the lifestyles and values of "community" dwellers, but less so for the "country" residents of Koolauloa and the North Shore. "Community" members have banded together in response to the closure of Kahuku Plantation and the possibility that Waialua Sugar too might close. "Country" residents have active community associations, but many residents have been most active in opposing new projects seen as encroaching on the area's character.

2.5 ISSUES AND CONCERNS INDEPENDENT OF THE PROJECT

2.5.1 Survey Data

Respondents to the 1990 Kuilima survey listed as the major problems facing their communities: traffic, housing, lack of roads and infrastructure, lack of nearby jobs, and the lack of recreational facilities.

Asked which is more important, the construction of affordable housing or keeping the area "as it is," Primary Study Area respondents differed from others in the study area:

	Total Study Area	Primary Study Area
More important:		
Affordable housing	38%	34%
Keeping "as is"	53%	55%
No answer or Don't know	9%	11%

In 1988, study area residents were most likely to count housing as a problem for their community, while many also mentioned cost of living issues, a lack of nearby jobs, and traffic as major problems. Residents' wish to "keep things like they are" rather than encourage new tourism jobs was a bit more pronounced than the views of others in Hawaii. (See Table 2-12 for findings.)

While study area residents confront local problems -- congestion on Kamehameha Highway, lack of sewage treatment facilities -- their views are broadly similar to those of other Oahu residents. In 1990, Oahu respondents to the Hawaii Poll listed housing and transportation/traffic as the biggest problems facing the state (Star-Bulletin, 1990). Education, crime, and drugs were also found to be important problems. In 1989, Oahu residents identified as issues of major concern (1) the cost of living; (2) housing; (3) education; (4) traffic; (5) drugs; and (6) economic and employment issues (Sunderland Smith Research Associates, 1990).

In 1988, a survey was mailed to all households in the North Shore Development Plan Area by the Neighborhood Board. The level of response was low, as is typical of such surveys. Hence the survey reveals the existence of strongly held opinions, rather than the exact percentage of area residents holding one view or another.

TABLE 2-12: GENERAL COMMUNITY ISSUES AND ATTITUDES, STATEWIDE TOURISM IMPACT CORE SURVEY, 1988

		STATE OF HAWAII	CITY AND COUNTY OF HONOLULU	STUDY AREA
COMMUNITY ISSUES -- %'S RATED "BIG PROBLEM IN YOUR PART OF THE ISLAND				
Cost of housing		64%	64%	66%
Cost of food and clothing		43%	42%	51%
Lack of nearby jobs		28%	28%	48%
Traffic		56%	60%	45%
Pollution of oceans or natural areas		29%	29%	29%
Population growing too fast		38%	39%	27%
Beauty of area being destroyed by development		25%	25%	26%
Not enough sports and recreation facilities		22%	20%	24%
Crowed beach parks		23%	23%	18%
Crime		30%	33%	17%
Not enough nearby stores, restaurants, entertain.		14%	13%	16%
Too many tourists		7%	6%	12%
Problems between people of different backgrounds		9%	10%	8%
QUALITY OF LIFE "IN THIS PART OF THE ISLAND" VS. FIVE YEARS AGO				
Today is ...	Better	29%	27%	22%
	Worse	24%	23%	25%
	Same	46%	48%	51%
	Not Sure	2%	2%	2%
TOURISM GROWTH -- %'S AGREEING WITH VARIOUS STATEMENTS				
In my part of the island, it's more important to keep things like they are than to have more tourism jobs.		63%	63%	65%
It is time to stop building new hotels on this island.		68%	70%	72%
We need more tourism jobs on this island.		43%	42%	44%
Survey Base:		3,904	1,305	163

SOURCE: Community Resources, Inc., 1989b.

Two-thirds of the respondents favored a future with a slow or moderate pace of residential and commercial growth for North Shore. The majority favored a policy whereby large undeveloped parcels would not be developed or would be made available for public recreation.

Among the main areas of concern, road improvements and traffic problems stood out as by far the most mentioned. Next came the Haleiwa Bypass Road and preservation of the rural character of this region.

2.5.2 Indications from Neighborhood Board Minutes

The minutes of meetings of the North Shore Neighborhood Board and Koolauloa Neighborhood Board from 1988 through 1990 were reviewed. Topics of major concern to members of both Neighborhood Boards include:

- **Traffic:** Traffic remains as one of the major issues of both communities. Both boards expressed concern about peak hour and weekend traffic. Both boards identified tour buses and sightseeing vehicles as contributing to the traffic slowdown.

  However, both boards are opposed to changes in roadways that would lead to major growth. The Koolauloa Neighborhood Board does not support widening Kamehameha Highway north of Kaneohe, and the North Shore Board opposed building a road around Kaena Point.

  Recognizing the danger posed to bikers and joggers along the highway, both boards support the development of a bike path connecting all beaches from Waialee to Waimea.

- **Haleiwa Bypass Road:** North Shore residents in general supported the Haleiwa Bypass Road (scheduled for completion in late 1991) as a way to ease the congestion in Haleiwa Town. However, some reidents opposed the current plan because of dangers from speeding and the diversion of traffic away from Haleiwa's business district.

- **Preserving rural character:** Both boards consistently expressed the need to preserve the "country" character of the regions. For example, the boards generally opposed variance requests for signs in residential areas, while insisting on uniform design of signs in commercial areas.

  Both boards have discussed population growth in the region as a potential threat to rural life, and evaluated proposed developments partly in terms of the chance that these would bring a change in residents' lifestyle.

- **Land Use Planning:** Both Boards favor a comprehensive plan for golf course development rather than on a case by case basis. The Koolauloa Neighborhood Board supports the Development Plan (DP) provision that require all applicants for golf course development to submit its plans for review six months before the actual DP annual review which begins in January 1991.

  When the Neighborhood Boards reviewed proposed recreational developments, common concerns include public trail access, water and sewage problems, aesthetics, and view planes.

- **Sewage and Wastewater Disposal:** Sewage and wastewater disposal is a concern to both boards, in relation to existing sewage plants as well as proposed developments. The major point of concern is possible pollution of the ocean or streams. An additional concern is the improvement of facilities in the region.

- **Water:** Water availability is a concern of both Neighborhood Boards with regard to golf course proposals. The Koolauloa Neighborhood Board also voiced concern that golf courses' use of water not affect residential or agricultural users. The Koolauloa Board further expressed concern that golf course fertilizers, pesticides, and herbicides could affect groundwater.

- **Beach Parks and Recreation:** Both boards have consistently supported city acquisition of beach front areas for development and expansion of beach parks. Both expressed concern about beach access and showed interest in rules being developed by the Development of Parks and Recreation to control surfing, scuba diving, and other ocean activities.

- **Protective and Civil Defense Services:** Both boards expressed concern that police did not have adequate resources to deal with crime in their communities. The North Shore Neighborhood Board expressed need for a better tidal wave warning siren system in the Waimea Beach area.

- **Transient Rentals:** The North Shore Neighborhood Board expressed concern about convenant violations regarding transient rentals and subdividing of buildings near Kawailoa Beach. It supports the City's positions that rentals for less than 30 days are permitted only in resort-designated area, and that Bed and Breakfast units must be owner-occupied, with no more than four guests per room.

- **Affordable Housing** is of particular concern to the Koolauloa Neighborhood Board. Concern is also raised about inadequate utilities in some areas, which limit construction of new housing. While recognizing the employment benefits of proposed developments, the Board also raised the issue of rising housing costs.

However, the Board has opposed one request for a change of designation from Agricultural to Residential, partly out of concern that new housing at that site could bring the area total above General Plan guidelines for growth in the next 20 years.

- **Drainage:** Both Boards want to see improvement in the drainage system of the regions. The Koolauloa Neighborhood Board talked about the flood control problem in Laie, and the North Shore Board expressed concern that the delay of the city-funded Niuuli Flood Study would put residents on Nuuili Road in jeopardy during the rainy season.

2.5.3 Issues Surrounding Golf Course Development

Golf course development has increasingly become a major public issue in recent years on both Oahu and the Neighbor Islands. While some economists view golf as a land-based export industry highly advantageous for Hawaii (Bank of Hawaii, 1989), others oppose golf course development strongly. In a public opinion survey taken in August 1990, 76% of the 800 respondents said golf courses are bad for Hawaii (Burris, 1990). Still, some residents support golf course development, mainly for economic and recreational reasons.

Several issues combine in many citizens' suspicions of golf course development, including environmental concerns, concerns about land use planning and control, attitudes toward growth in general, and views of Japanese ownership of land and businesses in Hawaii.

Applications for or inquiries about new golf course developments expanded dramatically in 1988-89. Since 1985, the City and County of Honolulu's Department of Land Utilization (DLU) has received nearly 40 applications or inquiries. The number of active projects fluctuates, as different projects are withdrawn or revived.

In 1990, two new golf courses opened in Leeward Oahu, the first new courses on the island since 1973. Others are under construction, but most of the courses proposed have either been denied permits or have been withdrawn. Consequently, some of the most visible courses are projects now under construction which were awarded permits in the mid-1980's, when the provision of tee times to residents at reduced rates and other community benefits were not demanded.

Islandwide Concerns. Residents' concerns about golf courses are both general and site-specific. In most cases, site-specific issues must be viewed as general concerns, since some residents expect that problems noticed in one place will arise again elsewhere. Hence this summary of concerns includes issues which do not apply to all courses, but which many expect to be true of golf courses and golf-related developments.

Sources for this summary include newspaper and magazine reports (including Dayton, 1990; Dooley 1989, 1990; Essoyan, 1989; Hartwell, 1988; Oshiro, 1990; Yamaguchi 1988a, 1988b; Young, 1988), editorials and letters to the editor (Black, 1989; Honolulu Advertiser, 1989a, 1989b, 1990; Murakami, 1988; Owens, 1989; Shimabuku, 1989; Teesdale, 1988); reviews of public testimony and letters in response to Environmental Impact Statements (EIS's) (Grady 1989; Hawaii Real Estate Research and Education Center, 1990), analyses of interviews for social impact assessments of golf course proposals (Community Resources, Inc. 1988a, 1988b, 1989; Earthplan 1990) and a City and County summary report (City and County of Honolulu, 1989).

Socio-economic issues arising with regard to the Lihi Lani Recreational Community will be identified in Section 4 and, if appropriate, discussed further in Section 5. (Other concerns are addressed in technical studies included in the project Environmental Impact Statement.) Table 2-13 provides a partial indication of Oahu residents' concerns, as indicated in City Council hearings in 1989 and EIS letters. The table indicates that different issues take on importance in different settings Oahu residents' concerns with golf development in general include:

- **Anticipated environmental impacts:** Water usage and the possibility that pesticides and other chemicals used on golf courses could affect groundwater are often mentioned as concerns. In some cases, golf courses are seen as affecting wetlands on or near the proposed projects.

- **Anticipated impacts on agriculture:** Some officials and residents are concerned that golf course development raises the price of open land, including agricultural land, lowering the viability of agriculture as a land use. Similarly, City officials have asserted that land acquisition for golf courses somehow makes agricultural land too expensive for housing development. In specific cases, the displacement of farmers has been of concern, and some think that golf courses generally are displacing agriculture.

  (At a general level, economists have argued that golf could replace plantation agriculture as an income-generating land use, to the benefit of Hawaii.)

TABLE 2-13: FREQUENCY OF MENTION OF ISSUES IN CITY AND COUNTY HEARINGS ON GOLF COURSES AND OAHU ENVIRONMENTAL IMPACT STATEMENT LETTERS

Public Hearings (1) Issue	%	Environmental Impact Statements (2) Issue	%
Compatibility with land use policies	90%	Permits	45%
Community issues	76%	Housing	73%
		Public safety	64%
		Location	45%
Hydrology, drainage	57%	Water	100%
		Wastewater, drainage	82%
		Coastal ecosystem	55%
Soils, Agriculture	38%	Agricultural land	91%
Lifestyles	38%	Bus service, park and ride, child care	27%
Hazards	38%		
Employment, economy	33%		
Population and socio-economic character	24%	Socio-economic impact	18%
		Population	27%
Public facilities	19%	Parks, recreation	55%
		Fire stations	55%
Fiscal impacts	19%	Public utilities	55%
		Schools	36%
		Police (personnel)	27%
		Refuse service	9%
Historical, archaeological and geographic issues	10%	Archaeological, hist. sites	100%
Physiography, geology	10%	Runoff, floods, erosion	91%
		Pesticides	73%
Flora and fauna	10%	Endangered species	82%
Infrastructure	10%	Traffic	82%
		Roadways	73%
		Infrastructure	36%
Air quality	5%	Air quality	45%
		Noise, nuisance	100%
		Pests, odor, dust	27%

NOTES:

(1) Adapted from Hawaii Real Estate Research and Education Center (1990), Table 3.

(2) Adapted from Ibid., Table 4, counting only the 11 Oahu EIS's included in that table.

- **Impacts on nearby communities:** Some expect golf courses to affect nearby property values and land uses, bringing higher values, and hence higher taxes. In some "country" and agricultural areas, increased traffic due to golfers is a concern. Golf courses are expected to attract affluent outsiders -- as visitors or perhaps as new residents -- to outlying communities, resulting in social friction.

- **Employment:** Some see golf courses as a source of nearby jobs for residents of communities far from urban centers. Others have contended that golf course employment is small and not well-paid.

- **Concerns over land ownership and use:** Many residents express concern over the acquisition of large parcels by foreign owners and the dedication of much acreage to a game. The cumulative effect may be experienced as a loss of control over Hawaii's land. A less often expressed view is that golf courses preserve land in open space, providing visual benefits and keeping land open for the future.

- **Return of Profit to Hawaii:** Developers are perceived as likely to make large profits from the sale of golf course memberships overseas. Some object to such profits under any conditions. Officials have suggested that exactions or development agreements should insure that developers of new golf courses provide sizeable sums to local communities or government bodies, to return to the islands some of the income made from golf course development.

- **Demand for golf:** New golf courses are widely seen as responding to demand from visitors. Some golfers see such demand as limiting their own opportunity to play, and welcome new courses as lowering the demand for golf tee times, whether at the new courses or existing ones. Interest in additional municipal courses is often mentioned. (Many golfers add that rates at proposed non-municipal courses are too high for their liking.)

Study Area Concerns. Specific issues with regard to the Lihi Lani project are discussed in Section 4. Many of these issues follow from residents' general concerns. For example, strong dissatisfaction with traffic congestion has led some to propose curbs on all further development, including golf courses, on the North Shore of Oahu.

A specific study area concern independent of the Lihi Lani Recreational Community proposal has to do with the number of courses proposed for the area. At various times, some 12 or 13 courses have been mentioned as possible in the study area. (See Section 3.2 for discussion of recent and current proposals.)

Development of many courses would make the North Shore marketable as a golf destination. The region is already renowned as a surfing area. Some residents have expressed concern that expansion of the Kuilima resort and development of several new golf courses would change the character of the entire region.

3.0 FORCES FOR CHANGE INDEPENDENT OF THE PROJECT

This section addresses developments and trends, apart from the project, that are likely to contribute to future changes in the study area.

Expansion of the Kuilima Resort is expected to bring thousands of additional jobs to the region. Other projects will create additional jobs, but no likely or proposed development is on the scale of the already-approved resort expansion. Along with new economic opportunities will come increases in traffic and demand for housing. Both resident opinion and city policy support controls on growth in the region. If those controls are exercised in the form of limits on housing, however, likely result will be severe crowding and continuing increases in the cost of housing.

3.1 PLANNED AND PROPOSED DEVELOPMENTS

3.1.1 Resort Developments

Kuilima Expansion: A major expansion of the resort is under way. The aim is to to create a critical mass of visitor facilities -- a resort area offering diverse attractions rather than a single hotel.

Expansion plans, which are under review, currently call for four new hotels, and two additional towers to the present hotel (making a total of 2,599 new hotel units); 1,000 resort condominium units; and a 112,000 square foot shopping village.

Construction on the expansion is planned in three phases:

	Major Facilities	Resort Units	Completion Date
PHASE I	H-2 Luxury Hotel	383	1992
	G-2 Golf, clubhouse	N/A	1992
	Tennis club	N/A	1992
	H-1 Activity-oriented hotel	650	1993
	G-1 Golf course (renovation)	N/A	1993
	H-4 Expansion of Turtle Bay Hilton	621	1994
	Shopping Village	N/A	1994
PHASES II AND III (1995+)	H-3 Hotel	530	N/A
	H-5 Hotel	415	N/A
	A-1 Apartments	250	N/A
	A-2 to A-5 Apartments	750	N/A

		3,599	

Phase I began in 1989 and is scheduled for completion by 1995. Timing of the next two phases is not yet set.

In addition, a new 18-hole golf course is being built. It is due to begin operations in 1992. When the new course is completed, the existing course will close down for extensive renovation. Other new recreational facilities, including stables, a clubhouse, tennis club, beach club, and visitor center are to be built soon.

Mokuleia: The Mokuleia Land Company has long-term plans for resort development. Plans include two 18-hole golf courses on the company's 3,000 acres. One course would be completely private, and the other would be open for public play. A single-story lodge is also being considered as low-impact resort accomodation for the prospective golfers. Permits are currently being sought, even though nothing would be built for another ten to 15 years (personal communication, Kuulei Kaio, Office Manager, Mokuleia Land Company, December 11, 1990).

Haleiwa/Kawailoa: The Kamehameha Schools/Bishop Estate (KS/BE) owns about 800 acres to the southwest of the Primary Study Area. Preliminary plans for long-term development were shared with the North Shore community. Possible components of new development under discussion included a dude ranch, a marine park, and housing (Tune, 1989).

The more than 350 acres of KS/BE land at Kawailoa, leased by Meadow Gold Dairy until 1989, are to be leased for pasture in the short-term future. A tentative masterplan offering alternative uses for the next two to three years is currently under examination by the Trustees. Potential uses for the site include a golf course, with major community-oriented facilities (personal communication, Elaine Brown, North Shore Land Manager, Kamehameha Schools/Bishop Estate, December 10, 1990).

3.1.2 Recreational Development

Golf Course Proposals: If somehow all the golf courses proposed for the study area were built, the total including the existing Kuilima course and the nine-hole Kahuku municipal course, would come to 14 courses. (See Table 3-1 for a list of proposed courses.) However, some of these projects have indefinite timetables. Developers in many cases hope to proceed when the approval climate for courses on Oahu is more favorable.

One new course is currently under construction; all the others listed in Table 3-1 are proposals, for which no land use permits have been obtained. Resort courses were mentioned in Section 3.1. Other proposals are:

- The Campbell Estate proposes four courses: three at Punamano (near Kuilima) and one at Malaekahana (near Laie). All would be 18-hole courses open for public

TABLE 3-1: STUDY AREA GOLF COURSE PROPOSALS

Location	Nearby Town	Owner/Developer	Number of Courses	Total Number of Holes	Comments
KOOLAULOA DEVELOPMENT PLAN AREA					
Kuilima	Kahuku	Asahi Jyuken	1	18	First course under construction. Second scheduled for 1993.
Punamano	Kahuku	Campbell Estate	3	54	EIS prepared; no current plans announced to seek permits.
Malaekahana	Laie	Campbell Estate	1	18	EIS prepared; no current plans announced to seek permits.
Malaekahana	Laie	Asahi Jyuken	1	18	EIS prepared; no current plans
NORTH SHORE DEVELOPMENT PLAN AREA					
Lihi Lani	Sunset Beach	Obayashi Hawaii, Inc.	1	18	Seeking permits.
Kawailoa	Haleiwa	KS/BE	1	18	No current action. (Long-term development plan not finalized.)
Mokuleia	Waialua	Mokuleia Land Company	2	18	Currently seeking permits; construction proposed for 10+ years from now.
Kaukonahua Road	Waialua	Castle & Cooke	1	18	No current action.

SOURCES: Personal communications with developers or their agents, December, 1990.

play. Two clubhouses would service the Punamano courses, while the Malaekahana course, being much further away, would require its own clubhouse and support facilities.

Although an Environmental Impact Statement has been approved, no public announcement to seek permits has yet been made. In any event, Campbell Estate hopes to have construction underway within three years, with completion anywhere from four to six years after initial work begins (personal communication, Chuck Ehrhorn, Development Manager, Campbell Estate, December 12, 1990).

- The company that owns the Kuilima Resort also has 225 acres of land at Malaekahana, currently used to graze cattle, on which it plans to develop an 18-hole course. No date for development is scheduled (personal communication, Alan Nii, General Counsel, Asahi Jyuken, December 11, 1990).

- Castle & Cooke Properties, Inc. proposes at some future date to construct an 18-hole golf course and clubhouse for public use on their Weed Junction-Kaukonahua Road site, mauka of Haleiwa (personal communication, Wallace Miyahira, Residential Development Manager, Castle & Cooke Properties, Inc., December 10, 1990).

It seems reasonable to conclude that the number of courses in the study area by the year 2010 would be fewer than the number now existing and proposed, due in part to critical responses by Oahu citizens and government, in part to the likelihood that the construction of new courses, whether in the study area or elsewhere in Hawaii, will lower demand for additional golf courses. Consequently, some developers may find golf course development less advantageous in the future than it now seems.

Parks: Since Koolauloa and the North Shore are two of the few areas left on the island with little shoreline development, the Honolulu Department of Parks and Recreation is actively pursuing a program of beachfront land acquisition and beach park expansion in the study area (personal communication, Don Griffin, Advance Planner, Facilities Development Division, Department of Parks and Recreation, December 14, 1990).

Additional parcels have recently been acquired for Kaaawa Beach Park and Waialee Beach Park, where expansion will occur as funds become available. The City also recently acquired Kakela Beach Park between Laie and Hauula, 11 acres of which the City hopes to use as a campground. Demolition and rebuilding are underway at Hauula Beach Park, and funds have been budgeted for the Aweoweo, Kawailoa, and Kokololio beach parks. Other expansion projects for the future include the following beach parks: Laie, Makaleha, Mokuleia, Puuiki, and Sunset. Major plans for the North Shore parks center on improving vehicle access and providing ample parking, especially at the most popular surf areas.

The only privately funded park project in the study area is the Kuilima Resort plan to dedicate a 4.8-acre public park at Kawela Bay and a 37-acre park near Kahuku Point. Two private parks are also planned within the resort: a six-acre park next to Punahoolapa Marsh and two acres at Hanakailio Beach at the resort's eastern end.

Waimea Falls Park, an attraction combining botanical gardens and Hawaiian cultural performances, is currently undergoing extensive repairs needed because of flooding. Plans are afoot to create larger gardens in the Park, and to provide more extensive cultural presentations. A general improvement of services is planned, entailing additional food, beverage, and gift outlets, along with an expansion of recreational facilities in the Park's northern valley (personal communication, Robert Leinau, General Manager, Waimea Falls Park, December 10, 1990).

3.1.3 Additional Proposals and Projects

Haleiwa has seen much recent commercial growth. Both commercial and light industrial expansion are possible, given continuing visitor income, should long-term leases become available. In addition to the Lihi Lani project and the sketchy resort proposals noted above, government actions are proposed for the North Shore, including:

- **Dillingham Airfield:** The State at present leases the airfield from the Department of the Army. It hopes to buy the field and expand it to service more small private aircraft. Dillingham's main purpose would then be to help alleviate the congestion faced by Honolulu Airport. The State is also considering placing a Honolulu Community College flight training school at the site (Edward K. Noda & Associates, Inc., 1990).

- The State anticipates eventually building a civic center for Haleiwa when the population of the region grows sufficiently to warrant it. Some development will occur on the 1-acre site of the old district court in Haleiwa, but no details are yet planned (personal communication, Alan Sanborn, Head of Tax Planning Branch, Department of Accounting and General Services, December 14, 1990).

In the Koolauloa Development Plan Area, new projects are focused in the Kahuku area:

- **Kahuku Light Industrial Park:** In 1989, the City and County approved a Development Plan amendment for a light industrial park of 28 lots (on 14.9 acres) adjacent to the Kahuku Sugar Mill. A 1992 completion date was planned, but that timetable is now on hold. The park will eventually provide approximately 200 permanent jobs (personal communication, Chuck Ehrhorn, Development Manager, Campbell Estate, December 12, 1990).

- **Kahuku Hospital:** Major renovations costing $1.5 million at the Kahuku Hospital are already underway, and will continue for some time. Construction of a new wing for same-day surgery patients will begin in 1991 and be completed by 1994 (Brian Stocker, Campaign Director, Community Counseling Services, December 11, 1990).
- **Kahuku Sugar Mill:** The Mill owners propose to erect a Landsborough maze of 35,000 square feet on its property in 1991. Additional parking lots are also planned in order to cater for the visitors the maze will attract (personal communication, Warrene Willard, Manager, Kahuku Sugar Mill, December 10, 1990).
- **Amorient Aquafarm:** Located makai of Kamehameha Highway between Kahuku and Kuilima, the Amorient Aquafarm has 40 acres of land, presently lying fallow, that it plans to use in expanding its shrimp farm operations. More than 30 new shrimp ponds with access roads are planned to go into operation within the next 18 months (personal communication, Linden Burzell, Manager, Amorient Aquafarm, December 13, 1990).

3.2 CHANGES IN EMPLOYMENT BASE

Operations at the completed Kuilima Resort facilities are expected to generate approximately 3,360 direct on-site jobs, and a further 1,210 direct, indirect, and induced jobs throughout the region. Phase I operations alone could provide 3,000 or more direct (including on-site), indirect, and induced jobs in the region.

Other major employers have indicated in interviews with Community Resources that their actions could lead to an approximate 2,500 new jobs over the next decade. This estimate includes new jobs created at light industrial and commercial areas. Many of these jobs could also be the indirect and induced jobs estimated as impacts of the Kuilima expansion. Others depend on timetables that are highly indefinite. Hence the total number of new jobs in the study area by 2000 can best be expressed as a broad range, from 4,000 to 6,000 jobs.

Due to the large number of union jobs that the resort expansion will bring to the region, many study area employers expect to have difficulty in finding and retaining staff. Wage levels will increase throughout the area. Consequently, study area jobs will become somewhat more attractive to workers living either in the area or nearby.

3.3 HOUSING AND POPULATION TRENDS

Besides the Lihi Lani project, there are no major proposals for additions to the Primary Study Area's housing stock. Elsewhere in the study area, Kuilima Resort proposes to erect approximately 200 affordable units outside the resort.

One major ongoing residential development is in Kahuku. The Kahuku Housing Corporation began construction of 289 units in 1987. Current construction is now overseen by the Kahuku Village Association. Approximately 177 units remain to be built by 1993, 106 of which are reserved for Kahuku sugar plantation families (personal communication, Mei Maghanoy, Manager, Kahuku Village Association, December 12, 1990).

The need for additional housing in Laie has been recognized by Zions Securities and the community. Plans for growth of the town, including new housing, have not yet been finalized. In Hauula, plans for a low- to moderate-income rental housing development of 114 units and for a school for autistic children, all on 18.5 acres, have been delayed due to infrastructural concerns.

With greater employment opportunities in the study area, increased demand for housing is likely. However, in-migration to the study area from other parts of Oahu may be affected by controls on new housing construction. The "development capacity" of the study area -- the number of housing units that could be added to the existing stock in areas now designated for residential use -- has been estimated (Honolulu Department of General Planning, 1990):

North Shore DP Area	1,260 units
Koolauloa DP Area	1,035 units

Total Study Area	2,295 units

The population that could be supported in those units, given city assumptions about likely household sizes in the different Development Plan Areas, is estimated as:

North Shore DP Area	4,000
Koolauloa DP Area	4,000

Total Study Area	8,000

It is not certain that the number of new housing units likely to be built and made available to residents, rather than to transients (such as surfers) will be adequate to meet demand for homes for study area workers.

3.4 PUBLIC FACILITIES AND INFRASTRUCTURE

Roads. The largest proposed infrastructural change affecting the North Shore is the State's 2.3-mile Haleiwa Bypass Road. The project, which includes five bridges, will divert circle-island traffic from the more congested districts of Haleiwa. Some work has begun, and major construction is due to start in early 1991. The bypass should be fully operational by mid-1993, given sufficient funding (personal communication, Herbert Tao, Project Manager, State Department of Transportation, December 11, 1990).

In Haleiwa itself, the City proposes to widen Kamehameha Highway to 50 to 60 feet, and improve the sidewalk along the Highway. Eventually, the City intends to upgrade Haleiwa Road and portions of Waialua Beach Road.

Extensive realignment and improvement of the Kamehameha Highway fronting the Kuilima Resort area will be carried out by the developer, subject to State approval.

Wastewater. New wastewater treatment plants are, according to recent City plans, to be built within six years at Hauula-Punaluu and Mokuleia. If need arises, a separate facility will be built at Haleiwa. At a later date, wastewater plants would eventually be built for the Pupukea-Sunset Beach area and Kaaawa.

The City is currently investigating the feasibility of alternatives to ocean outfall for the North Shore projects, partly in response to resident concerns. At the Mokuleia site, for example, processed effluent likely can be used to create a wetlands bird sanctuary (personal communication, J. Hamai, Civil Engineer, Planning Section, Department of Public Works, December 11, 1990).

The Kuilima Resort is developing a plant for its needs. Construction on the sewerage system is already underway, and plans for wells, pump stations, and drainage are close to fruition.

Expansion of the Kahuku Wastewater Treatment Plant, to twice its current size, is being funded by a combination of City, State, and private sources (personal communication, J. Hamai, Civil Engineer, Planning Section, Department of Public Works, December 14, 1990).

In Laie, the existing plant has proved unable to meet the demands of the community. Expansion will begin in November 1991 and take almost a year to complete. Processed effluent from the plant will be used as irrigation and fertilizer for farms in the Laie district (personal communication, Don Kleinman, Project Co-ordinator, Zions Securities, December 12, 1990).

Water Supply. The Board of Water Supply has extensive plans for developing new sources of potable water in Windward Oahu in anticipation of increased demand throughout the whole island. Many of these projects are concentrated in the vicinity of the Koolauloa-Koolaupoko boundary, but wells are slated for much of the study area. Also, a new main will be installed from Pukea Road to Crawford's Convalescent Home.

Fire Protection. The City has long-term plans to build fire stations at Kawela and Laie, and to replace the existing station at Kaaawa. Funds have been appropriated to reaplace the existing Sunset Beach station in the next two years in order to provide improved services (personal communication, Chief Leonardi, Battalion Chief, Administrative and Services Bureau, Honolulu Fire Department, December 17, 1990.

4.0 COMMUNITY ISSUES AND CONCERNS

4.1 OVERVIEW

This section describes a complex history of dialogue between Obayashi Hawaii and members of the study area community. Major events are listed. Next, special attention is given to actions and views of the Joint Planning Committee (JPC), a group of concerned residents of the primary study area working with the project's representatives to identify ways the project can be made compatible with community character and desires. Following this, the issues and concerns expressed by community members are discussed. Finally, many of the ways in which the project is responsive to community concerns are specified.

Since a recreational community was proposed in 1987, Obayashi Hawaii has been engaged in dialogue with study area residents. The current proposal has been developed through a continuing community involvement process. Information has been shared at informal gatherings and public meetings, through mailings, and in site tours. Both task forces focusing on particular aspects of the project and the JPC have provided community input used by Obayashi Hawaii and its planners to revise the project plans.

Over three years, a wide range of community concerns has been voiced. Nearly all dealt with earlier project plans or alternative concepts, not the current project design. Many issues raised with regard to earlier plans may no longer apply to the project.

Major areas of concern have included:

- Environmental issues, such as measures to avoid groundwater contamination;
- Compatibility of the project and its residents with both the general character of the area and with the specific communities adjoining the project site;
- Public access to the project;
- Affordable housing;
- Traffic;
- Employment;
- Recreational opportunities for study area residents; and
- Impacts on Sunset Beach Elementary School, situated near the project's portion of Kamehameha Highway.

Many of these issues were raised with regard to a project concept that aimed nearly exclusively at an upscale market. Along with other measures, the inclusion of an affordable housing component, the expansion of the trail system, the change from two golf courses to one, and the designation of a site and funds for community facilities have been the developer's major responses to community input.

Information for this section derives in part from prior involvement by Community Resources, Inc. (CRI) with the project. CRI staff prepared an assessment of the earlier proposal for Lihi Lani and attended community meetings in 1988 and 1989. CRI staff developed lists of issues raised in public meetings during that period. Interviews and conversations with many study area residents occurred at that time. Next, CRI staff reviewed the project files kept by Group 70 Limited and noted issues and concerns raised by residents. Comments by residents at a 1990 meeting, noted on a survey concerning three alternative uses for the project site, were also analyzed. Residents concerns expressed in newspapers and in the newsletter published by Obayashi Hawaii were also noted.

Resident members of the Joint Planning Committee were asked (in December 1990) for interviews concerning community views about the current project plans. They preferred to respond as a group, rather than individually, but did not have time to prepare a statement before this report was finished.

4.2 THE COMMUNITY INVOLVEMENT PROCESS

Early Interactions. Obayashi Hawaii's initial involvement with the community consisted of presentations to the North Shore Neighborhood Board (No. 27), community associations, clubs, and other groups in the study area in 1987 and early 1988. The presentations were announced as intended to initiate a dialogue so the developer and project planners could get input from the community.

One outgrowth of the initial interactions with the community was the formation of a group strongly opposed to the project. A petition claiming that the development was not in keeping with the North Shore's "country" character was submitted to the State Land Use Commission in early 1989. (For further discussion of the issue of "country" character, see sections 5.2.5 and 5.7.2.)

Community Advisory Group Meetings. In February, 1988, Obayashi started a series of open community meetings. These Community Advisory Group (CAG) meetings were held as often as every two weeks for a year. The number of area residents attending the CAG meetings varied from as few as 10 or 20 to as many as 50 or 60.

The CAG meetings provided a context to raise and discuss issues and concerns. Also, technical information regarding traffic, sewage, water usage, environmental effects and social impacts was presented to residents.

Obayashi initiated the formation of three smaller committees out of the CAG. Hiking, Equestrian, and Golf Committees assessed the recreational needs of the community and answered questions about the specific recreational activities proposed. Each committee had at least one member connected to Obayashi Hawaii's planning and community involvement effort.

Meeting participants' reactions to the initial master plan were noted in the CAG minutes. Many residents of the North Shore continued to express dissatisfaction or specific concerns with regard to the plan.

North Shore Neighborhood Board Presentations. North Shore Neighborhood Board (NSNB) minutes reflect three separate presentations made to them by Obayashi Hawaii or the Joint Planning Committee. The presentations were made in April 1988, July 1988, and July 1990. An update on Obayashi Hawaii's plan is scheduled for January 1990.

The first presentation, made in April 1988, was a brief introduction to preliminary plans for a golf course and residential development in Pupukea. The next presentation was made three months later in July 1988. At that time Obayashi representatives told the Board about the project in some detail and distributed a "Community Issues and Concerns" fact sheet.

The September minutes of the Neighborhood Board indicate that the Board was asked to submit comments regarding the project to the Department of General Planning. No official vote for or against the development was made, but a list of concerns was submitted. In November 1988, a committee was appointed within the NSNB to keep the Board up to date on plans for the property.

The most recent presentation to the NSNB was made by the JPC in July 1990. At that time the Board was informed of the work of the JPC on the Master Plan for the Obayashi property.

Additional Presentations and Community Involvement Efforts. The developer's representatives continued to give presentations to various community groups in 1988 and 1989.

In February 1989 Obayashi Hawaii Inc. withdrew its petition to reclassify 813 acres, with the explicit aim of developing stronger community involvement with the project. The withdrawal meant a delay of at least a year before the petition could be resubmitted.

CAG meetings were held less frequently after the withdrawal, and ended in mid-1989. New efforts at community involvement were begun. A newsletter, Lihi Lani News, was first circulated in March, 1989. In May, the Lihi Lani Information Center opened in the Haleiwa Shopping Center.

Throughout the spring, summer, and fall of 1989, site tours were conducted. The Equestrian and Hiking Committees took group tours of the site. Tours were also conducted by vehicle. Initially the tours were advertised and scheduled for every Saturday.

Comments written by North Shore residents after taking the tours were generally positive. People were glad to be able to see the property and get a better understanding of the project concept.

Formation of the Joint Planning Committee. In September 1989, the Joint Planning Committee (JPC) was organized. The formation of the JPC was initiated at the suggestion of the Sunset Beach Community Association and the Pupukea Highland Community Association. The principal objective of the JPC was to evaluate future uses of the property that would be acceptable to the community and the developer.

The Joint Planning Committee started as a group of nine people, three from Pupukea Highlands Community Association, four from Sunset Beach Community Association, and two representatives of Obayashi Hawaii. Community members of the JPC were selected by the executive boards of their respective associations. Meetings were held every two weeks for the first few months, then weekly for the past eight months.

The Joint Planning Committee currently consists of three members of the Sunset Beach Community Association, three members of the Pupukea Highlands Community Association, and two or three Obayashi representatives.

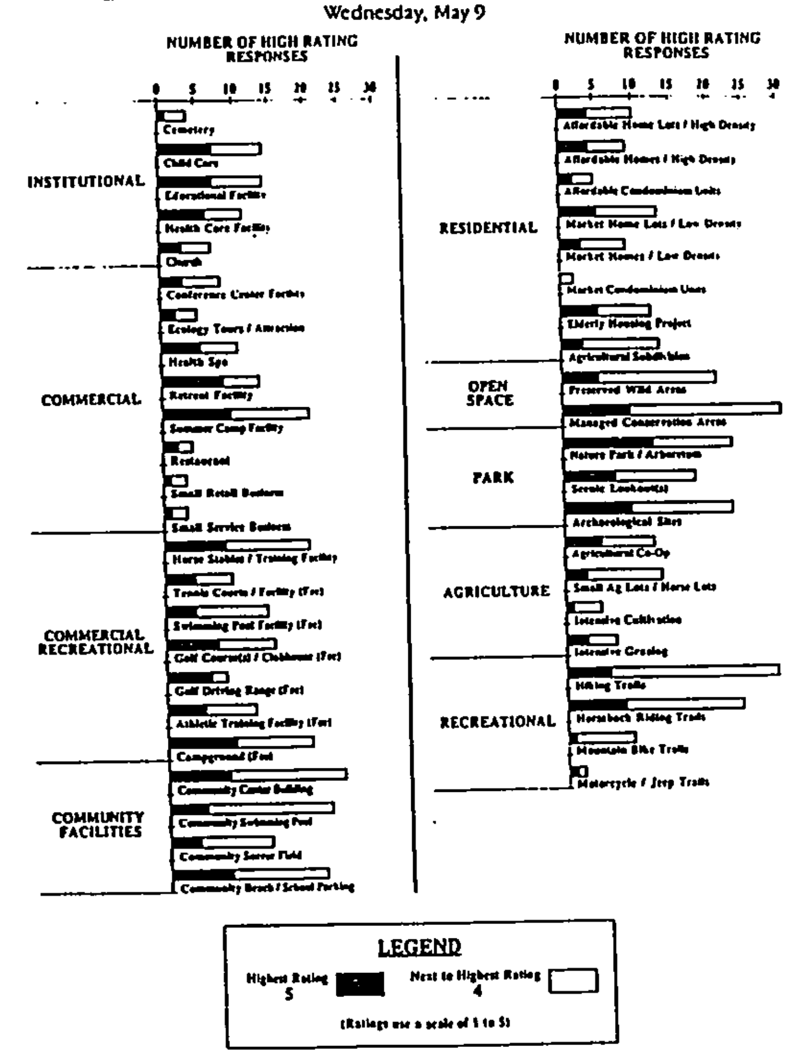
Presentations of Land Use Alternatives. The regular JPC meetings were small working sessions. The JPC also coordinated four public meetings which were advertised throughout the study area. The first public meeting was held in December 1989. Alternate land uses were discussed and a survey was completed by thirty respondents. A summary sheet of the community survey questionnaire results was prepared by the JPC. It indicated that the most popular land use preferences were, in order: park use, agricultural use, recreational use, and residential use. The summary also included concerns over potential adverse impacts. (These concerns are detailed in Section 4.3.)

The second open JPC meeting was held at the Sunset Beach Elementary School in May. Approximately 35 community members attended. Land use alternatives were presented and a survey was completed. Results of that survey were published in the June 1990 JPC Update. The land uses rated the highest were: managed conservation areas, preserved archaeological sites, hiking and horseback riding trails, and horse stables/training facilities. Recreational uses were thus valued, while commercial uses received the lowest ratings. Residential land uses were rated highly by 40% of those surveyed. (see Figure 4-1.)

FIGURE 4-1:

LAND USE ALTERNATIVES SURVEY RESULTS

Wednesday, May 9



Source: JPC UPDATE, June 1990

Principles for Development. Drawing on comments and suggestions from the open meetings, the JPC started compiling a set of principles for the development of the Obayashi property. The current list of guidelines includes 16 points, listed in Table 4-1.

Alternative Plan Presentations. Using the results of the December and May land use surveys, the JPC put together more specific plan alternatives.

The third JPC community meeting was held in July 1990 in Sunset Beach. At that time seven alternative plans were explained by the JPC. The community members were asked to rank the alternatives by order of preference. There were 42 responses to the questionnaire. The alternative plans were titled and briefly described as follows:

(1) Large Scale Agriculture:
- prime Ag land - 328 acres, suitable for sugar cane, pineapple, vegetables/truck crops
- other Ag land - 238 acres, suitable for tree fruit orchards, vegetables/truck crops

(2) Agricultural Subdivision:
- 350 lots, minimum size 2 acres
- community facilities

(3) Recreational
- golf course and golf clubhouse
- tennis/health club
- equestrian center
- summer camp/retreat/campground
- hiking/riding trails
- community facilities

(4) Country Zoning/Recreational
- 250 lots, minimum size 1 acre
- community facilities
- equestrian center
- tennis center
- campground
- hiking/riding trails

(5) Country Zoning/One Golf Course
- 200 lots, minimum size 1 acre
- golf course and golf clubhouse
- community facilities
- equestrian center
- tennis center
- campground
- hiking/riding trails

TABLE 4-1: JOINT PLANNING COMMITTEE GUIDELINES

Any future use of the property shall comply with the following minimum requirements:

1. It will not cause an increase in soil erosion.
2. It will not cause an increase in silt and suspended sediment in run-off from the property.
3. It will not cause an increase in the rate of storm water run-off from the property.
4. It will minimize the reduction of vegetation on the property.
5. It will utilize brackish water in place of potable water where possible for irrigation water uses, and establish irrigation water conservation measures.
6. It will minimize the amount of potable water used, and establish potable water conservation measures.
7. It will control the application of fertilizers and pesticides in a manner consistent with an Integrated Pest Management (IPM) program.
8. It will preserve the most significant archaeological resources on the property, and properly document any other sites that would be affected.
9. It will minimize the impact on vehicle through-traffic along along Kamehameha Highway.
10. The visual impact of any new use of the property will be minimized. Any access road to the project shall be designed to minimize views of the roadway, bench cuts in the bluff and vehicles. Any structures developed on the site should be located and designed to minimize their visibility from off-site. Any use of lights on the property should not be intrusive at off-site locations.
11. Noise generated by any new construction and post-construction activities on the property will be minimized.
12. It will insure that any toxic sprays and gases, dust and/or noxious odors generated or released on the property do not reduce air quality in neighboring communities.
13. It will include some recreational usage by the community.
14. It will create an overall image which is similar to the image and feeling experienced in Pupukea Highlands, and other rural country areas of Hawaii.
15. Disposal of sewage shall have no deleterious effects on the surrounding ecosystems, including the ocean. An ocean outfall shall not be used to dispose of sewage effluent.
16. It will not cause an adverse impact on ocean water quality and ocean ecosystems.

(6) Country Zoning/Two Golf Courses,
- 160 lots, minimum size 1 acre
- golf course and golf clubhouse
- community facilities
- equestrian facilities
- tennis center
- hiking/riding trails

(7) Country Zoning
- 560 lots, minimum size 1 acre
- community facilities

Plan 5 received more votes (15) than any other. (See Figure 4-2.) Comments and suggestions from the meeting generally show the desire for recreational use and low density affordable housing. Agricultural land use was thought to be economically unrealistic. Environmental concerns were raised regarding all of the alternatives presented.

The fourth open JPC meeting took place in August at the Sunset Beach Elementary School. Approximately 140 community members attended the meeting. The purpose of the meeting was to identify preferences among three refined land use concepts. Four choices (described in more detail in Table 4-2) were presented:

(1) Country Zoning/Recreational
(2) Country Zoning/One Golf Course
(3) Country Zoning/One Golf Course/Agriculture
(4) Other

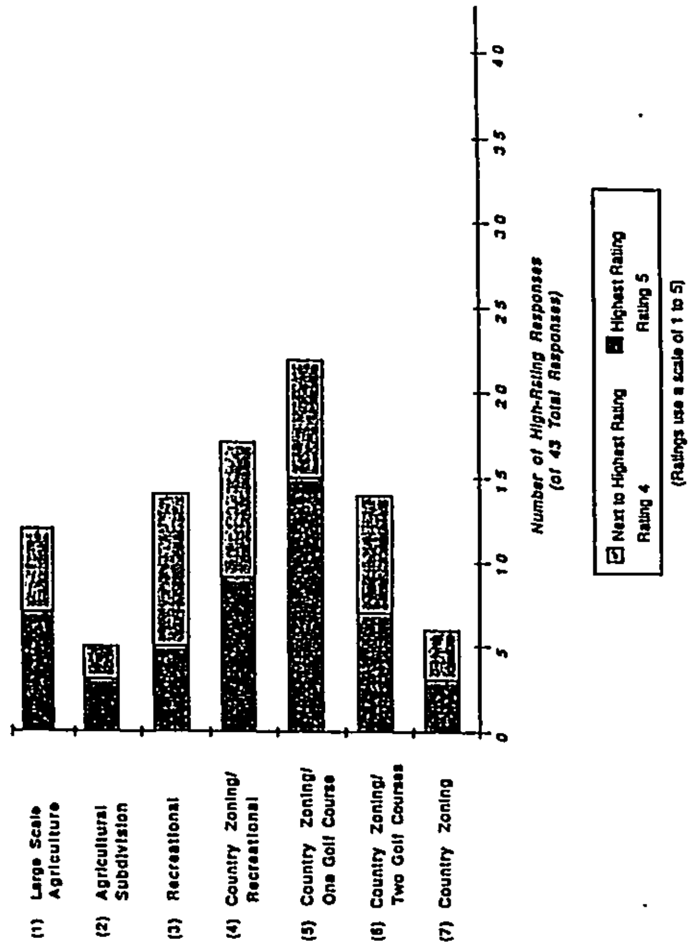
Approximately 38 people left the meeting before the surveys were completed; 102 survey responses were completed. The instructions were to select only one concept and select "Other" only if the land use concept was very different from the three provided. Nonetheless, "Other" gained the most votes, followed by Concept 2, on which the current proposal is modeled. (See Table 4-2 for votes.)

Of the 102 surveys, 69 had comments. These were reviewed and summarized by CRI (Table 4-2).

The JPC concluded from the survey of August 22, that there was no clear community consensus about the future use of the property. However, comments made in the survey seemed consistent with meetings and discussions over the previous months. A strong preference for affordable low-density housing is mentioned in many surveys.

Following the JPC evaluation of the August 22 meeting, Obayashi Hawaii considered the information and comments. Drawing on indications of community support for specific land uses -- one golf course, hiking and riding trails, affordable housing, community facilities, and campgrounds -- Obayashi developed a new master plan. That master plan is the basis for the current development proposal.

FIGURE 4-2:
OBAYASHI PROPERTY
ALTERNATIVE PLAN PREFERENCE SURVEY
11 JULY 1990 COMMUNITY MEETING



Source: Group 70 Ltd.,1990.

TABLE 4-2: LAND USE CONCEPTS REVIEWED AT AUGUST 1990 JPC COMMUNITY MEETING

Concept #1 Country Zoning/Recreational

- 160 market lots (one-acre minimum)
- 240 affordable lots (6,000 sq. ft. minimum)
- equestrian center, tennis/health center, campground

Number of persons preferring: 9.

Survey Comments
(*) indicates number of people with the comment

(1) no development
(1) agriculture land
(1) fewer units
(1) larger affordable lots (1/4 acre)

Concept #2 Country Zoning/One Golf Course

- 120 market lots (one-acre minimum)
- 180 affordable lots (6,000 sq. ft. minimum)
- equestrian center, tennis/health center, campground
- one 18-hole golf course, clubhouse & driving range

Number of persons preferring: 33.

Survey Comments
(*) indicates number of people with the comment

(6) add 1 golf course
(3) open pavilion/campground with cabins/soccer baseball field
(2) affordable golf
(2) area for children (swings/seesaw)
(2) affordable housing
(2) community facilities
(1) if roads can be developed to handle traffic
(1) affordable housing off-site
(1) no golf course
(1) protect archaeological & historical sites
(1) emergency shelter
(1) agriculture not viable
(1) equestrian area not smell

TABLE 4-2 (Cont.):

Concept #3 Country Zoning/One Golf Course/Agriculture

- 120 market lots (one-acre minimum)
- 180 affordable lots (6,000 sq. ft. minimum)
- 100 acres agricultural lands conserved
- equestrian center, tennis/health center, campground
- one 18-hole golf course, clubhouse & driving range

Number of persons preferring: 12.

Survey Comments
(*) indicates number of people with the comment

(1) Best feasible but need more definition
(1) Eliminate golf course
(1) Community facilities
(1) Day care center
(1) Elder care center
(1) Low density housing
(1) Add one golf course
(1) Good because ag homes and 1 golf course

Concept #4 Other

Number of persons preferring: 48.

Suggestions: Residential/ Conservative/ Agriculture
Residential/ Two Golf Course
Agriculture/ Cluster
Affordable Housing Only
Agriculture/Recreation
Ecology Research Site
Recreation Only

Survey Comments
(*) indicates number of people with the comment

(15) No zoning change
(11) Traffic/Access
(8) No opinion/ Need more data
(6) Improve infrastructure first
(4) Study area impacts first
(4) Recreational only/ leave alone
(4) Affordable housing
(4) Density less than 400 houses
(3) Sewage, Erosion, Run-off
(2) Need for agriculture lots
(1) No golf course
(1) Two golf courses
(1) Chemical usage

The JPC continues to meet. The focus of the group has changed somewhat. They will continue their community outreach efforts by making further presentations to community groups, such as the one scheduled for the North Shore Neighborhood Board in January. They are also reviewing specific plans for community facilities and discussing how to involve the wider community in that process.

There has been some discussion about the creation of a bilateral agreement between the community and the developer to spell out the developer's commitments. The JPC could be involved in drafting such a document.

Through the efforts of City Council member Rene Mansho, a task force to initiate a regional master plan for Central Oahu and the North Shore has been formed. The task force has begun informal meetings. Obayashi representatives and the JPC hope to work with the task force in 1991.

4.3 ISSUES AND CONCERNS RAISED WITH REGARD TO DEVELOPMENT PROPOSALS AT LIHI LANI

The community issues and concerns discussed in this section are drawn from several different sources spanning the time of the initial proposal to the present.

4.3.1 Overview

The proposal to develop Lihi Lani elicited response from residents all along the North Shore. Study area residents attended community meetings to find out more about the project and voice their views. Residents in closer proximity to the project have somewhat different concerns than those residents living farther away. Most residents of the entire study area, however, are concerned about the cumulative effects of development on the North Shore.

The majority of the people at the CAG and JPC meetings were primary study area residents. They expressed concern about immediate impacts that the development might have on their community. Environmental impacts and traffic congestion were almost always the first topics of discussion at community meetings.

Residents of the secondary study area expressed strong concern about traffic, and the overall impact of development on the North Shore. They were also interested in the potential employment generated by the development for residents of the North Shore.

Some area residents are hopeful that the developer might help with current problems, so these concerns were expressed for discussion at the meetings too. Some Sunset Beach residents have looked to the developer for help in developing regional sewage systems.

Many of the issues raised have to do with the physical environment. Residents are concerned with potential impacts on their own homes, or beaches and surfing areas they use, and on the special qualities of their region. In short, these issues, like many of the social concerns described here, imply desire to preserve the area with few changes.

Even though environmental impacts were a primary concern of residents, these will be listed last in this section and not covered in detail. These are addressed in the Environmental Impact Statement and by other consultants. Potential ocean water and fresh water pollution, handling of sewage, and soil erosion were most frequently discussed.

Social concerns, such as seeing that the development fits with the area's "country" character, were also mentioned often by residents.

In general, residents of the community liked the idea of affordable housing, but there was some debate about the desirability of locating it on the project site. Residents expressed the desire for all project housing to be low density.

Major community concerns about the project are summarized in Table 4-3. The order of the non-environmental issues is based on a judgment of frequency with which these issues were raised by residents, with the most frequent listed first.

Unless otherwise noted, the issues discussed are those mentioned by many people, not just members of an identifiable group.

4.3.2 Socio-Economic Concerns

Rural Character: The primary social issue has been the character of the proposed development. Residents of the North Shore want to "keep the country country", and they have been concerned that the project will go against that aim.

Foreign Ownership: One initial reaction to the proposed development was concern that the project will be an upscale resort run by and for the Japanese. Because of its foreign ownership, residents were concerned that the project would cater to affluent Japanese nationals and would not be affordable for North Shore residents.

Residents were concerned that golf memberships would be sold to only the Japanese.

TABLE 4-3: ISSUES AND CONCERNS RAISED WITH REGARD TO DEVELOPMENT PROPOSALS AT LIHI LANI

GENERAL SOCIO-ECONOMIC ISSUES AND CONCERNS
- Is project incompatible with aim to "keep the country country"?
- Is the development just for the benefit of affluent Japanese nationals?
- Will the project be within finacial reach of area residents?
- Will the project change in lifestyle of the existing community?
- Is changing the designation of Agricultural land required?
- Will there be job opportunities (construction and operational) for North Shore residents and businesses?
- Will there be added traffic?
- Is there genuine commitment to the community from the developer?
- What will the visual impact from Kamehameha Highway be?

HOUSING AND LOTS CONCERNS
- How dense will the housing be?
- Is it appropriate to have affordable housing on site?
- Will there be restrictions on land use of individual lots?
- Will there be homes built on steep slopes?

IMPACT ON ADJACENT GROUPS
- What will happen to the tenant currently on the property?
- How many access roads will there be, and where will they be located?
- Will there be an increases in adjacent land prices and property taxes?
- What are the plans for the 30 acre parcel beside the Elementary School?
- Will the developer substitute more intensive land use if grazing land is not economically feasible?
- Will there be increased traffic at Sunset Hills?

COMMUNITY BENEFITS
- Recreational facilities are needed on the North Shore - what facilities will Lihi Lani provide the community?
- How accessable will the facilities to public?

ENVIRONMENTAL CONCERNS
- Will there be water pollution from fertilizers, pesticides, sewage?
- Will there be a depletion of the water supply?
- Will there be coastal water pollution from chemical run-off?
- Will the development make the current erosion problems better or worse?
- Will there be increased erosion during construction?
- How many trees will be cleared?
- Will the archeological sites be protected?
- How will the rare trees near the site be protected?
- Will there be a loss of natural beauty?

Change in Lifestyle: Area residents have expressed concern that the project will initiate a change in the lifestyle of the area. Some in Sunset Hills have seen the project as a way to improve the area. However, others in Pupukea Highlands viewed the development as a threat to their present lifestyle.

Agricultural Land: The proposal to change the designation of Agricultural land to any other designation has raised concern from a broad base of North Shore residents. Many believe that rezoning forever changes the natural state of the land. It was the opinion of some that the land should keep some kind of Agriculture designation that would allow large housing lots without "all of the frills". This concern is tied to the desires of maintaining a rural atmosphere and keeping the housing density low.

Employment: North Shore residents have been interested in employment opportunities that the project may create for people in the area. A detailed explanation of the project's short-term and long-term employment impacts is presented in Sections 5.2.1 and 5.2.2. The desire of North Shore residents and businesses is that they will be able to benefit from the employment opportunities at Lihi Lani.

Traffic: The traffic situation on the North Shore is of great concern to the community. Any discussion of the possibility that the project would add more traffic was an issue. Traffic is covered in detail in a separate consultant's report.

Intentions of the Developer: Many people in the community have expressed suspicion about the intentions of the developer. They would like to have a legally binding agreement between the community and the developer so that plans for community benefits do not change. Generally, residents expressed appreciation for the efforts by Obayashi to initiate community involvement. But some apprehension remains that the developer may not deliver its promises.

Visual Impact: Many have shown concern about the possible visual impact of the project from Kamehameha Highway. Residents frequently mentioned their concerns about the visibility of roads and buildings on the project property from outside the boundaries of the project.

4.3.3 Housing and Lot Concerns

Density of Housing: A frequently mentioned concern has been the density of the housing. Residential land use has been supported quite consistently by the area residents, with affordable housing more desired than market housing. However, a priority of residents for any housing was that it be low density.

Affordable Housing: A majority of the residents have been in favor of affordable housing on the project site. However, there

have been some area residents who felt that affordable housing would not be appropriate for the project and should be built off-site.

Uses of Lots: Some concern has been expressed about the possibility of restrictions on housing lots. For example, one person hoped that horses would be allowed on the lots, in keeping with the country feeling of Pupukea.

Some people who took tours of the property and saw the steep slopes expressed concern about the idea of placing homes in these areas.

4.3.4 Concerns Regarding Adjacent Groups

Displacement: Area residents have had some concern about the displacement of the current tenant of the property. People have also questioned how others who use the property for recreational purposes -- hiking, horse-riding, and motorbike-riding -- will be affected.

Access Roads: Many area residents have been concerned that the access road to the project from Kamehameha Highway will increase traffic congestion. They have also shown concern that project traffic could cause problems for those entering and exiting the nearby access to Sunset Beach Elementary School.

Some residents of Sunset Hills have expressed concern that an access road to the project through Sunset Hills would increase the traffic flow in their neighborhood. But others have agreed that an access road would be beneficial under circumstances of emergency. Evacuations from either Lihi Lani or Sunset Hills would be possible via such a road.

Surrounding property: Property taxes and prices of land in close proximity to the project were frequently discussed. Many have expressed concern that the project will cause an increase in their property taxes. There has also been concern over the possibility that nearby property prices will become too expensive for residents.

Project Property: An important economic issue to area residents has been the definition of affordability. They have questioned the reality of the term "affordable" and been concerned that the project lots will only be affordable to outsiders.

Other Impact Concerns: Residents have been curious about plans for the development of the 30 acre parcel of land next to the Sunset Beach Elementary School. Their concerns regarding development of the property have been the potential for further traffic congestion, and environmental impacts which may be detrimental to the adjacent land occupied by the Elementary School.

Some question about the economic feasibility of pasture and grazing land has been expressed by area residents. They have been concerned that the developer would seek a more intensive land use if these land uses do not prove to be profitable.

4.3.6 Recreational Component Issues

General Recreational Issues: It has generally been agreed by North Shore residents that recreational facilities are needed, and that they would greatly favor such facilities on the project site. However, accessibility of facilities to the public is one issue that has surfaced often. Residents have been afraid that they will not be able to take full advantage of the facilities because they will be too expensive, or because of other restrictions, such as available times for public use.

Committee Issues: The individual committees described in Section 4.2 raised specific issues relevant to their respective recreational activities. Some of these issues are listed below for the Hiking, Equestrian and Golf Committees. See Section 4.5 for an explanation of how the developer addressed these issues.

Hiking Committee Issues: The Hiking Committee met for one and a half years and made four hikes on the property. Topics for discussion included:

- trail guide and rules preparation
- parking space requirements
- exact areas where horse trails and hiking trails would overlap
- safety and erosion
- detailed trail layout
- trail surfacing requirements
- trail amenities (water, benches, and signs)
- maintenance operations
- access and security details

A trail system with prescribed widths was mapped out by the Hiking Committee. The trail system was recommended to be 11 miles rather than the initially proposed 6 miles. The natural quality of the trails adjacent to the residential and golf course sites was said to be questionable. However, the trails planned for mauka areas were said to have the best potential to become high quality hiking trails.

Equestrian Committee Issues: The Equestrian Committee discussed the following topics:

- evaluation of facilities being considered
- interest in use of property by 4-H
- liability issues
- trails network
- rates
- trails on the Kahuku side of the property

- evaluation of activities at the equestrian center
- width of trails

Golf Committee Issues: The Golf Committee reviewed the following issues:

- rates for Kamaainas and residents of Lihi Lani
- Number of times a year local residents can play at special rate
- rates for twilight or early morning play
- reservations and starting times
- Junior Golf Program
- local golf tournament

4.3.7 Environmental Concerns

Water Quality: Concern was expressed about the possibility of pesticides, fertilizers, and other chemical run-off polluting the coastal ocean waters and ground water. Most often this concern was expressed in connection with the golf course. The demand placed on the water supply was a further golf course issue.

Residents also expressed concern about sewage contaminating ocean and ground water.

Sewage: Other concerns regarding the handling of sewage were often mentioned. Odor and disposal of sludge were additional area resident concerns.

Residents were quite concerned about any impact the development would have on their present sewage system.

Erosion: Some residents who took a tour of the property were especially concerned about the erosion currently taking place. They were concerned that clearing of trees during the construction stage would exacerbate the current erosion problem and perhaps lead to mud contamination of the shoreline.

One resident expressed concern about the possibility of flooding the property makai of the project, presumably due to the clearing of land.

Archaeological Sites: The protection of archaeological sites on the property has been important to many people. Concern was expressed that some sites could be completely destroyed or damaged during the construction of the project.

Endangered Trees: At one point early in the planning process it was thought that there were some rare trees on the project site. In fact, the trees in question are on the property adjacent to the project. However, some feel that disruption of the adjacent project land during construction may harm the trees.

4.4 JPC INTERPRETATION OF COMMUNITY INPUT

The Joint Planning Committee has received continuing community input. In the latest JPC Update, of September 1990, the JPC gave an interpretation of the community input to date.

The resident members of the JPC are highly visible and active in their respective communities. As members of the North Shore community, their interpretation of the issues and concerns is especially valuable. The current Master Plan is intended to respond to the guidelines and concerns identified by the JPC.

In assessing the input of the community, the JPC looked at the results and comments of the August 22 survey and previous surveys given at the open community meetings in July 1990 and December 1989. The overall input led the JPC to the conclusion that there is no clear consensus about the use of the project property among the members of the community. However, there are some statements that can be made regarding the desires of the majority of community members.

The JPC felt that the following concerns have consistently been raised by the community:

- development impacts
- inclusion of a golf course
- density
- open space provision
- affordable housing on the project site
- development and zoning

A summary of the JPC interpretation of the listed concerns is below.

The problems of traffic and environmental impacts were raised. The total impact of all developments proposed on the North Shore, and the perceived inadequacy of infrastructure have also been frequently raised issues. The JPC guidelines (see Table 4-1) list the development parameters for Lihi Lani in detail.

More residents outside the Sunset Beach and Pupukea communities indicated support for golf courses in the August 22 survey. Approximately half of the people outside the Sunset-Pupukea communities voted for a concept which included a golf course. One third of the residents of Sunset-Pupukea voted for a concept including a golf course.

In keeping with the desire for a country community, residents are quite concerned with the density of homes, and the overall number of homes and open space provided by the project. The JPC concluded the following points:

- 160 market lots and 240 affordable lots are perceived as too many;

- open space, such as pasture and golf course, is desired over additional housing units; and
- affordable housing on-site seems acceptable, provided it is low density.

Approximately 28 percent of the people who took the survey have preference for no development at this time (14 votes), or development under the existing AG-2 zoning (15 votes).

4.5 PROJECT DESIGN AS RESPONSIVE TO COMMUNITY ISSUES AND CONCERNS

Obayashi Hawaii has stated that the current master plan has evolved from the JPC planning process and input from the community members residing in various areas along the North Shore. They believe the plans have been environmentally and socially designed to fit the rural fabric of the North Shore.

Issues and concerns raised with regard to development proposals were presented in section 4.2. In this section, CRI will present the major changes in the development plan that were made at least partly in response to community issues and concerns.

Residential. During the lengthy community interaction process, residents of the North Shore community indicated they were highly in favor of residential land use. In response to community input, Obayashi Hawaii has designed the current master plan to include more residential land use. Presently, the residential component of the development plan proposal includes 120 market lots and 180 affordable housing units, whereas the 1987 plan called for 160 market lots in the project.

Inclusion of the affordable units was made in response to the community desire to have more affordable housing available in the area. Obayashi Hawaii has attempted to clarify the definition of "affordable" as it will apply to this project in response to questions raised by the community. Preliminary plans call for 50% of the affordable units to be "affordable" to families whose income is between 80% and 120% of median income. The remaining 50% will be "affordable" to families whose income is between 120% and 140% of median income. Presumably, some of the housing available to those whose income is below 100% of median income will be rental units.

Most area residents wanted the affordable housing component built on the project site to insure that there would be a mixture of people with different economic backgrounds in the community. They felt that having a mixture of affordable and market homes would discourage any formation of an exclusive affluent community.

The residents' most important wish is that the development fit in with the present rural character of the North Shore. One of the JPC guidelines for the development of the property addresses this issue directly. The development will "create an overall image which is similar to the image and feeling experienced in Pupukea Highlands, and other rural country areas of Hawaii." Obayashi is planning to build low density housing with structures that are compatible with architecture currently in the North Shore community. Community covenants will impose similar restrictions on lot buyers.

Recreational. Obayashi Hawaii has made several changes in the recreational components of the proposed development in response to community requests.

- **Golf Course:** The current plan calls for the development of one semi-private 18-hole golf course rather than the two golf courses (one private and one semi-private) initially proposed. This is partly in response to community's desires not to have a private course.

  Another reason that one golf course was eliminated was in response to environmental concerns of area residents. Community concerns about pesticides, chemical run-off, and depletion of water supply were influential in the decision to include only one golf course in the development plans.

  Area residents were generally in favor of a course that they could take advantage of, but felt that private memberships would be more expensive than they would be able to afford. Obayashi has proposed a golf course that will be available and affordable to area residents. It has been proposed that 30% of tee times be reserved for kamaaina play, with a 40% reduction off rack rates.

  A Junior Golf Program has been proposed for full-time residents living on the North Shore between the ages of five and eighteen years of age. It has been stated that adequate hours of free play will be established to fully encourage and develop the program.

- **Trail System:** In response to recommendations made by the Hiking and Equestrian Committees, the trail system was expanded approximately 3 miles, from 6-8 miles to 9-11 miles.

- **Hiking:** All of the hiking trails will be free for public use. Parking for hikers will be provided in the parking areas for the tennis center, equestrian center, and golf course.

- **Equestrian Facilities:** The current proposal calls for pasture land, 80-100 stables, a covered practice arena, and open areas to practice. The pasture land will be

available to 4-H Clubs. It is proposed that up to 30% of the facility be eligible for a kamaaina rate for stabling charges and the use of the facilities.

- **Campground and Conservation Park:** Community desires for more and different kinds of recreation prompted the developer to add a 15-acre campground and a conservation park. The conservation park is proposed in the mauka regions where the majority of native species have been described as excellent. The trail system will wind through the conservation area. Many area residents thought that these recreational facilities would be beneficial to area residents and allow the natural beauty of the area to be fully appreciated and shared.

Community Facilities. Obayashi Hawaii has proposed a tentative plan to dedicate the 10-acre site next to the Sunset Beach Elementary School to the City or community. The land would be dedicated for public use and developed into a recreation area and community center.

The proposed community facilities include:

- Community Center (used for meeting room and community programs)
- baseball/soccer field
- outdoor pavilion
- children's playground
- picnic and barbecue area
- parking
- swimming pool and pool deck

Funding for the operation and maintenance of the proposed facilities would be partially subsidized by Obayashi through a funding program tied to golf course green fees. Each golfer would be charged $1.50 to be put into the operation fund for the community center. Additional funding would be provided by charging an additional $2,000 for each golf membership sold, to be placed in the operation fund.

The developer has also proposed to set aside a one-acre site to be donated to the City to provide for a Child Care Center.

Another one-acre site is proposed for dedication to the City to allow residents to participate in the City's "Community Gardening Program".

Additional Community Benefits. In addition to the community facilities, other community benefits have been proposed.

- **Education Program:** It is proposed that an endowment fund be created to support educational programs and provide some scholarships to schools in the North Shore area. Funding for this would be accomplished through a $5,000 premium attached to all initial market lot sales. Proposals for the use of the money include: scholarships to Kahuku and Waialua High Schools to promote college studies in environmental programs or golf course superintendent programs, and support for educational programs in private and public North Shore Elementary Schools.

- **Job Training Program:** It has been proposed that a job training program be established and maintained to assist community residents in preparing for job interviews and employment in the project. This program would be jointly developed with the community.

Wastewater Management Plan. Obayashi Hawaii has proposed an environmentally sound wastewater management plan for the Lihi Lani community. One of the biggest environmental concerns of the community has been disposal of wastewater and sewage.

The currently proposed wastewater treatment system consists of a wastewater collection system and a treatment scheme. Pumps will carry wastewater to a central treatment facility where it will enter the treatment system. The treatment system consists of stabilization ponds followed by a wetlands system. The plan is discussed in detail in a separate report.

Eliminated Components. In direct response to community opposition, two major components of the initial project do not surface in the current proposal. As already mentioned, Obayashi Hawaii eliminated one 18-hole golf course from the project proposal. The other major component that was dropped from the proposed development was the helipad. The helipad was dropped at least partly in response to community concerns about noise and perceptions that the helipad was unnecessary and not appropriate for the area.

5.0 SOCIO-ECONOMIC IMPACTS AND MITIGATIONS

5.1 INTRODUCTION

Impacts: This section deals with socio-economic impacts of the proposed Lihi Lani development in light of anticipated trends in the study area and islandwide economy and society. Quantifiable impacts associated with the project have been estimated by another consultant (KPMG Peat Marwick, 1990). Those impacts are summarized here, and the consequences for the region are discussed.

Community issues and concerns with regard to a project are appropriately viewed as expectations aroused by the project, and hence as impacts. However, the issues and concerns reviewed in Section 4 include concerns with earlier project plans. Hence, some of the specific concerns no longer apply to the project.

An objective "impact" is usually defined as the difference between two possible futures: future conditions which would occur even without the project, and the future with the project. As indicated in Section 3, future conditions in the combined study areas include:

- The creation of at least 4,000 new jobs (compared to an estimated 1990 study area labor force of 11,500 and a projected study area maximum population of 32,000 in 2010);
- Development of the Kuilima Resort and, possibly, of Haleiwa as visitor attractions; and
- Strong demand for housing for area workers and their families, with the available supply affected by City and County policies. The likely result would be increased crowding and more illegal housing units in the area.

It must be stressed that the future conditions projected by private developers and public agencies alike rest on the assumption of continuing prosperity for Hawaii and the United States. In the present climate of uncertainty about both U.S. foreign policy and the world economy, those assumptions may well be questioned. They are retained here in order to identify and assess maximal impacts.

Mitigations: Strictly speaking, mitigations consist of steps taken to minimize or avoid adverse impacts. In the processes of planning and developing permit applications for Lihi Lani, the developer has worked to formulate a project which would be well integrated with the community. Moreover, several different ways that the project can be of benefit to the surrounding community have been incorporated into the project. Accordingly, benefits and likely beneficial impacts are listed here.

5.2 QUANTITATIVE IMPACTS

5.2.1 Employment

Direct construction employment associated with the project is estimated at an annual average of 204 person-years in the three years from 1993 to 1995, and an annual average of 79 person-years from 1996 to the year 2000 (KPMG Peat Marwick, 1990). Indirect and induced employment in the State as a result of project construction would amount to an annual average of 163 person-years in the first period, and an annual average of 63 person-years in the second period. After 2000, construction is projected as ending.

The Lihi Lani project will involve about 45 operations jobs by 1995. After buildout, on-site direct operational jobs should stabilize at about 60 jobs. Indirect and induced jobs associated with project operations are estimated as amounting to about 42 jobs statewide by the year 2000. In light of an earlier estimate of regional jobs associated with the Kuilima Resort development, at least 15% of indirect and induced employment associated with project operations -- at least six jobs in 2000 -- could well be located in the study area (Community Resources, Inc. and A. Lono Lyman, Inc., 1985.)

5.2.2 Economic and Employment Impacts in Relation to Regional Trends

The developer is committed to encouraging study area workers and suppliers. Moreover, the developer has indicated that $100,000 would be spent on job training before the opening of the golf course and clubhouse. After opening, an estimated $8,000 per year would be dedicated to job training. Training programs and schedules will be developed through consultation with the community.

Obayashi Hawaii has proposed programs to help community residents to prepare for interviews and employment. In addition, the developer's representatives have compiled lists of study area contractors and suppliers, to insure that local enterprises compete for business from Lihi Lani.

Currently, unemployment in the study area is under 3% -- a low figure that is close to the islandwide average. Tract 101, including the primary study area, has a somewhat higher rate of unemployment.

The Kuilima expansion will bring many new jobs to the study area, so the future outlook is for a tight labor market. The challenge, for facilities operators at Lihi Lani as for other employers in the area, will be to find and encourage a stable workforce.

Employment at Lihi Lani will include both indoor jobs and outdoor ones, and both full-time jobs and part-time employment. In areas such as grounds maintenance, staff are likely to be long-term workers. In golf operations, many jobs are typically held for a term of a few years or less by young people, before they move on to other careers. The diversity of job types at the project means that people in varied circumstances can fit into jobs at Lihi Lani, increasing the likelihood that the project can find and retain much of its staff among residents of the study area.

Workforce development at Lihi Lani will likely include the following components:

- Active recruitment of workers from nearby communities; and
- Provision of part-time jobs, where possible, to encourage involvement by members of the community who are now underemployed or are not now in the labor market.

Potential sources for the Lihi Lani workforce include:

- The "hidden" unemployed -- persons who want work but are not currently seeking it. A recent study (Community Resources, Inc., 1990) shows the "hidden" unemployed to be more numerous than the recognized unemployed in the study area.

  Survey respondents mentioned the lack of "good jobs" near home and responsibilities for children at home as major impediments to employment. For some area residents, the project's location and the availability of part-time work or work at early hours may remove important barriers to employment.

- Persons currently holding only part-time jobs. About 20% of employed study area residents surveyed in 1990 held only part-time jobs.
- Commuters, who amount to about half the study area's employed labor force. While many would likely demand opportunities for advancement beyond their current job level or high compensation, it seems likely that project jobs will meet the needs of some study area residents now commuting outside the area.
- Eventually, Obayashi's support of Junior Golf and provision of scholarship funds for students from local high schools will help to recruit young employees to golf jobs.

In the event of any major changes in agricultural employment in the area, Obayashi will be ready to co-operate in retraining programs. However, the major agricultural employer, Waialua

Sugar, has no plans to change its level of operations (personal communication, John Hirota, Manager, December 17, 1990).

5.2.3 Population

According to KPMG Peat Marwick (1990), the on-site population associated with the project at buildout will include:

- On-site residents -- nearly 700 people, on average; and
- Day visitors -- about 260 people, on average.

Additionally, some of the project's operations workforce will likely be new residents of the study area. Employees and their families are expected to account for about 60 new residents of the combined study areas by the year 2000.

In-migration to Oahu will occur due to in-migration by both Lihi Lani residents and staff. At buildout, an average daily population of some 27 Lihi Lani residents -- about 15 full-time residents, and about 10 part-time residents -- will come from outside Oahu. An estimated nine project employees and another nine dependents would also be in-migrants to the island. The total in-migrant population impact is hence estimated as less than 50 persons.

A proposed development is usually viewed as having two sorts of population impact, residential and de facto:

- The residential impact of the project on the total study area consists of the new residents added to the area's population. It is estimated as reaching a maximum of nearly 760 persons at buildout.
- The de facto population impact consists of the persons present in the area due to the project's existence, including short-term visitors. It is estimated as stabilizing at about 1,000 persons.

The above figures may overestimate impacts, inasmuch as project employees and project residents are counted separately. However, Lihi Lani employees and their families, including ones new to the study area -- up to 60 people -- could well live on-site.

Also, it is likely that many of the residents of the project will come from within the study area. In some cases, new project residents who previously lived with family members may not be replaced in their old households, so the increase in regional population will likely be lower than projected.

5.2.4 Housing

The project will add 300 units to the study area housing supply. However, in light of the estimate that 30 employees and their families will likely move into the Koolauloa/North Shore region, the project will generate some additional demand for housing.

The amount of new demand created by in-migrant employees to Oahu depends on the type of workers attracted to the area. Housing impacts are smaller if the project attracts young workers, many of whom live apart from their families and are willing to share housing with other young singles. A stable family-oriented workforce is likely to need more housing.

Based on resort studies conducted by Community Resources, Inc., the housing impact of employee in-migration to the combined study areas is likely to amount to about 10 to 25 housing units after buildout (Community Resources, Inc., 1987b; Belt Collins & Associates, 1990). The high end of this range amounts to less than 15% of the affordable housing to be built at the project.

5.2.5 Population and Housing Impacts in Relation to Regional Trends and Policies

The new jobs to be created by various developments in the North Shore/Koolauloa area, coupled with projections for little or no growth in housing stock, will increase the tendency toward residential crowding and the development of illegal units in the study area. This trend could add to infrastructural problems in centers such as Laie, where existing densities are already above the regional average.

As a low density recreational community, the project will not contribute to the projected trend towards crowding. Both the additional housing provided in the project and the low density of residential development at the project site are in line with the broad goal of maintaining low density "country" land use in the study area in a situation of high demand for housing.

The residential population of the project at buildout (about 700 persons) is about 3% of the current population of the combined study areas. In relation to the population of the Primary Study Area -- 3,212 in 1980 -- the project is a significant development. However, it is smaller in size than the adjacent Sunset Beach and Pupukea communities (as shown in Table 5-1).

The proposed population and housing at Lihi Lani are, in relation to the total Lihi Lani site, less dense than any part of the Primary Study Area. Even if the large areas of open space and golf course in the project are excluded from consideration, the project's residential areas, taken together, would be less

TABLE 5-1: POPULATION AND HOUSING DENSITIES AT LIHI LANI IN COMPARISON WITH 1980 PRIMARY STUDY AREA COMMUNITY DENSITIES

	Population	Number of Housing Units	Acreage	Persons per Acre	Housing Units per Acre
Sunset Beach	1,191	486	373	3.19	1.30
Pupukea Highlands	1,157	384	1,329	0.87	0.29
Lower Pupukea	576	275	150	3.84	1.83
Waimea	494	161	59	8.37	2.73
Proposed Lihi Lani Community at Buildout					
Total Acreage	700	300	1,143	0.61	0.26
Residential Acreage	700	300	189	3.70	1.59

NOTES: Communities and acreages based on 1980 U.S. Census Block Group maps and counts. Lihi Lani population estimate adapted from KPMG Peat Marwick, 1990. Lihi Lani acreages from master plan (Figure 1-2).

SOURCE: U.S. Bureau of the Census, 1983.

dense than the Waimea area and the built-up area at the foot of Pupukea Road.

City and County of Honolulu policies for land use in the area are aimed at preservation of "country" lifestyles and land uses. The objective was spelled out in a City Council Resolution passed in 1989 (No. 88-404). Instead of mandating a restrictive rule, that each DP Area continue to be home to a set proportion of the islandwide population, the Council emphasized a positive goal, that population densities should be consistent with area character and desired environmental qualities.

With densities similar to or lower than those of nearby areas, the project appears in accord with the aims described above.

The City Council further specified planning goals by establishing population guidelines for development in the Development Plan Areas. The guidelines are expressed in terms of percentages of the total City and County population, as shown in Table 5-2.

City estimates of 1989 population (in Table 2-1) show the current population as well within the upper limits shown in Table 5-2:

	1989 Population as:	
	Percentage of 1989 City and County Population	Percentage of 2010 Upper Limit for Area(s)
North Shore DP Area	1.7%	77.8%
Koolauloa DP Area	1.5%	88.5%
Combined Areas	3.1%	82.5%

In short, the current population density in North Shore is within the guideline of 1.6% to 1.8%, while Koolauloa's official population exceeds the guideline of 1.3% to 1.4%. The current population is less than that projected for 2010 in both areas.

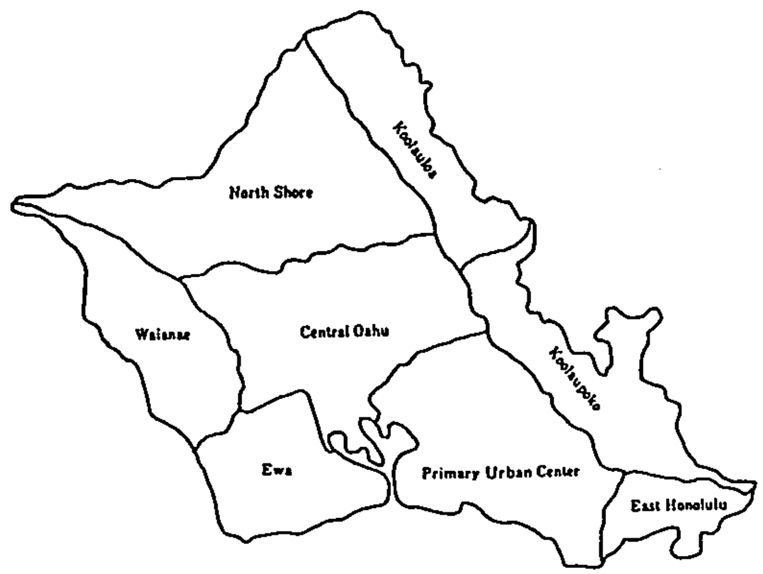
The project will add about 700 on-site residents to the North Shore DP Area, along with some employees and their families -- a total of about 730 people. (Some of the 60 persons in employee households identified by KPMG Peat Marwick as moving to the study area will likely live in Koolauloa.) That additional population amounts to less than 20% of the difference between the estimated 1989 population level and the upper limit for 2010 for the North Shore DP Area.

TABLE 5-2: TARGET POPULATION LEVELS FOR OAHU DEVELOPMENT PLAN AREAS

Location	1980 Resident Population	1980 Pct. of Total	2010 Target Pct. of Total	2010 Projected Range of Resident Population (1)
Primary Urban Cente	417,240	54.7%	45.1% - 49.8%	450,800 - 497,800
Ewa	35,523	4.7%	12.0% - 13.3%	119,900 - 132,900
Central Oahu	101,685	13.3%	14.9% - 16.5%	148,900 - 164,900
East Honolulu	43,213	5.7%	5.3% - 5.8%	53,000 - 58,000
Koolaupoko	109,373	14.3%	11.0% - 12.2%	109,900 - 121,900
Koolauloa	10,983	1.4%	1.3% - 1.4%	13,000 - 14,000
North Shore	13,061	1.7%	1.6% - 1.8%	16,000 - 18,000
Waianae	31,487	4.1%	3.8% - 4.2%	38,000 - 42,000
Oahu Total	762,565	100.0%	95.0% - 105.0%	949,500 - 1,049,500

NOTE:
(1) Population ranges based on target percentages specified in the General Plan and the State Department of Business and Economic Development Series M-K population projection of 999,500 for the year 2010.

SOURCE: City and County of Honolulu, GENERAL PLAN: OBJECTIVES AND POLICIES, Supplement 1 to the 1988 Edition, Honolulu, 1989.



A question arises about the overall density of population in the North Shore DP Area if the Lihi Lani project is built, should other lands which are zoned for possible residential use be developed. The "development capacity" of the North Shore DP Area -- the housing and population estimated by the City's Department of General Planning as likely in the area in 2010 if all land currently zoned for residential use is developed -- amounts to 6,451 units and 18,000 persons. From this perspective, the DP Area population would exceed current guidelines by about 700 persons, or 3.7%, with Lihi Lani built out.

It is difficult to estimate whether all other land available for housing would be developed by 2010. Such full-scale development seems unusual, but demand for housing is expected to be strong. More importantly, the Lihi Lani project's density and mixture of housing types are broadly in keeping with the values, supported by the City and community alike, of low density housing and maintaining extensive open space.

With strong demand for housing, it is quite possible that the North Shore DP Area population could meet or exceed the guideline by 2010 even if little new housing were built -- many people would live in more crowded conditions than now. Hence Lihi Lani does not add population to the area so much as provide low-density housing in which a small part of the expected population can live.

5.3 DISPLACEMENT

There are no residents of the project site, so no displacement of population will occur.

The current lessee of the site has been involved in ranching as a recreational and educational activity, not as a full-time commercial venture. The lessee and representatives of the developer have been discussing ways to continue use of the property during the project development phase and after the project is built. The equestrian ranch and pasture areas included within the project will provide space where the lessee may be able to continue to keep horses and to train young people.

The Lihi Lani site has been used by some nearby residents for hiking and riding. Development of the site will not involve displacement except during construction. After construction, the project will provide maintained trail facilities for both riders and hikers. These will be open to the public. Consequently, the project will increase opportunities for these uses of the site.

5.4 RECREATIONAL BENEFITS

The project is planned as a recreational community that will greatly enhance local recreational resources:

- On the golf course, 30% of tee times will be reserved for residents at reduced rates.
- A Junior Golf Program for full-time students living in the study area will provide play for free.
- Obayashi Hawaii has sponsored a local golf tournament to support local youth groups, including the Kahuku High School golf team. Similar fund-raisers are proposed after the project is built.
- The trails established and maintained on-site will benefit resident hikers and riders.
- The swimming facilities provided to the community will provide not only recreation but also swimming and water safety instruction. The need for such instruction is evident, since similar facilities are lacking nearby, and the study area's famous beaches and surfing areas offer exceptional, but dangerous, water recreation.
- Community participation in riding activities will be encouraged. Lihi Lani will allot up to 30% of stable space for community residents' use at a reduced rate. Other facilities will also be available to residents of the study area at reduced rates. Community 4-H clubs will be able to use pasture areas for free. Equestrian programs on-site will encourage involvement by young people from the surrounding area.
- Obayashi has sponsored a <u>pa'u</u> riding team of North Shore riders for two years. The team has ridden in the Kamehameha Day and Aloha Week parades. Obayashi intends to continue support for this team at Lihi Lani.
- The baseball/soccer field included in the community facilities will allow young people increased participation in team sports.
- The Lihi Lani tennis facilities will be made available for use by area residents.
- A safe playground area for the community will benefit local families.
- The parking area near the community facilities will make those facilities easily accessible for the community. It is likely that this area will also be used by those attending surf meets at Ehukai Beach Park, or by surfers at times of peak usage.

- Clubhouse facilities will be available to golfers. Also, it is anticipated that community residents will be able to use some dining facilities at the clubhouse.

5.5 IMPACTS ON ADJACENT OR NEARBY RESIDENTIAL AREAS

5.5.1 <u>Access</u>

The project will have little impact on current uses of adjacent lands. (See Section 5.7.2 for discussion of relations between Lihi Lani and the Sunset Beach Elementary School.) It is separated from inhabited areas of Sunset Beach, Sunset Hills, and Pupukea Highlands by a gorge which will remain under vegetation.

A paved roadway connecting the project to Makana Road in Sunset Hills will be built. This will be closed -- it will be used to inspect and repair water lines or in case of emergency. Hence there will be no regular access between the project and Sunset Hills.

Nearby residents will be able to reach the Lihi Lani trail system on foot or horseback from Sunset Hills. Additional connections from Sunset Beach and upper Pupukea Highlands are possible, but would depend on other landowners.

5.5.2 <u>Land Values and Property Taxes</u>

Both nearby residents and the islandwide public largely expect that golf courses and upscale developments such as Lihi Lani will have an impact on real estate values and property taxes in the surrounding area. Research conducted by Community Resources, Inc. and Locations, Inc. shows that value and tax impacts of the project are likely to be localized, not community-wide, and to be possible over the long term, not as an immediate impact of the development of Lihi Lani.

Summary. Golf courses and golf-related communities (as distinct from resort destinations) in Hawaii have very limited impacts on nearby property values. A few nearby properties may increase in value due either to physical improvements, such as improved roadways, or, for a few adjacent properties, market advantage due to having a golf course as an extension of one's back yard. Several studies have shown no discernible long-term impact of golf courses on land values in the larger communities surrounding them.

Lihi Lani's golf course will not affect the value of existing properties, since none gain either a physical improvement or a clear market advantage from the golf course. Accordingly, the project should have no short-term impact on off-site property values and taxes.

Any judgment as to whether the development of Lihi Lani will, over the long term, affect values in nearby areas must be tentative. However, both existing studies and the pricing policy established for Lihi Lani suggest that Lihi Lani will have minimal impacts or no impact on existing residential values in Pupukea, Sunset Hills, and Sunset Beach. No impact on values and taxes is expected outside the Primary Study Area.

Methodology. The above findings follow from repeated studies done by Community Resources, Inc. between 1987 and the present. They draw on:

- Repeated interviews with real property tax assessors;
- Market studies of changes in property values over time, using the Multiple Listings Service database, by Locations Inc.
- Interviews with real estate professionals, developers, and Oahu residents who, as long-term neighbors of golf courses in rural areas, can evaluate the impact of golf developments on surrounding land values;
- A review of zoning and assessment practices in the area immediately surrounding the Lihi Lani project; and
- Research on City and County policies concerning golf courses and other developments in "country" areas.

Tax Assessment Policies. As part of socio-economic research for several recent Oahu golf course proposals, Community Resources, Inc., reviewed City and County tax assessment policies. Community Resources, Inc. has also studied assessment policies on Maui and the Big Island with regard to proposed golf developments. Based on interviews with officials in the City and County Finance Department's Real Property Assessment Division in 1988 through 1990:

- A new development can affect the assessment of other properties, but assessments will be raised only if there is evidence of increased value. That evidence can take one of three forms:
  - **Improvements:** A development can provide a physical improvement, such as a paved road, that adds to the value of properties that share the improvement.
  - **Amenities:** A development can make nearby properties more marketable. Assessors do not assume that new developments affect the market value of nearby properties unless they can identify both a specific advantage gained from the development and the likely effect of that advantage on the sales price of such properties.

Residential properties with an expansive golf course view, which gain a sense of open space from golf course development, have a specific amenity. Agricultural land in the same place does not gain an amenity, since golf course views do not help in raising crops. Again, residential properties at some distance from a golf development do not gain an identifiable amenity from the course.

  - **Market Data:** Assessors look to real estate sales prices to establish market value for properties closely similar (in location, zoning, use, and size) to the ones that were sold. Market data are used regularly to estimate changing real estate values.

    In the long run, market data are the basis for most tax assessments. However, such data do not clearly show <u>why</u> prices rise or fall. Changes in price may reflect trends in the islandwide market, or any of several local influences.

- Residential properties are grouped in "neighborhoods" of properties judged to be similar in zoning, use, size, and value. "Neighborhoods" are relatively small areas of properties with similar values.

  An increase in property values in one area can be attributed to an increase in value for the neighborhood or an increase attributable to a specific amenity applying only to part of the neighborhood. Thus, for example, the higher price of beachfront homes (as opposed to other single-family homes) throughout the North Shore can be treated as an amenity or as a characteristic of neighborhoods of oceanfront houses. In either event, the impact of a rise in values confined to properties with a salient quality, ocean frontage, is not automatically treated as applying to other properties nearby.

  Lihi Lani's two residential components would likely be treated as two separate neighborhoods. Neither would, at first, probably be identified as part of the same neighborhood with existing homes. If, however, market trends showed that market trends in two areas (such as Sunset Hills and the Lihi Lani market lots) were the same, they might well be treated as a single neighborhood.

Implications for Lihi Lani's Neighbors. Lihi Lani's potential impacts on assessments are minimized by several factors:

- Real estate prices on the North Shore have already risen to a level reflecting strong demand from affluent buyers.
- Except for community facilities, all of the Lihi Lani project will be built above and behind the cliffs that

overlook Sunset Beach. Hence no improvements or amenities affecting Sunset Beach residential properties can be identified.

- The golf course is located on the Kahuku side of the property. Existing lots in Pupukea Highlands and Sunset Hills are far from the course. Pasturage and project residential areas are situated between the golf course and existing residential areas. (The Comsat site, on the Kahuku side of the Lihi Lani property, is largely undeveloped and is zoned as Agricultural land.)

- The community will include both market lots, some of which will be near Sunset Hills, and affordable housing, in view of the more "country" area of Pupukea Highlands. Hence comparable properties are, if not contiguous -- a deep gully separates Pupukea and Lihi Lani -- aligned with each other.

In sum, no improvements or amenities will be created affecting the assessed values and taxes of existing properties. Such properties will be affected only if there are actual increases in sales prices.

The next sub-sections address the question of indirect, long-term impacts through (1) interviews with area realtors, and (2) analysis of quantitative data on property values in areas near golf courses and golf-related communities in Hawaii.

Realtor Expectations. Community Resources, Inc. interviewed area realtors repeatedly in 1989 and 1990 to learn whether they expected Lihi Lani to have an impact on existing real estate values. The following were interviewed in December 1990:

Marianne Abrigo	President, Marianne Abrigo Properties
India Andrews-Noe	President, Mokuleia Management, Inc.
Marlene Lindsay	Principal, Marlene Realty
Jacqueline Mansard	Principal, Jacqueline Mansard Realty
Ron Scott	Principal, Scott Cooperative Realty
Richard Sterman	President, Sterman Realty

Major findings from the most recent interviews were:

- Real estate prices in Koolauloa and the North Shore -- particularly for beachfront properties -- had risen sharply from 1988 to mid-1990, but the market has stabilized in recent months. The drop in the number of sales has been dramatic, but the realtors interviewed were not worried. They viewed the slowdown partly as a normal "breathing period," to be expected after a jump in prices, partly as an understandable response to the uncertainty the world economic situation.

  When asked, in early 1989, whether Japanese investment had affected the study area real estate market, real estate professionals saw no direct impact (Community Resources, Inc., 1989a). Only a few Japanese nationals have bought property in the area. However, some thought there might be an indirect effect -- Japanese purchases in Kahala may have led some Kahala residents to move to Kailua, while "displaced" Kailua residents may have then come to buy property in the study area.

- Little housing affordable for families with moderate incomes is available.

- The scheduled Kuilima expansion was not expected by most interviewees to have much impact on housing sales, because the current price of homes in the combined study areas is outside the reach of families depending on service jobs. (However, two persons discussed the idea that the North Shore would come to be seen as a "growth area" of interest to investors as well as residents.)

  Demand for rental housing is expected to increase as a result of the creation of new jobs at the Resort.

  (Earlier, area real estate professionals expected the Resort expansion to affect housing prices, either because of new interest in the area on the part of out-of-state buyers (who would be attracted mainly to waterfront or "view" properties), or because of demand for more modest housing from new workers.)

- Surfers are an increasingly important segment of the region's rental market, but landlords generally consider them poor prospects because they are short-term renters and are reputed to be likely to damage housing units.

  (With an increasing shortage of rental housing in the study area, this group could be especially affected.)

- In relation to the general study area, the Lihi Lani project was seen as simply adding to the impact of the Kuilima Resort expansion. For those who saw Kuilima as having little or no further impact on the market, Lihi

Lani was similarly lacking in impacts. For the minority who foresaw major changes due to the Kuilima expansion, Lihi Lani would add to those changes.

One real estate professional expected the project to have an impact on land values in the Pupukea Highlands.

Moreover, increasing values in the Highlands could eventually lead to higher values at Lihi Lani itself.

In 1989, realtors did agree that any upscale housing which fronted a golf course could easily find a well-paying market. However, they thought that current City policies and community attitudes would make rezoning for such development difficult in the foreseeable future.

Quantitative Analyses of Historic Changes in Values. Locations, Inc. has drawn on the Multiple Listings Service database to search for indications that the creation of golf courses and upscale neighborhoods near existing communities has affected real estate values in nearby communities (1989a, 1989b). Major findings of these studies include:

- For the North Shore/Koolauloa area, average single-family sales prices for <u>oceanfront</u> homes suddenly soared in 1988, to more than double the 1987 averages. But <u>off-water</u> North Shore residential values -- while rising somewhat the past few years -- have been substantially lower than Oahu-wide average sales values.

  North Shore off-water single-family and condominium prices have remained below islandwide averages (as shown in Figures 2-3 and 2-4).

- To determine impacts of golf-related developments elsewhere, Locations examined changes over time in middle-class neighborhood sales prices located very near the developments. (The developments in question were generally golf/residential projects, both on resorts such as Makaha and Wailea and also some non-resort projects.)

  In all cases from three different islands, the new upscale golf/residential developments had <u>no apparent impacts</u> on single-family home sales prices in neighboring areas by early 1989. Values in these neighboring areas did rise in certain years, but at a rate which paralleled islandwide rises and not in any other sudden spurts after the new developments occurred.

  <u>Islandwide economic market conditions seemed to far outweigh nearby improvements such as golf courses in affecting values of existing housing stock</u>.

  More recent data, reflecting the acceleration of real estate values throughout Hawaii in 1989-90, are less

dramatic. Neighbor Island residential areas near <u>resort</u> golf developments have come to increase in value at levels similar to or just above island averages. <u>On Oahu, the value of neighborhoods near golf-related developments still is increasing more slowly than the islandwide average.</u>

- The creation of new upscale residential developments such as Waialae Iki and Hawaii Loa Ridge in East Honolulu, Queen's Gate in Hawaii Kai, and Royal Summit in Pearl City did not affect the prices of nearby developments.

The Locations studies and recent updates suggest that golf courses and recreation-oriented communities have little or no impact on nearby property values in Hawaii. Similarly, studies of tax assessment and land use data for properties near rural golf developments on Oahu and Maui by Community Resources, Inc. have shown:

- Residential properties that abut golf courses are valued above nearby properties without golf course frontage;
- The value of non-residential properties next to golf courses is not higher than comparable properties nearby;
- Land near golf courses has not been transformed from rural to urban uses. Even when developers hoped for just that result -- as at Pukulani on Maui, where a golf course was developed as part of a residential project -- residential growth near a golf course may be slow. (Discovery Harbor, in Ka'u on the Big Island, is an example of a residential/golf development that has seen low appreciation in on-site values, and no off-site impact.)

The forecast by one real estate professional that land values in Lihi Lani could affect Pupukea Highlands, and vice versa, implies that the creation of Lihi Lani will make people aware of the Pupukea Highlands as a choice residential area. In the long term, this hypothesis cannot be supported without severe qualifications, for three reasons:

- Pupukea already includes residential areas, notably Sunset Hills, that command high prices;
- Islandwide demand for housing will likely make large residential lots and view lots increasingly valuable, independent of impacts of local developments;
- Both recreational facilities at Kuilima and the severity of traffic congestion on Kamehameha Highway -- both factors separate from Lihi Lani -- will likely influence potential buyers' views of the area.

With the development of Lihi Lani, more people will likely be aware of the existence of a relatively affluent population in the North Shore highlands. Whether such a group takes on prominence and a reputation as exclusive depends on both planning for community integration and the attitudes of area residents, as discussed further in Section 5.7.

5.6 PUBLIC FACILITIES

Project impacts on public services for police and fire protection, health care/hospitals and education are addressed in this section.

5.6.1 Police

Existing Conditions. The project site is located in the Honolulu Police Department's District 2. The region encompasses the area marked by the following boundaries: Kaena Point along the North Shore coast to Waialee Stream, down the Koolau Mountain Ridge to Kipapa Stream, across to Waiahole Ditch near Kunia, and up the Waianae Mountain Ridge back to Kaena Point. Police protection is provided to the project area from the Wahiawa Substation.

The beat boundaries of the second District encompass an area of approximately 190 square miles. This area is covered by 71 field officers. Response time to the Pupukea area fluctuates over time, but was recently estimated to be 2 to 2.5 minutes (personal communication, Captain William Bennett, Wahiawa Substation, Dec 11, 1990).

Anticipated Impacts. It is estimated that a de facto population of about 1,050 persons will be on the project site at buildout. There will be occasional and sometimes unavoidable demand for police services at the project. During large events which may be held at the golf course or equestrian facilities, additional police protection would be required to control traffic and pedestrians.

Mitigation Measures. The applicant will take measures to provide security on-site during construction. In addition, private security services will be provided within the project upon completion. Besides private security measures, additional private manpower would be provided by event sponsors, in co-ordination with local police officials. If the project were designated as a "beat" by the City and County, up to 6 additional officers would be required by the Wahiawa Substation. Tax revenues generated by the project should more than cover the cost of additional police services attributable to the development (KPMG Peat Marwick, 1990).

5.6.2 Fire

Existing Conditions. The Sunset Beach and Kahuku Fire Stations are nearest to the project. They are able to provide ladder, engine, medical and marine rescue services. The Sunset Beach Fire Station is the closest to the proposed community, located approximately 1.5 miles from the project entrance. From this station fire trucks are expected to be able to reach the community in less than five minutes (personal communication, Captain Dan Miyashiro, Sunset Beach Fire Station, Dec 11, 1990). Backup fire fighting support for the area would be provided by the Kahuku Fire Station, located approximately eight miles away.

Anticipated Impacts. The planned community's facilities will require fire protection from the local municipal fire department. Tax revenues generated by the project should more than cover the cost of additional services required of the fire station attributable to the development (KPMG Peat Marwick, 1990).

Mitigation Measures. Water lines and storage with adequate fire fighting capacity will be installed by the applicant within the project. The location of fire hydrants will be reviewed and approved by the Board of Water Supply and the Fire Department.

Buildings and facilities within the project will be designed with adequate attention to the principles of fire safety, and will also be built to follow necessary City and County fire protection standards. Safety precaution measures such as the installation of sprinkler systems and smoke detectors in buildings will also be undertaken.

The additional potential demand on fire protection services is not expected to place an unusual burden on the fire department or require the provision of additional facilities or equipment.

5.6.3 Health Care

Existing Conditions. The nearest health care facility is the 26-bed Kahuku Hospital, at approximately ten to fifteen minutes distance by car from the project site. This facility has one City and County ambulance and a helipad for medical evacuation helicopters.

The Kahuku Hospital offers comprehensive medical services on a 24-hour per day basis. Other facilities at the hospital include a private dental office and a medical office/clinic with three physicians in private practice.

Anticipated Impacts. The residents at the project's eventual 300 homes, and visitors and workers at the various facilities in the project, can be expected to add slightly to existing demand for Kahuku medical facilities. The impact is expected to be slight since the hospital is presently not operating at full capacity. (Rikio Tanji, Administrator, Kahuku Hospital, Dec 11, 1990)

Mitigation Measures. No mitigation measures are considered necessary.

5.6.4 Schools

Existing Conditions. The nearest elementary school to the project is the Sunset Beach Elementary School (grades kindergarden to six), which is located adjacent to the makai section of the project site. Kahuku High/Intermediate School (grades seven to twelve) is in Kahuku, about eight miles from the project. The schools are now operating at or beyond full capacity.

Anticipated Impacts. The project calls for the development of 120 market-priced homes on large lots and 180 affordable homes. The current schedule anticipates that all housing could be built by 1997. Upon completion, the project could produce an approximate enrollment of 85 to 100 students in grades kindergarden to six, and 55 to 65 students in grades seven to twelve (letter from Charles T. Toguchi, Superintendent, State Department of Education, Dec 21, 1990).

Without the project, enrollment at the Sunset Beach Elementary School is expected to be stable in the future, keeping the school at full capacity. The added enrollment of students generated by the project would amount to an estimated 20% of the existing enrollment. It is anticipated to have a substantial impact on the school.

Project residents are expected to constitute only about 3.5% of the existing enrollment at Kahuku High and Intermediate School. However, need for new classrooms is anticipated, and the additional pupils enrolled as a result of project development contribute to the anticipated impact on facilities.

Some Lihi Lani houses will likely be used as part-time residences. Hence Community Resources, Inc. expects that increases to the school age population will be less than the maximum figures indicated above.

Mitigation Measures. Additional physical facilities may be needed to serve the increased enrollment of the Sunset Beach Elementary School. These may be portable classrooms or more permanent structures. The proportion of State tax revenues generated by this project which will be allocated to education is projected as more than covering any additional operational expenses (KPMG Peat Marwick, 1990).

In addition, Obayashi Hawaii will establish a trust fund for scholarships and other educational programs. Contributions would amount to $5,000 per market lot, from initial lot sales.

Contributions would hence total about $900,000. Contributions plus interest would go to study area schools and students.

5.7 COMMUNITY CHARACTER AND CHANGE

5.7.1 Impacts of Regional Change on Existing Communities

Economic development in the area is expected to bring:

- increased traffic;
- higher wages, and new opportunities for small businesses;
- more, and more visible, tourists; and
- increased demand for housing, above all for housing for families with moderate incomes.

Increased traffic and greater numbers of users of the North Shore's best-known resources, such as beach parks, may lead some residents to view parts of the area as no longer worth visiting. (The minority of Hawaii residents who reported in 1988 that they felt that tourists had "taken over" part of their area identified outdoor sites above all as ones lost to tourists (Community Resources, Inc., 1989b).)

New jobs in the area will reduce the strain placed on family lives by long-distance commuting. On the other hand, since many of those jobs involve changing, weekend, or evening schedules, it may become even more difficult to bring residents together for community gatherings.

In these circumstances, many residents will likely find their experience of the general North Shore area changed, and may concentrate their interests and social ties in the immediate vicinity of their homes. Consequently, the availability of nearby facilities and amenities -- perceived as easy to reach and more likely than other regional facilities to be places where neighbors and friends can be found -- will likely be increasingly important to residents.

Located half way between Kahuku and Haleiwa, Lihi Lani's community facilities will probably be used by residents of both towns. However, these facilities will be of value especially to the residents of the Primary Study Area and nearby residential areas. Lihi Lani would intensify the existing trend for many nearby residents to treat the area surrounding Sunset Beach Elementary -- which already offers playing fields and some parking spaces -- as a community focus.

5.7.2 Integration of Lihi Lani with the Surrounding Community

As described in Section 4.4, the master plan for Lihi Lani has been extensively changed to increase both resident use of the project's facilities and project compatibility with nearby communities.

Elements of project design tending to increase the integration of Lihi Lani into the larger North Shore population include:

- Conformance with the guidelines enunciated by the JPC, which make it likely that the project will respect the environment, will minimize any visual or aural intrusion, and will "create an overall image" in keeping with the character and experience of Oahu's "country" areas;
- Planning for low-density residential development;
- A commitment that project architecture, including structures built by residents, will tend to blend in with the surrounding environment due to selection of materials, heights, design styles, and color schemes;
- Inclusion of 180 units of affordable housing;
- Removal of a private golf course and a helipad from the project plan, elements which were thought to attract a new sort of visitor to the area;
- Provision of upland recreational facilities -- trails, stables, riding areas, a golf course and clubhouse -- to which members of the community are guaranteed access either for free or for reduced rates;
- Sponsorship of a pa'u riding group and planned support for young riders;
- Development of a Junior Golf Program, encouraging local young people to use project facilities; and
- Providing community facilities, probably including a meeting area, swimming pool, picnic facilities, and parking. The makai community area could both augment the Sunset Beach Elementary School physical education program and provide a focus for informal and formal community gatherings. A proposed community garden area and a child care facility would increase the site's attractiveness as a center for social life.

The developer has shown support for the school through various donations. A proposed education endowment would commit funds from lot sales to study area schools and students.

Again, the developer has supported recreational events -- surf meets and golf tournaments -- and has encouraged clean-up activities benefitting the community.

These plans and programs constitute a major effort to integrate the project with the surrounding community. Further processes likely to increase community involvement in the project and a sense that Lihi Lani is accessible to the North Shore community will likely follow:

- Recreational programs and events such as rodeos will make Lihi Lani a venue for different sectors of the community;
- Lihi Lani residents will likely include people now living in the surrounding community;
- Employment of area residents will populate the site with known faces; and
- New employees of the project, and some new residents, will become recognized figures in the community, with ties to established members of the community or membership in local groups.

However, Lihi Lani's population will still have two distinct sub-groups, and its facilities may well attract two distinct clienteles. It is possible that the market residential area and the golf facilities will be perceived by many as exclusive and out of contact with the rest of the North Shore. This potential is by no means a new one for the North Shore -- widespread criticism of homes such as the Sullivan property in Sunset Hills has indicated a sense that some affluent residents are at odds with the larger community.

As an area of large-lot properties, including several spectacular view lots, Sunset Hills is quite distinct from both the higher density neighborhoods along Kamehameha Highway and more rural neighborhoods inland. By adding 120 estate lots to the Primary Study Area's inventory, Lihi Lani will make the more affluent segments of the population more visible. Whether those segments remain well integrated with the rest of the Primary Study Area community depends on the actions and good will of existing and new residents.

Steps to minimize potential divisions in the population using and enjoying Lihi Lani could include:

- Formation of a community group in which residents of both the market lots and the affordable housing at Lihi Lani have a voice.
- Establishment of a structure for joint discussions and community action bringing together Lihi Lani residents with residents of nearby communities. The JPC is an example of the possibility of such co-operative action.

- Programs to encourage more affluent residents of Lihi Lani to come to know their neighbors in recreational contexts. Proposed riding and golf programs for young people could play an important role in community integration, especially if young people not in public schools are included along with public school students.

The project's planning process has extensively drawn on community input. As a result, Lihi Lani has the opportunity to be established as part of the regional community, unlike many new upscale residential developments in Hawaii.

Finally, it should be noted that the surrounding North Shore area is not an isolated enclave, but a cosmopolitan area drawing people from around the world because of its surf, beaches, and character. As newcomers have been integrated into the "country" community in the past, so Lihi Lani residents could well become part of the North Shore.

In an important sense, the final judge of changes brought by the project is the surrounding community itself. To the extent that nearby residents find the benefits offered by the project valuable, and new residents are able to take a place in the larger community, the project should not be disruptive.

5.7.3 Golf Development and Study Area Communities

Many Oahu residents have been concerned that golf course development will affect the character of rural areas. In the study area, news of several different golf course proposals have incited concern that the area's open spaces will be transformed into golf courses and fairway homes, affecting both the experience and composition of local communities.

As noted above, Lihi Lani is expected to have little impact on property values and development off-site. Consequently, it will not have the catalytic development impacts that would, some fear, change rural communities.

The concern that cumulative golf development will bring a new population and feeling to the North Shore region is not, strictly speaking, concern over an impact of the project. By making a golf course part of a larger recreational community, in which riding and hiking are also featured, Lihi Lani will tend to attract residents sharing some interests with neighboring groups. Accordingly, the project is less likely to bring to the North Shore golfers who do not respect the area than are other proposed developments which include only golf or place golf in a resort context.

APPENDIX A:

REFERENCES

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APPENDIX T

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January 7, 1991

Mr. Toshiharu Hino, President
Obayashi Hawaii Corporation
c/o Mr. Craig Yamagishi
Pauahi Tower
1001 Bishop Street, Suite 2000
Honolulu, Hawaii 96813

Dear Mr. Hino:

We are pleased to present the findings and conclusions of our economic and fiscal impact assessment for Obayashi Hawaii Corporation's proposed Lihi Lani Recreational Community, located near Pupukea in the Koolauloa area on the island of Oahu.

The attached report, entitled "Economic and Fiscal Impact Assessment for the proposed Lihi Lani Master-planned Community," is organized into four chapters as follows:

I. Introduction and Executive Summary
II. Project Overview and Regional Setting
III. Economic Impacts
IV. Fiscal Impacts

We have appreciated this opportunity to assist you in the planning and evaluation of this project, and have enjoyed working with you and all the other members of your project team.

Very truly yours,

KPMG Peat Marwick

Economic and Fiscal Impact Assessment for the Proposed Lihi Lani Master-planned Community

Pupukea, Oahu, Hawaii

Prepared for

OBAYASHI HAWAII CORPORATION

January 1991

LIHI LANI RECREATIONAL COMMUNITY

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LIHI LANI RECREATIONAL COMMUNITY

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LIHI LANI RECREATIONAL COMMUNITY

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I - EXECUTIVE SUMMARY

This chapter presents the background and objectives of the assistance provided to the Obayashi Hawaii Corporation and summarizes the study conclusions. More detailed findings and conclusions are presented in the following chapters.

STUDY BACKGROUND AND OBJECTIVE

The Obayashi Hawaii Corporation (Obayashi) is planning the development of a recreation-oriented master-planned community to be named Lihi Lani or the "Edge of Heaven." It will be located on a 1,143-acre parcel at Pupukea in the Koolauloa Census Division of Oahu.

In December 1990 KPMG Peat Marwick assessed the market for the project in a report entitled "Market Assessment for the Proposed Lihi Lani Master-planned Community." The objective of this study is to evaluate the anticipated economic and fiscal impacts of the proposed development in the State of Hawaii and City and County of Honolulu. This study assumes that the project is developed and received in the marketplace as described in the December 1990 market report.

SITE DESCRIPTION AND PROJECT CONCEPT

The proposed project site is located near the North Shore edge of the Koolauloa division on Oahu, defined as the area from Kaaawa to Waimea Bay. The site is about 60 minutes by car from Honolulu and overlooks the Sunset Beach area, affording spectacular ocean and sunset views from the majority of the site.

Lihi Lani is proposed to be a recreation-oriented community with one semiprivate 18-hole golf course, a clubhouse, tennis center, equestrian ranch, campgrounds, cabins, 120 one-acre and larger country lots and 180 affordable homes. The availability of this variety of facilities and amenities is expected to establish Lihi Lani as a recreational community area. Lihi Lani could provide family-oriented activities with golf, tennis, horseback riding, hiking and centralized facilities at which to meet before and after activities. Lihi Lani is anticipated to attract buyers and users primarily from Hawaii and secondarily from the U. S. mainland.

ECONOMIC IMPACTS

The proposed development could be expected to impact the state and county economy by generating additional consumer expenditures, construction and operational employment, personal income and population growth.

Consumer Expenditures

Green and cart fees could be expected to range from $75 to $85 for the semi-private course, in 1990 dollars. Including these and other anticipated resident and visitor expenditures for other recreation-related fees, food, beverages and retail items at the various facilities of the development, the

community could be expected to generate $5.0 million in direct annual consumer expenditures by 1995, $6.1 million per year in 2000 and about $6.0 million per year by stabilization in 2001, in 1990 dollars.

Including their anticipated multiplier effects throughout the state's economy, these direct expenditures could be expected to support total additional spending in Hawaii of about $9.8 million by 1995, $12.1 million in 2000 and stabilizing at $11.8 million by 2001, in 1990 dollars.

Construction and Operational Employment

Lihi Lani would generate both construction and operational employment in the state. Direct employment effects would be those supported directly by construction or by the consumer expenditures generated by the project. However, the total employment effects of the project would also include its indirect and induced effects through spending multipliers throughout the state.

The anticipated total direct, indirect and induced employment effects of the project are expected to represent about 250 to 450 average annual person-years in the 1993 to 2000 period. Permanent operational employment effects could represent about 102 full-time equivalent positions throughout the state:

Projected Employment at Lihi Lani
(Average annual person-years)

	1993 to 1995	1996 to 2000	Stabilized (2001)
Construction:			
Direct	204	79	-
Total	367	142	-
Operational:			
Direct	45	60	60
Total	78	102	102
Total:			
Direct	249	139	60
Total	445	244	102

Personal Income

Wages and salaries paid to direct employees of the project could be anticipated to represent about $8.4 million by 1995 and $4.0 million by 2000. After completion of all construction the stabilized income effects could represent about $0.9 million per year in 1990 dollars, as shown below:

Projected Annual Personal Income
From Direct Employment Effects of Lihi Lani

(Millions of 1990 dollars)

	1993 to 1995	1996 to 2000	Stabilized (2001)
Construction	$ 8.1	3.1	-
Operational	.3	.9	0.9
Total	$ 8.4	4.0	0.9

The above does not include the potential wages and salaries paid to those employed through the project's indirect and induced economic effects, and does not include proprietors' income. Thus, the total household income effects of the project's development could be considerably greater than the direct personal income effects shown above.

Population

The region of major project impacts is defined as the North Shore and Koolauloa census divisions. The project could be expected to impact population in this region by generating three types of population growth:

- Full- and part-time residents of the lots who did not previously live in the region.
- Day visitors using the project's recreational facilities.
- Direct employees of the project new to Oahu or the North Shore and Koolauloa regions, including their dependent household members.

Day visitors to the project and employees who commute into the region would impact only the de facto population of the region, that is, the average daily number of persons present, including visitors and residents. In contrast, residents and employees who choose to move into the region because of the availability of homes or the employment generated by the project would contribute to the region's resident, or "overnight," population growth.

The population impact for the island as a whole would be somewhat less than for the North Shore and Koolauloa region, since some day visitors, employees and residents attracted to the project may already reside on or be visiting Oahu. Thus, all of the above mechanisms also impact the population of the island of Oahu, but only in the cases where visitors to or residents of the project are attracted from off-island.

The total North Shore and Koolauloa region de facto population is projected to increase by about 578 persons by 1995, 1,097 persons by 2000 and 1,019 persons at stabilization, in 2001. Projected new residents attracted to Oahu by Lihi Lani has been estimated at 14 by 1995 and 45 by 2000, as summarized below:

Projected Project Impacts
on North Shore and Koolauloa De Facto and
Island of Oahu Resident Population

	1995	2000	Stabilization (2001)
North Shore and Koolauloa regions	578	1,097	1,019
Island of Oahu	14	45	45

FISCAL IMPACTS

The fiscal impacts of the proposed development are evaluated by comparing the tax revenues and operating expenditures that could be expected to be incurred by the governments of the City and County of Honolulu and the State of Hawaii.

Potential fiscal benefits of the project's development, in terms of additional tax revenues, are anticipated to exceed the government operating expenditures generated by additional demands for state and county services as a result of the project's development. Projected net additional revenues for the county are expected to be about $570,000 in 1995 and $840,000 by 2000 and thereafter, representing a benefit cost ratio of about 30 to 1 in 1995 and 13 to 1 at stabilization.

Likewise, estimated net additional revenues for the State are projected to be about $180,000 in 1995 and about $110,000 at stabilization in 2001, excluding income and other taxes that may be associated with construction employment at the project. Thus, expected benefits would outweigh costs to the State by about 7 to 1 in 1995, and about 2 to 1 by stabilization.

Projected net additional revenues, and the ratio of projected new government revenues to new government operating expenditures are as summarized below:

Projected County and State Revenue
and Expenditure Comparison

(Millions of 1990 dollars)

	1995	2000	Stabilization (2001)
County government:			
Net additional revenues	$ 0.57	0.84	0.84
Revenue/expenditure ratio	29.5	13.0	13.0
State government:			
Net additional revenues	$ 0.18	0.12	0.11
Revenue/expenditure ratio	7.0	1.7	1.6

II - PROJECT OVERVIEW AND REGIONAL SETTING

This chapter describes the proposed Lihi Lani master-planned community at Pupukea and surveys economic and demographic trends for the island of Oahu as a whole and the North Shore and Koolauloa areas of Oahu in particular, as pertinent to the outlook for development at the project site.

PROJECT OVERVIEW

This section presents the preliminary development plans for the master-planned community and the characteristics of the project site.

Preliminary Development Concept

Obayashi Hawaii Corporation plans to develop a residential community named Lihi Lani or the "Edge of Heaven" on about 1,143 acres of land in the Pupukea area in the Koolauloa region of Oahu, as shown in Exhibit II-A.

The development would be a recreation-oriented community with facilities and amenities, as shown in Exhibit II-B. The project would feature one 18-hole golf course, golf clubhouse, tennis center, equestrian ranch, camp ground, cabins, 180 affordable homes and 120 one-acre and larger lots. The development is proposed to be built in three parts. The first phase of development would include the golf course, clubhouse, equestrian ranch, campgrounds, the first increment of about 60 lots, 90 affordable houses and major infrastuctural improvements by 1995. The second phase would encompass the tennis center and a second increment of about 30 lots and 50 affordable homes to be completed by 1996. The last increment of about 30 lots and 40 affordable homes would complete the third phase of the development of Lihi Lani by 1997. All homes are expected to be constructed by 2000.

Thus, the community is expected to have the majority of its facilities developed by 1997, as shown in Exhibit II-C, based on information from the "Market Assessment for the Proposed Lihi Lani Master-planned Community" prepared by KPMG Peat Marwick in December 1990. Development expected to occur after 1997 will primarily be that of single-family home development and possibly a second phase of tennis courts at the tennis center.

Site Location and Description

The project site is located on the mauka (mountain) side of Kamehameha Highway, near the Boy Scout and Girl Scout camps and Sunset Hills subdivision in the Pupukea area of Oahu, about a 60-minute drive from Honolulu. The property is distinguished by two plateaus and three valleys. Rising from the highway to about 850 feet above sea level, it offers spectacular sunset and ocean views of the North Shore.

Residents of the subdivision and members of the golf and tennis clubs would have minimal traveling time by car to the area's white, sandy beaches and the nearby Kuilima Resort. Lihi Lani residents and other Hawaii residents would also have access to golf, tennis, equestrian activities, campgrounds, parks and dining at the project's clubhouse.

Exhibit II-A

LIHI LANI RECREATIONAL COMMUNITY

Location Map of the Proposed Lihi Lani Recreational Community

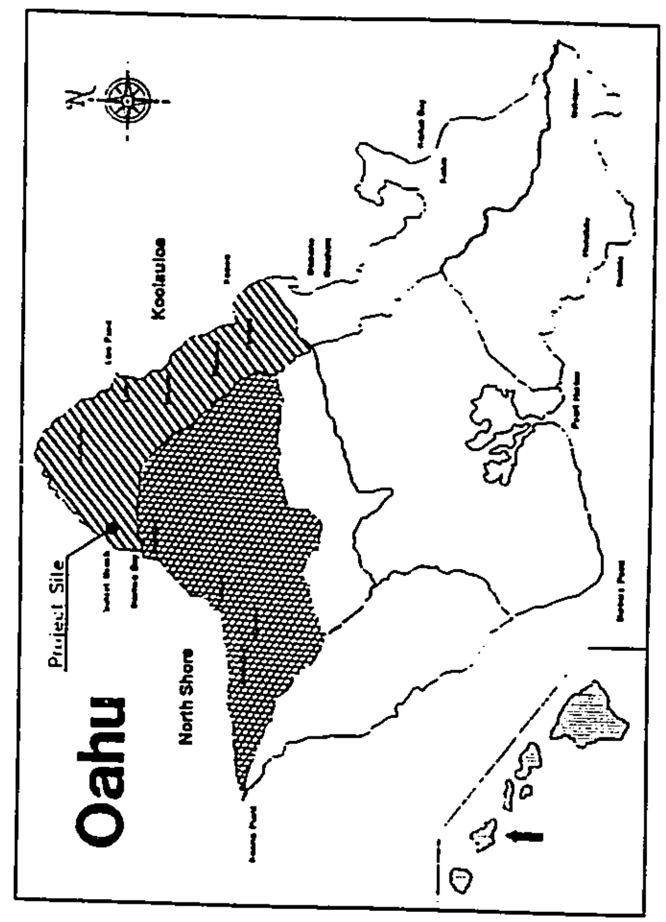

Exhibit II-8

LIHI LANI RECREATIONAL COMMUNITY

Proposed Site Plan

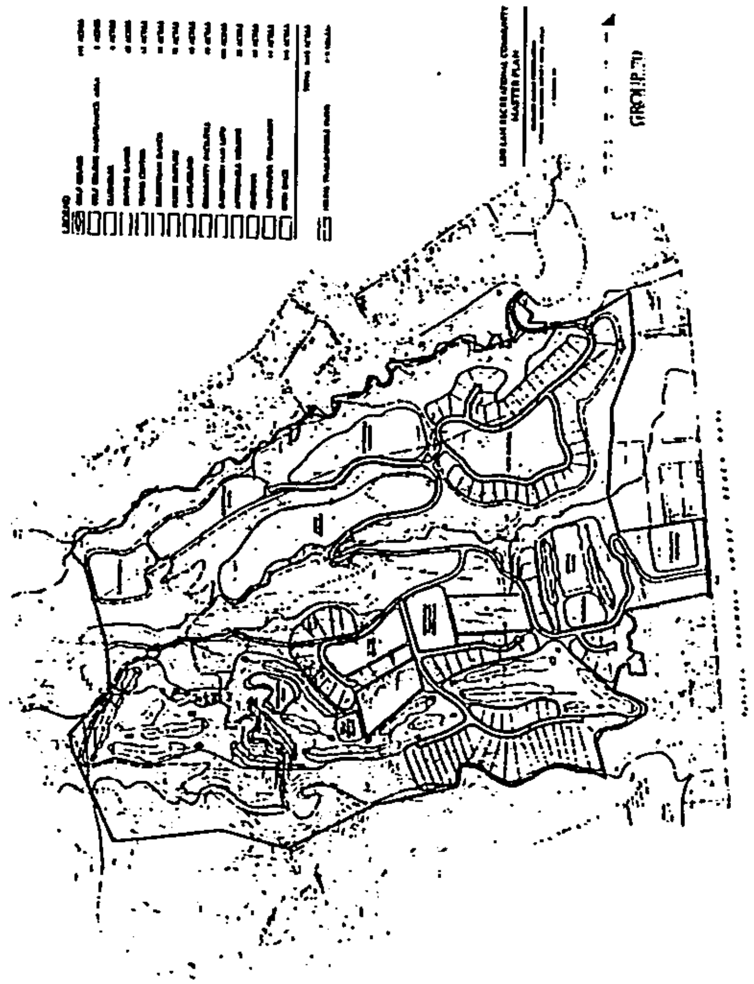

Exhibit II-C

LIHI LANI RECREATIONAL COMMUNITY

Projected Cumulative Development Upon Build-out
at Lihi Lani Master-planned Community

Golf course development:	
Number of holes	18
Clubhouses	1
Tennis courts	4
Other recreational development:	
Tennis center (number of courts)	12
Equestrian ranch (number of stalls)	100
Camp cabins	12
Single-family lots(1)	120
Affordable housing units	180

(1) Assumes incentives applied for total build-out of houses by 2000: Quon - Yamagishi Partnership.

Source: Compiled based on information from the report entitled "Market Assessment for the Proposed Lihi Lani Master-planned Community," KPMG Peat Marwick, January 1991.

ISLAND OF OAHU

Oahu, the third largest island in Hawaii, covers a land area of 618 square miles and is the center of business and government for the state. This section briefly reviews the demographic characteristics of residents and visitors on the island of Oahu.

Resident Population

In 1989, Oahu contained about 76% of Hawaii's resident population although it comprises only about 10% of the state's land area. As of July 1989, Oahu was estimated to have a resident population of 841,600, including military personnel.

Growth in resident population is projected by the Hawaii State Department of Business and Economic Development (DBED) to decrease from the 1.1% per annum rate of growth experienced from 1987 to 1990, to 0.7% per annum from 1990 to 2000.

Visitor Arrivals

Oahu has been and continues to be the most visited island in the state. The 1989 de facto population of about 916,200 reflected an average daily visitor population of 74,600 for the island, with this sizable visitor base located primarily in Waikiki.

In 1989 the total Oahu visitor arrivals reached 5 million, representing a compounded annual increase of 9.8% from 1980. In recent years there has been a shift in the make-up of visitors with an increasing proportion of travelers from Japan. Japanese visitors have shown a preference for the metropolitan Oahu over the less developed neighbor islands and are estimated to spend an average of $589 per day, more than four and a half times what the average westbound traveler spends.

The percentage of westbound visitors to the state who visit Oahu has declined from 94% in 1970 to 68% in 1989. This is attributed to the increase in tourism and resort development on the neighbor islands rather than a decline in visitors to Oahu.

Visitor arrivals to the state were projected by the DBED to reach 6.1 million and 7.8 million visitors by 1990 and 2000, respectively, with Oahu capturing approximately half of the visitors. This would represent a visitor growth rate on Oahu of about 3.4% compounded annually.

NORTH SHORE AND KOOLAULOA REGIONS

The subject site is located near the North Shore edge of the Koolauloa region which is defined as U. S. census districts 101, 102.02 and 102.01. The area constitutes the northern half of Oahu's windward coast bounded by the north end of the Koolau Mountains and extends from Kaaawa Stream to Waimea Bay. Kamehameha Highway is the main roadway linking this area with the adjacent North Shore region. Residential communities bordering the highway include Kaaawa, Kahana, Punaluu, Hauula, Laie, Kahuku, Sunset Beach and Waimea.

The Koolau and Waianae mountain ranges and the areas from Waimea Bay to Kaena Point form the main boundaries for the traditionally rural communities of the North Shore. The primary land uses in this region have been agricultural, residential and second home areas concentrated at Mokuleia, Waialua, Haleiwa and Kawailoa. The distric is defined as U. S. census divisions 99.01, 99.02 and 100.

This section reviews the economic and population trends of the North Shore and Koolauloa regions.

Economic Trends

The two regions are evolving from a primarily rural area to one that now also includes one of Oahu's major resorts and residential commuting suburbs.

The opening of the Kuilima Resort in 1972 had the most significant economic impact on the area creating an estimated 500 jobs since its inception. According to information from the development branch of Kuilima, the total job count could grow to 3,000 by the time all planned phases of development are completed.

The North Shore and Koolauloa regions could have increased tourism and drive-through visitors in the years ahead as Kuilima Resort expands and as attractions such as the Polynesian Cultural Center (PCC), Waimea Falls Park and professional surfing events continue to draw visitors. PCC, located in Laie, is Hawaii's largest paid tourist attraction according to state tourism statistics.

Resident Population

The 1980 resident populations of the North Shore and Koolauloa regions were 9,800 and 14,200, respectively, as shown in Exhibit II-D. This represents annually compounded growth rates of 0.6% and 3.0% from 1970 to 1990 for the North Shore and Koolauloa regions, respectively.

The 1989 resident populations of the North Shore and Koolauloa districts were estimated at 11,500 and 14,200, respectively, by the state. This represented an annual compounded growth rate of 1.8% and 2.2% from 1980 to 1989 for the North Shore and Koolauloa, respectively.

Employment Patterns

Civilian labor force participation rates have been relatively stable in the North Shore and Koolauloa regions as has been the case for the City and County of Honolulu, as shown in Exhibit II-E. Between 1970 and 1980, labor force participation rates for the two regions have averaged 57%, 9% lower than the county-wide average. This could be attributed to the relatively lower number of jobs in the North Shore and Koolauloa areas.

Information on labor force characteristics since 1980 is not available by regions, but the State of Hawaii, Department of Labor and Industrial Relations (DLIR) prepares labor force estimates for the county as a whole. The DLIR estimates that from 1980 to 1989 the civilian labor force has increased by 1.4% per year to about 384,500 persons in 1989 as shown in Exhibit II-F. In addition, county employment appears to have strengthened with the labor force growth

Exhibit II-D

LIHI LANI RECREATIONAL COMMUNITY

Historical and Projected Resident Population of the North Shore and Koolauloa Regions of Oahu

1970 to 1989

Year	North Shore(1)	Koolauloa(2)	Total
Historical:			
1970	9,200	10,600	19,800
1980	9,800	14,200	24,000
Estimated - 1989(3)	11,500	17,200	28,700
Compounded annual percentage increase:			
1970 to 1980	0.6%	3.0%	1.9%
1980 to 1989	1.8	2.2	2.0

(1) Defined as census tracts 99.01, 99.02 and 100.

(2) Defined as census tracts 101, 102.02 and 102.01.

(3) Based on July 1, 1989 estimates by State of Hawaii, Department of Business and Economic Development for census areas. County estimates are 14,000 and 12,400, respectively, for North Shore and Koolauloa Development Plan areas as of June 1989.

Sources: U. S. Bureau of the Census, 1972 and 1981a; City and County of Honolulu, Department of General Planning, 1990; State of Hawaii Department of Business and Economic Development, 1990.

Exhibit II-E

LIHI LANI RECREATIONAL COMMUNITY

Labor Force Characteristics of the North Shore and Koolauloa Regions and City and County of Honolulu

1970 and 1980

	North Shore(1)		Koolauloa(2)		City and County of Honolulu	
	1970	1980	1970	1980	1970	1980
Potential labor force (persons aged 16+)	5,960	7,370	6,800	9,830	426,600	574,900
Civilian labor force	3,510	3,840	3,720	6,120	237,340	516,880
Percentage distribution:						
Armed services	-%	12.0%	-%	2.0%	12.0%	10.1%
Civilian labor force	59.0	52.0	55.0	62.0	56.0	59.1
Not in labor force	41.0	36.0	45.0	36.0	32.0	30.8
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Civilian labor force participation rates:						
Male	76.0	64.0	71.0	61.0	83.0	75.0
Female	38.0	50.0	43.0	51.0	49.0	57.6
Average	57.0%	57.0%	57.0%	56.0%	66.0%	66.0%

(1) Defined as census tracts 99.01, 99.02 and 100.

(2) Defined as census tracts 101, 102.02 and 102.01.

Sources: U. S. Bureau of the Census, Census of Population and Housing, 1970, Census Tracts (Final Report, PHC(1)88, Honolulu, Hawaii, SMSA), 1972; and summary tape files 1-A and 3-A, 1980; and State of Hawaii, Department of Planning and Economic Development, Community Profiles for Hawaii, 1973; and The Geographic Distribution of Hawaii's Racial Groups, 1970 and 1980 (SR #152), 1982.

resulting in an estimated 2.2% rate of unemployment in 1989, about 2.4% less than in 1980.

Job losses since 1979 have occurred in the manufacturing industry while job increases were noted in the areas of construction, transportation, trade, services, finance and government as also shown in Exhibit II-F.

Household Income

Median household incomes in 1980 in the North Shore and Koolauloa regions at $17,900 and $15,400, respectively, were notably lower than the county and state averages of $21,100 and $20,500, as shown in Exhibit II-G.

Social Characteristics

Education, ethnicity and age characteristics of the regional population in 1970 and 1980 are summarized in Exhibit II-H. The North Shore and Koolauloa regions have exhibited increasing levels of educational achievement over the decade, as shown in the exhibit. Both regions also showed increases in the share of population of working force and retirement age categories along with overall decreases in the 17 years and below age categories.

Comparison of 1970 and 1980 U. S. Census data on ethnicity, unfortunately, is not meaningful because of the significant differences in the means of classifying ethnicity in the two years.

Exhibit II-F

LIHI LANI RECREATIONAL COMMUNITY

Average Annual Labor Force Estimates of the City and County of Honolulu

1980 and 1989

	1980	1989	Average annual percent change 1980 - 1989
Civilian labor force	340,350	384,500	1.4 %
Percent unemployed	4.6%	2.2%	N/A
Nonagricultural wage and salary jobs by industry:			
Construction	19,000	22,450	1.9
Manufacturing	17,100	16,050	(.7)
Transportation, communications and utilities	26,000	32,650	2.6
Trade:			
Wholesale	16,300	18,500	2.2
Retail	71,300	83,500	1.8
Services and miscellaneous:			
Hotels	15,200	18,700	2.3
Other services and miscellaneous	64,100	90,250	3.9
Finance, insurance and real estate	28,500	35,100	2.6
Government	75,500	84,800	1.3
Total	333,000	395,600	1.9 %

N/A Not applicable.

Sources: State of Hawaii, Department of Labor and Industrial Relations, Labor Force Data Book, annually updated, and Labor Area News (December), 1989.

Exhibit II-G

LIHI LANI RECREATIONAL COMMUNITY

Median Household Income in the North Shore and Koolauloa Regions and City and County of Honolulu

1979

Area	Median household income(1)
North Shore	$ 17,900
Koolauloa	$ 15,400
City and County of Honolulu	$ 21,100
State of Hawaii	$ 20,500

(1) Income of households in 1979.

Source: U. S. Bureau of the Census, 1980 Census of Population, Hawaii, 1981.

Exhibit II-H

LIHI LANI RECREATIONAL COMMUNITY

Social Characteristics of the North Shore and Koolauloa Regions and City and County of Honolulu

1970 and 1980

	North Shore		Koolauloa		City and County of Honolulu	
	1970	1980	1970	1980	1970	1980
Total population	9,200	13,100	10,600	11,000	630,500	762,600
Education (population aged 25+)(1):						
Less than 8 years	35.7%	25.6%	31.4%	15.2%	20.8%	14.4%
12 years	31.1	32.0	28.9	32.0	37.5	35.5
16 or more years	7.7	15.0	12.3	20.2	15.5	21.7
Ethnicity(1):						
Hawaiian	6.7	11.6	25.0	22.9	8.5	10.5
Japanese	24.1	17.7	8.7	7.4	26.8	24.9
Caucasian	31.8	31.2	39.5	38.2	41.2	34.4
Chinese	2.0	1.0	4.0	3.2	7.7	6.9
Filipino	32.0	32.4	10.7	7.1	10.4	12.6
Other	3.4	6.0	12.1	21.2	5.5	10.4
Age:						
Under 5 years	10.5	9.0	11.5	11.6	9.3	7.9
5 to 17 years	28.1	20.0	28.0	22.8	26.2	20.2
18 to 64 years	54.7	61.9	55.7	59.4	59.5	64.6
65 or older	6.7	9.1	4.8	6.3	5.0	7.3

(1) Estimates based on 15% sample.

Sources: U. S. Bureau of the Census, Census of Population and Housing, 1970, Census Tracts (final report, PHC(1)88, Honolulu, Hawaii, SMSA), 1972; Census of Population and Housing, 1980, Census Tracts (PHC 80(2)13), 1983; summary tape files 1-A and 3-A, 1980; State of Hawaii, Department of Planning and Economic Development, Community Profiles for Hawaii, 1973; and The Geographic Distribution of Hawaii's Racial Groups, 1970 and 1980 (SR #152), 1982.

III - ECONOMIC IMPACTS

The proposed Lihi Lani community is expected to generate significant positive economic benefits to the County of Honolulu and the State of Hawaii. This chapter describes the expected economic impacts of the planned Lihi Lani recreational community in terms of expenditures, employment, resident income and population.

CONSUMER EXPENDITURES

The master-planned community would contribute to direct, indirect and induced consumer expenditures in Hawaii. Visitors and residents of Lihi Lani would make direct expenditures for recreation-related fees, rentals, and purchases of food, beverages, and other goods and services. These expenditures would, in turn, require those establishments serving direct resident and visitor demands to purchase goods and services from other establishments in the state. The latter expenditures are considered indirect expenditures. Induced expenditures are those made by employees and proprietors with income derived from establishments benefiting from these new direct and indirect expenditures.

Direct Expenditures

Direct annual expenditures at the community were estimated based on the following:

- Projected cumulative development, as shown in Exhibit III-A.
- Projected recreational facility utilization and membership absorption at Lihi Lani, as presented in Exhibit III-B.
- Projected fees and other sales proceeds based on the experiences of comparable facilities, as shown in Exhibit III-C.

Based on these factors, direct expenditures could be expected to amount to $4.8 million per year in 1995 to $5.9 million per year in 2000 and stabilizing at $5.8 million per year in 2001, in 1990 dollars, as shown in Exhibit III-D.

Indirect and Induced Expenditures

The Hawaii State Department of Business and Economic Development (DBED) Input/Output model estimates the total economic activity generated in the state by various types of direct expenditures. Based on the multiplier of 1.95 for eating and drinking places and 2.15 for other retail trade sectors, an average 2.05 multiplier was derived from the most recent DBED model. The projected direct expenditures could be expected to generate indirect and induced expenditures throughout the state amounting to about $5.0 million in 1995, $6.1 million per year in 2000 and stabilizing at $6.0 million per year, as also shown in Exhibit III-D.

Exhibit III-A

LIHI LANI RECREATIONAL COMMUNITY

Projected Cumulative Development
at the Lihi Lani Master-planned Community

1995 to 2000

	1995	2000
Golf course development:		
Number of holes	18	18
Clubhouses	1	1
Tennis courts	4	4
Other recreational development:		
Tennis (number of courts)	6	12
Equestrian (number of stalls)	100	100
Cabins	12	12
Single-family lots (1):		
Homes built	0	120
Vacant lots, sold	60	0
Vacant lots, unsold	30	0
Total lots	90	120
Affordable housing units:		
Occupied	90	180
Unoccupied	50	0
Total affordable units	140	180

(1) Assumes incentives applied for total build-out by 2000: Quon - Yamagishi Partnership.

Source: Compiled based on information from the report entitled "Market Assessment for the Proposed Lihi Lani Master-planned Community," KPMG Peat Marwick, January 1991.

Exhibit III-B

LIHI LANI RECREATIONAL COMMUNITY

Projected Lihi Lani Recreational Facility Utilization
and Membership Absorption

1995 to 2000

	1995	2000
Golf memberships:		
Lihi Lani lot owners	20	80
Other Oahu residents	60	295
Out-of-state residents	30	125
Total golf memberships	110	500
Tennis memberships (1)	0	210
Daily rounds of golf:		
Nonmember Oahu residents	30	60
Members	15	50
Visitors	30	20
Total rounds	75	130
Daily tennis court reservations (2)	0	94
Equestrian center stable rentals (3)	20	80
Cabin occupancy percentage (4)	9%	9%

(1) Assumed number of memberships sold based on number of courts at the complex and a suggested ULI ratio of 30 club members per court with absorption at three courts in year one and one court per year thereafter until 2005.
(2) Projection based on following assumptions: 7 a.m. to 8 p.m. Tennis hours, one-hour reservations, number of courts and a 60% utilization rate based on rates of play at comparable facilities.
(3) Projection based on following assumptions: 100 stalls available for rental and an assumed 80% occupancy rate by 2000.
(4) Occupancy percentages estimated by Quon - Yamagishi Partnership at 65% occupancy on half of all weekends.

Exhibit III-C

LIHI LANI RECREATIONAL COMMUNITY

Assumptions Regarding Sales Revenues at
Lihi Lani Recreational Community

1995 to 2000

(1990 dollars)

	1995	2000
Club membership fees (1):		
Golf-		
Initiation	$23,800	23,800
Monthly dues	130	130
Tennis-		
Initiation	5,100	5,100
Monthly dues	70	70
Green and cart fees:		
Members (2)	4	4
Non-members (3)	75	85
Food and beverage/retail sales:		
Golf club members (4)	3,400	3,400
Non-member course users (5)	23	23
Other revenues:		
Tennis (6)	227,600	227,600
Equestrian (7)	250	250
Cabin rental (8)	38	38

(1) Based on weighted average membership fees.
(2) Per member per round, cart fee only, two players per cart.
(3) Per nonmember per round.
(4) Per member per year.
(5) Per round.
(6) Projected gross annual sales at tennis center based on comparable tennis facility revenues. Includes court fees, merchandise, sundries and other income.
(7) Per month.
(8) Per night, including cabin rental, parking, and other fees: estimated by Quon - Yamagishi Partnership.

Exhibit III-D

LIHI LANI RECREATIONAL COMMUNITY

Projected Total Annual Non-Lihi Lani Resident Expenditures Attributable to Lihi Lani Recreational Community

1995 to 2001

(Millions of 1990 dollars)

	1995	2000	Stabilized (2001)
Direct expenditures (1):			
Golf club and course (2)	$4.75	5.29	5.29
Tennis (2)	0.00	0.47	0.34
Equestrian (3)	0.04	0.16	0.16
Cabins	0.02	0.02	0.02
Subtotal	4.81	5.93	5.81
Indirect and induced expenditures:	4.95	6.11	5.98
Total (4)	$9.76	12.05	11.78

(1) Based on sales revenues assumptions shown in Exhibit III-C. Adjusted to remove Lihi Lani resident spending to avoid double counting of revenues.
(2) Non-resident spending estimated at about 82% of total based on proportion of non-resident members to total members.
(3) Non-Lihi Lani residents stable renters assumed at 66%.
(4) Projected at about $2.05 per $1 direct expenditure. Based on a weighted average of spending multipliers for eating and drinking, retail trade, real estate and other services: Department of Business and Economic Development Input-Output Model, 1987; as reported in 1989 State of Hawaii Data Book.

Total Expenditures

Direct, indirect, and induced expenditures attributable to the use of the community facilities are projected in 1990 dollars to total $9.8 million in 1995, $12.1 million per year in 2001 and stabilizing at $11.8 million per year.

EMPLOYMENT

Planned development will generate short-term employment during the construction of new facilities and long-term employment in the operation and support of those facilities. Employment effects may also be classified as being direct, indirect or induced. Direct employment is that supported by expenditures at the community, such as those at its recreational facilities and food and beverage establishments. Most of the direct employment effects would occur at Lihi Lani. As for expenditures, however, indirect and induced employment resulting from the community may be supported throughout the state's economy.

Direct Construction Employment

Direct construction employment is that which would be supported directly by the construction of the facilities. Such employment includes on-site laborers, operatives and craftsmen, as well as the professional, managerial, sales and clerical workers whose usual places of employment may be elsewhere on the island or in the state.

Construction employment would be highest during the first three years of development, before facilities are operational, when the major portion of the infrastructure, affordable homes, golf course and residential lots are constructed. Construction employment is estimated to average about 204 person-years per year from about 1993 to 1995 as shown in Exhibit III-E. Construction employment would then average about 79 person-years per year from 1996 to project completion in 2000.

Indirect and Induced Construction Employment

The direct employment of construction workers at the development will stimulate additional employment on the island and elsewhere in the state. The DBED estimated that 0.8 full-time jobs are created in the state for every full-time job in the building construction industry. This multiplier is used to project the indirect and induced employment to be supported by the direct construction employment, as shown in Exhibit III-F. As with direct construction, the greatest employment would occur in the first construction period of 1993 to 1995 when indirect and induced construction employment effects are expected to provide employment opportunities for about 153 person-years per year. Indirect and induced construction employment would then average about 63 annual person-years from 1996 to 2000.

Direct Operational Employment

The majority of direct operational employment at the development would occur at the recreational facilities. Private golf clubs in Hawaii are found to employ between 30 and 50 full-time equivalent direct employees. Employment at the tennis center, equestrian ranch, property management and real estate sales is estimated to range between 5 and 10 direct employees at each facility.

Exhibit III-E

LIHI LANI RECREATIONAL COMMUNITY

Projected Direct Employment for Facility Construction
(Person-Years)

1993 to 2000

	Average annual 1993-1995	Average annual 1996-2000	Total
Golf course(1)	17	-	50
Golf club and tennis courts (2)	33	5	127
Equestrian (2) (3)	7	-	22
Cabins (2)	6	-	18
Single-family lots:			
Lot development (4)	6	1	24
Home construction (5)	0	65	324
Affordable units:			
Land development (6)	6	-	18
Unit construction (7)	42	7	162
Community facility (2)	9	-	27
Infrastructure (8)	78	-	233
Total	204	79	1,005

(1) Estimated at 25 full-time equivalent jobs per year construction, planting and grading with a two year construction period based upon comparable golf construction projects.
(2) Employment demand estimate assumes: labor cost is 50% of construction cost: average union labor wages and benefits of $55,000 per worker; and average construction period of one year.
(3) Adjustment of 20% fewer person years to account for trail and other site work.
(4) Demand calculated at 0.2 full-time equivalent jobs per year per lot, and average one-year construction period per lot.
(5) Demand calculated at 2.7 full-time equivalent jobs per year per home, and average one-year construction period per home.
(6) Demand calculated at 0.1 full-time equivalent jobs per year per unit, and average one-year construction period per unit.
(7) Demand calculated at 0.9 full-time equivalent jobs per year per home, and average one-year construction period per home.
(8) Based on construction costs of $58.2 million estimated in 1990 by Quon - Yamagishi Partnership. Demand calculated at 4.0 full-time equivalent jobs per year per million dollars. Areas of single-family lots and affordable units anticipated to be included in infrastructure construction.

Source: Based on information from contractors and construction engineers. 1990 construction costs estimated by Quon - Yamagishi Partnership.

Exhibit III-F

LIHI LANI RECREATIONAL COMMUNITY

Projected Indirect and Induced Employment for Facility Construction
(Person-Years)

1993 to 2000

	Average annual 1993-1995	Average annual 1996-2000	Total
Total direct, indirect and induced employment	367	142	1,810
Less direct employment (1)	204	79	1,005
Indirect and induced employment (2)	163	63	804

(1) As shown in Exhibit III-E.
(2) Indirect and induced effect estimated at 0.8 full-time equivalent positions per direct position, based upon the DBED Input-Output model, 1987; as reported in the 1989 State of Hawaii Data Book.

Thus, the recreation-oriented community could be expected to have generated about 45 full-time equivalent direct operational positions by 1995 and about 60 full-time equivalent positions by 2000, as shown in Exhibit III-G.

Indirect and Induced Operational Employment

Facility operations at Lihi Lani would also indirectly generate employment elsewhere in the state. Recent studies on the total economic impacts of direct, indirect and induced employment multipliers in the food and beverage and other retail trade industries by the DBED suggest that the activities at the community could be expected to support .7 indirect and induced full-time equivalent positions elsewhere in the state for each direct job created.

Thus, indirect and induced operational employment could be expected to amount to 33 full-time equivalent positions by 1995 and 42 full-time equivalent positions by 2000, as shown in Exhibit III-H.

Total Operational Employment

Total direct, indirect and induced operational employment is estimated to represent about 78 full-time equivalent positions by 1995 increasing to 102 positions by 2000, as also shown in Exhibit III-H.

PERSONAL INCOME

Lihi Lani would have an impact on personal income for residents of the island and state through employee wages, salaries and fringe benefits, as well as through revenue to its proprietors. Personal income is defined as the wages and salaries paid to the direct construction and operational employees of the development. Personal income is projected on the basis of average industry wages and salaries for the various types of employment anticipated and on the projected future employment demands.

Personal income paid to Hawaii residents could be expected to average about $8.1 million per year during initial construction in 1993 through 1995 and about $4.0 million per year from 1996 to 2000 for both construction and operational employment. In the ensuing years following project development, it could amount to $0.9 million per year as construction activity ends and operational employment demands continue, as shown in Exhibit III-I.

POPULATION

The development of facilities will lead to a population increase at the Pupukea site and elsewhere on the island. People will be residing during most or parts of each year in the residential portion of the community, while day visitors to the recreational areas will contribute to the average daily population.

Operational employees may also add to the off-site population of the region and the island. It is assumed that most construction employees will already be Oahu residents and will commute to their places of employment if not living nearby. Thus, construction employment is not expected to generate significant population impacts for the region or island.

Exhibit III-G

LIHI LANI RECREATIONAL COMMUNITY

Projected Direct Operational Employment

1995 to 2000

	1995	2000
Golf club and course (1)	30	40
Tennis (2)	-	10
Equestrian (3)	5	5
Property management and sales (4)	10	5
Total	45	60

(1) Operational employment based upon local courses similar to the semi-private golf course. Includes clubhouse, food and beverage, and retail facilities as well as course management and maintenance.
(2) Tennis operational employment based upon employment patterns at comparable local club operations.
(3) Equestrian operational employment based upon employment patterns of comparable local equestrian and stable operations.
(4) Property management and sales operational employment based on discussions with realtors and developers. Includes campground rental operations.

Source: Based on interviews and published information of selected local and national private club and resort operations, 1990.

Exhibit III-H

LIHI LANI RECREATIONAL COMMUNITY

Projected Direct, Indirect and Induced Operational Employment at the Lihi Lani Residential Community

1995 to 2000

	1995	2000
Direct(1)	45	60
Indirect and induced:		
Golf club and course (2)	20	27
Tennis (2)	-	7
Equestrian (2)	3	3
Property management and sales (3)	9	5
Subtotal	33	42
Total	78	102

(1) As shown in Exhibit III-G.
(2) Estimated at 0.7 full-time equivalent positions per direct position based on the DBED Input-Output Model, 1987; as reported in the 1989 State of Hawaii Data Book.
(3) Estimated at 0.9 full-time equivalent positions per direct position based on the DBED Input-Output Model, 1987; as reported in the 1989 State of Hawaii Data Book.

Exhibit III-I

LIHI LANI RECREATIONAL COMMUNITY

Projected Total Annual Personal Income from Direct Employment

1993 to 2001

(Millions of 1990 dollars)

	Average annual 1993-1995	Average annual 1996-2000	Total	Stabilized (2001)
Construction (1)	$8.12	3.13	40.01	0.00
Operational (2)	0.33	0.87	5.32	0.87
Total	$8.45	4.00	45.33	0.87

(1) Average annual wage is projected at $39,805, comparable to the average annual income for the construction industry in the City and County of Honolulu. Inflated from 1988 dollars using a total personal income inflation rate of 9.6% in 1988 and 8.5% in 1989.
(2) Excluding tips. Estimated at $17,160 per full-time equivalent position, based on weighted average of eating and drinking places, miscellaneous retail stores, personal services, real estate, and amusement and recreation services sector wages in the City and County of Honolulu. Inflated from 1988 dollars using an inflation rate as described above.

Source: Department of Labor and Industrial Relations, "Employment and Payrolls in Hawaii: 1988," 1989; First Hawaiian Bank, "Economic Indicators," 1989 and 1990.

Day Visitor Population

Day visitors to the recreation-oriented community would be those using the golf course, golf clubhouse, tennis center, equestrian ranch, campground, community facility or cabins. The guest population was estimated by using the projected facility utilization shown in Exhibit III-B, less residents of the community. With these assumptions, the average daily visitor population is projected to be about 77 persons by 1995, increasing to about 262 persons by stabilization at 2000, as shown in Exhibit III-J.

Resident Population

Resident population at Lihi Lani was projected using the assumptions concerning home development shown previously in Exhibit III-A and assumptions about full- and part-time residential usage of the housing units shown in Exhibit III-K. Thus, resident population at the community is projected to be about 252 persons by 1995, increasing to 697 persons by stabilization at 2000, as also shown in Exhibit III-J. The majority of this growth is attributable to the affordable housing component of the project.

Employee Population

Direct construction workers, as calculated in Exhibit III-E, are all projected to commute to the site during the day. Thus they impact only the daily on-site population. This impact decreases over the development period as the majority of construction is completed in the beginning of the development period, as shown in Exhibit III-J.

Due to the region's currently low unemployment and the possibility of full employment once Kuilima Resort proceeds with the expansion of its resort area, it has been estimated that personnel moving to the region from other parts of the island could approximate 50% of the total operational employment. The operational employee impact, including one projected additional person per household, could amount to 45 persons in 1995 and 60 persons in 2000, as shown in the same exhibit.

Total Projected De Facto Population

The facility development at the Lihi Lani recreational community is projected to generate total daily population growth of about 578 persons in 1995, increasing to 1,097 persons by 2000 and decreasing to 1,019 persons thereafter, with the end of construction, as shown in Exhibit III-J.

In-Migrant Population

Residents to the community are expected to include no new residents to Oahu in 1995 and about 27 in-migrant residents in 2000, as shown in Exhibit III-L. In terms of in-migrant operational employees, estimated at about 15% of the total employees, and their accompanying household members, the in-migrant employee population impact is projected to be 14 persons in 1995 and stabilizing at about 18 persons by 2000. In total, the projected in-migrant population is expected to amount to about 14 new residents in 1995, increasing to about 45 persons by 2000, as shown in the same exhibit.

Exhibit III-J

LIHI LANI RECREATIONAL COMMUNITY

Projected De Facto Population Impacts of the Lihi Lani Residential Community on the North Shore and Koolauloa Districts of Oahu

1995 to 2001

	1995	2000	Stabilized (2001)
Day visitors:			
Golfers (1)	71	120	120
Tennis (2)	0	131	131
Equestrian (3)	2	7	7
Campgrounds (4)	4	4	4
Subtotal	77	262	262
Residents (5):			
Single-family lots	0	193	193
Affordable units	252	504	504
Subtotal	252	697	697
Construction workers (6)	204	79	0
Noncommunity residents:			
Operational employees (7)	23	30	30
Other household members (8)	23	30	30
Subtotal	45	60	60
Total	578	1,097	1,019

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(1) Based on projected rounds of play, as shown in Exhibit III-B. Excluding residents of project.
(2) Based on number of courts, projected daily court reservations, as shown in Exhibit III-B, and assumes 60% singles and 40% doubles play mix and 50% of play is by existing Lihi Lani and North Shore and Koolauloa residents.
(3) Assumes 70% of stable renters are Lihi Lani, North Shore and Koolauloa residents, and that renters visit twice a week.
(4) Based on cabin development assumptions in Exhibit III-A, usage assumptions in Exhibit III-B, and four persons per cabin.
(5) Full-time resident equivalents based on home development assumptions in Exhibit III-A and on-site resident population assumptions in Exhibit III-K.
(6) Represents the average number of direct construction workers projected to be on-site during the day in the periods shown in Exhibit III-E.
(7) Personnel moving to North Shore and Koolauloa for jobs estimated at 50% of direct operational employment, as shown in Exhibit III-G.
(8) Projected at one additional person per household.

Exhibit III-K

LIHI LANI RECREATIONAL COMMUNITY

Assumptions for On-site Resident Population

	Distribution (1)	Occupancy	Average Party Size (2)
Single-family lot development:			
Full-time-			
Hawaii	45%	95%	2.8
Other	5%	95%	2.8
Subtotal	50%		
Part-time-			
Hawaii	35%	25%	2.4
Other	15%	25%	2.4
Subtotal	50%		
Total	100%		
Affordable unit development:			
Full-time, Hawaii	100%	95%	3.0

(1) Occupied units only. Based on information from "Market Assessment for the Proposed Lihi Lani Master-planned Community," KPMG Peat Marwick, December 1990.
(2) Based on 1988 average state household size of 2.95 adjusted for user profile: State of Hawaii Data Book, 1989.

Source: Based on published information and interviews with brokers at similar developments.

Exhibit III-L

LIHI LANI RECREATIONAL COMMUNITY

Projected In-Migrant Population to the Island of Oahu (Average Daily Population)

1995 to 2000

	1995	2000
On-site community residents (1)	0	27
Off-site residents:		
Construction employees (2)	-	-
Operational employees (3)	7	9
Dependents (4)	7	9
Subtotal	14	18
Total in-migrant population impact	14	45

(1) Assumptions shown in Exhibit III-K.
(2) Construction employment demand is projected to be satisfied by existing Oahu construction labor supply.
(3) Based on 15% of operational employment estimated to be in-migrants to the island, as shown in Exhibit III-G.
(4) Projected at one additional person per household.

IV - FISCAL IMPACTS

The proposed Lihi Lani Recreational Community is expected to generate significant positive fiscal benefits for the City and County of Honolulu and for the State of Hawaii. These fiscal impacts have been evaluated by comparing the tax revenues and operating expenditures which are projected to be incurred by the state and county governments.

GOVERNMENT REVENUES

Development at the Pupukea site would bring additional tax revenues to the county and state governments. County government revenues would be principally in the form of real property taxes on the new facilities. Revenues to the state government would be composed principally of general and specific excise taxes and personal income taxes paid by new state residents and the general excise tax on sales revenues attributable to day visitors to the community. The sections following project the additional revenues that could be generated for the county and state governments as a result of the recreation-oriented development.

County Revenues

Real property in the county is currently taxed from $4.70 to $10.71 per $1,000 of assessed value depending on the land use class. Golf courses are currently taxed at the agricultural-zone rate of $9.00 per $1,000 assessed value, while commercial tax rates of $9.45 per $1,000 assessed value are applied to golf clubhouses, their surrounding lands and their related facilities. Improved residential property is taxed at $4.95 per $1,000 building value and $4.70 per $1,000 land value, while unimproved residential property is taxed at $4.95 per $1,000 of both building and land assessed values.

Net additional real property taxes were projected according to assessed values for other comparable golf club facilities in the state, preliminary construction costs provided by Obayashi Hawaii, and projected sales prices of the residential components, less the current property taxes generated by the undeveloped site.

Based on these tax rates and estimated assessed values, the proposed private club, golf course, tennis, equestrian, cabins, lots, affordable homes, community facilities and other lands could be expected to generate net new property tax revenues for the City and County of Honolulu of about $590,000 per year by 1995 in 1990 dollars, and increase to about $910,000 per year by 2000, as shown in Exhibit IV-A.

State Revenues

New revenues to the state government would be generated by the 4% general excise tax on direct expenditures by day visitors to Lihi Lani. In addition, new residents attracted to the state by the employment or residential opportunities of the project would bring in additional excise sales taxes, individual income taxes and other state taxes such as liquor, tobacco, fuel, inheritance, estate and conveyance taxes. Cabin rentals would bring in transient accommodation room taxes.

Exhibit IV-A

LIHI LANI RECREATIONAL COMMUNITY

Projected Real Property Tax Revenues to the County Government
Attributable to Development at Lihi Lani Residential Community

1995 to 2000

(Millions of 1990 dollars)

Source of property tax revenue	1995	2000
Golf course (1)	$0.16	0.16
Golf culb and tennis courts (2)	0.10	0.13
Equestrian (2)	0.00	0.03
Cabins (2)	0.02	0.02
Single-family:		
With homes (3)	0.00	0.37
Unbuilt lots (4)	0.05	0.00
Less: Owner occupant exemption (5)	0.00	(0.03)
Subtotal	0.05	0.35
Affordable units:		
Completed (6)	0.09	0.12
Undeveloped phase land (7)	0.03	0.00
Less: Owner occupant exemption (8)	(0.03)	(0.05)
Subtotal	0.10	0.07
Community facility (2)	0.03	0.03
Other developed land (9)	0.17	0.18
Undeveloped land (10)	0.06	0.06
Total new property tax revenues	0.70	1.02
Less: Current property tax revenues (11)	(0.10)	(0.10)
Net new property tax revenues	$0.59	0.91

(1) Based on estimated assessed value of $1 million per hole; an agricultural property tax rate of $9.00 per $1,000 assessed valuation.
(2) Based on estimated improvement values as follows: $14 million golf club house and tennis; $3 million equestrian; $2 million cabins; $3 million community facility; commercial property tax rate of $9.45 per $1,000 assessed value.
(3) Based on estimated value of $650,000 per home and lot; a blended land and building tax rate of $4.80 per $1,000 assessed value.
(4) Based on estimated value of $300,000 per lot and tax rate of $4.95 per $1,000 assessed value.
(5) Based on an estimated average owner occupant deduction value of $70,000 per home.
(6) Based on estimated value of $140,000 per unit; a blended land and building tax rate of $4.80 per $1,000 assessed value.
(7) Based on estimated land value of $75,500 per unit and tax rate of $4.95 per $1,000 assessed value.
(8) Based on an estimated average owner occupant deduction value of $50,000 per unit.
(9) Includes 520 acres of zoned land under golf club house and tennis courts, equestrian, cabins, community facility, and infrastructure, less pasture acreage, assessed at a weighted average of about $52,500 per acre. Land zoned but undeveloped is assumed to be assessed at half this amount. Tax is at the commercial rate of $9.45 per $1,000 assessed value.
(10) Based on current assessed value of $10,300 per acre; about 620 acres; an agricultural property tax rate of $9.00 per $1,000 assessed value.
(11) Current property taxes estimated at $104,300 based on a 1990 assessed value of about $10,300 per acre from the TMK on-line database; an agricultural property tax rate of $9.00 per $1,000 assessed value.

Using state tax receipts in fiscal 1989 and adjusting for inflation to 1990 dollars, individual income and other taxes mentioned above, averaged $966 per state resident. Thus, new total tax revenues to the state government attributable to the project's development are expected to be about $210,000 per year in 1990 dollars by 1995 and increase to about $290,000 in 2000 and stabilize at about $280,000 by 2001, as shown in Exhibit IV-B.

GOVERNMENT OPERATING EXPENDITURES

New visitors and residents attracted by the project would also necessitate additional expenditures of state and county public resources.

In-migrant residents would incur public costs in terms of public safety, maintenance of highways, recreational facilities and natural resources, health and sanitation measures, special cash capital improvements, education, retirement and pension funds, public welfare and other government functions.

Day visitors increase the average daily population of the community and also require public expenditures in terms of public safety, maintenance of highways, health and sanitation, recreation and special cash capital improvements. Because visitors are expected to spend half a day or less at the site, the projections assume each day visitor incurs 50% of the average visitor operating costs to the county and the state.

County Expenditures

The various county government operating expenditures for fiscal year 1989 were analyzed with respect to the relevant population served by each of the government functions. This analysis indicates that Honolulu City and County government expenditures in 1989 totaled about $607 per resident and $337 per visitor as shown in Exhibit IV-C. A 7.2% annual increase, equal to the rise in the Honolulu Consumer Price Index between 1989 and 1990 would be equivalent to expenditures in 1990 dollars of about $629 and $349 per capita for residents and visitors, respectively.

Based on these county government outlays, public expenditures by the county on behalf of the service population for the Lihi Lani could be expected to total about $20,000 per year by 1995 and increase to about $70,000 per year by 2000, in 1990 dollars, as shown in Exhibit IV-D.

State Expenditures

A similar analysis of state government operating expenditures and the relevant populations for the various government services indicate that expenditures in 1989 totaled about $2,886 per resident and $574 per visitor, as shown in Exhibit IV-E. This is equivalent to about $2,990 per resident and $595 per full-time equivalent visitor when adjusted upwards by 7.2% annually to estimate 1990 dollars.

Based on these operating costs, state government expenditures are projected to total about $30,000 per year by 1995 and increase to about $170,000 per year by 2000, as shown in Exhibit IV-F.

Exhibit IV-B

LIHI LANI RECREATIONAL COMMUNITY

Projected Annual Revenues to the State Government Attributable to Development and Operation at Lihi Lani Recreational Community

1995 to 2001

(Millions of 1990 dollars)

	1995	2000	Stabilized (2001)
Number of in-migrant households (1):			
Full-time households	0	6	6
Part-time households	0	5	5
Employee households	7	9	9
Total households	7	19	19
Full-time residents and employee in-migrant population (1):			
Full-time residents	0	16	16
Employees and dependents	14	18	18
Total persons	14	34	34
Tax revenue source (millions):			
Visitors-			
General excise tax on sales revenues (2)	$0.19	0.24	0.23
Visitor accommodations tax (3)	0.00	0.00	0.00
In-migrant resident and in-migrant employee-			
General excise tax (4)	0.00	0.02	0.02
Individual income & other taxes (5)	0.01	0.03	0.03
Total tax revenues	$0.21	0.29	0.28

(1) Based on Exhibits III-J, K and L.
(2) Based on 4.0% of direct visitor expenditures at Lihi Lani, as shown in Exhibit III-D.
(3) Based on 5.0% of cabin rental revenues, as shown in Exhibit III-D.
(4) Based on 4.0% of selected household budget items. Budget items estimated at 38% of household incomes assumed at $100,000 for full-time residents; $120,000 for part-time community residents; $17,160 for in-migrant operational employees; and number of households as shown above.
(5) Estimated at $966 per year for each full-time resident in 1990 based on inflated 1989 state revenue receipts per capita. Number of full-time residents as shown above.

Sources: Department of Planning and Economic Development, The State of Hawaii Data Book, 1989; Tax Foundation of Hawaii, Government in Hawaii: A Handbook of Financial Statistics, 1990.

Exhibit IV-C

LIHI LANI RECREATIONAL COMMUNITY

City & County of Honolulu Per Capita Government Expenditures

Fiscal Years 1989 and 1990

(Millions of 1990 dollars)

	Expenditure (000's) (1)	Service Population (2)	Expenditure: Per resident	Expenditure: Per visitor
General government	$64,015	840,010	$76	--
Public safety	138,694	909,120	153	153
Highways	23,963	909,120	26	26
Health and sanitation	58,397	909,120	64	64
Economic and urban development	23,144	840,010	28	--
Recreation	38,582	909,120	42	42
Interest	39,001	840,010	46	--
Bond redemption	17,863	840,010	--	--
Retirement and pension	17,644	840,010	21	--
Mass transit	48,427	840,010	58	--
Cash capital improvements	46,983	909,120	52	52
Miscellaneous	34,194	840,010	41	--
Total, 1989 dollars	$550,907		$607	$337
Estimated total, 1990 dollars (3)			$629	$349

(1) County government operating expenditures for fiscal year ended June 30, 1989 as reported in Tax Foundation of Hawaii, Government in Hawaii, 1990.
(2) Resident or de facto population estimates for the county as of January 1, 1989.
(3) Adjusted to 1990 dollars based on a 7.2% increase in the Consumer Price Index between 2nd quarter 1990 and year earlier; as reported by Bank of Hawaii Information Center, 1990.

Exhibit IV-D

LIHI LANI RECREATIONAL COMMUNITY

Projected Annual County Government Expenditures Attributable to In-migrant Population of the Lihi Lani Residential Community

1995 to 2000

(Millions of 1990 dollars)

	1995	2000
Population (persons):		
Average daily visitors (1)	75	255
Single-family lot residents (2)	0	27
Operational employees and dependents (2)	14	18
Total	89	300
Expenditures:		
Average daily visitors (3)	$0.01	0.04
Single-family lot residents (4)	0.00	0.02
Operational employees and dependents (4)	0.01	0.01
Total expenditures	$0.02	0.07

(1) From Exhibit III-J less those stable renters assumed to be from Oahu.
(2) In-migrant full-time equivalent residents, as shown in Exhibit III-L. Construction workers anticipated to be prior Oahu residents.
(3) Visitors require $349 in 1990 dollars per capita per year. Lihi Lani day visitors allocated the equivalent of 50% of the annual County expenditure per visitor total since they may be spending a significant portion of the day elsewhere on the island.
(4) Residents require $629 in 1990 dollars per capita annually in county government expenditures.

Exhibit IV-E

LIHI LANI RECREATIONAL COMMUNITY

State of Hawaii Per Capita Government Expenditures

Fiscal Years 1989 and 1990

(Millions of 1990 dollars)

	Expenditure (000's) (1)	Service Population (2)	Expenditure Per resident	Expenditure Per visitor
General government	$287,802	1,105,270	$260	--
Public safety	119,991	1,240,900	97	97
Highways	76,911	1,240,900	62	62
Natural resources	38,327	1,240,900	31	31
Health and sanitation	120,440	1,240,900	97	97
Hospitals and institutions	147,452	1,105,270	133	--
Public welfare	396,944	1,105,270	359	--
Education	986,588	1,105,270	893	--
Recreation	27,025	1,240,900	22	22
Utilities and other enterprises	174,257	1,240,900	140	140
Debt service	248,062	1,105,270	224	--
Retirement and pension	85,727	1,105,270	78	--
Employees' health insurance	584	1,105,270	1	--
Unemployment compensation	49,112	1,105,270	44	--
Grants-in-aid to counties	42,348	1,105,270	38	--
Urban redevelopment and housing	263,908	1,105,270	239	--
Cash capital improvements	155,598	1,240,900	125	125
Miscellaneous	46,921	1,105,270	42	--
Total, 1989 dollars	$3,267,999		$2,886	$574
Estimated total, 1990 dollars (3)			$2,990	$595

(1) State government operating expenditures for fiscal year ended June 30, 1989 as reported in Tax Foundation of Hawaii, Government in Hawaii, 1990.
(2) Resident or de facto population estimates for the state as of January 1, 1989.
(3) Adjusted to 1990 dollars based on a 7.2% increase in the Consumer Price Index between 2nd quarter 1990 and year earlier; as reported by Bank of Hawaii Information Center, 1990.

Exhibit IV-F

LIHI LANI RECREATIONAL COMMUNITY

Projected Annual State Government Operating Expenditures
Attributable to In-migrant Population of the
Lihi Lani Residential Community

1995 to 2000

(Millions of 1990 dollars)

	1995	2000
Population (persons):		
Average daily visitors (1)	75	255
Single-family lot residents (2)	0	27
Operational employees and dependents (2)	14	18
Total	89	300
Expenditures:		
Average daily visitors (3)	$0.02	0.08
Single-family lot residents (4)	0.00	0.08
Operational employees and dependents (4)	0.01	0.01
Total expenditures	$0.03	0.17

(1) From Exhibit III-J less those stable renters assumed to be from Oahu.
(2) In-migrant full-time equivalent residents, as shown in Exhibit III-L. Construction workers anticipated to be prior Oahu residents.
(3) Visitors require $595 in 1990 dollars per capita per annum. Lihi Lani day visitors allocated the equivalent of 50% of the annual state expenditure per visitor total.
(4) Residents require $2,990 in 1990 dollars per capita in state government expenditures per annum.

REVENUE AND EXPENDITURE ANALYSIS

The net fiscal impacts of the planned development to the county and state operating budgets are estimated by comparison of the projected revenues and expenditures.

County Cost/Benefit

Comparison of projected public revenues and expenditures attributable to the project's development indicates that the county government could expect to net an additional $570,000 per year by 1995 and $840,000 per year by 2000 and thereafter, in 1990 dollars as shown in Exhibit IV-G. The analysis also indicates that additional county government revenues generated by the proposed community and its facilities could be almost 30 times the operating expenditures incurred by the county government initially, and about 13 times these expenditures by 2000 and thereafter, as also shown in the exhibit.

State Cost/Benefit

Based on a similar analysis, net fiscal benefits to the state government are projected to be about $180,000 per year by 1995, decreasing to about $120,000 per year by 2000, and stabilizing at about $110,000 per year, in 1990 dollars, as shown in Exhibit IV-H. In addition, state government revenues generated by the development could be seven times the expenditures incurred by the state government in 1995 and nearly two times the expenditures in 2000 and at stabilization, as also shown in the exhibit.

RECREATION

The planned recreation-oriented community development is expected to enhance the variety of recreational opportunities on the North Shore for residents.

Existing and Planned Facilities

In the North Shore area, recreational activities available to area and island residents include sun bathing, swimming, surfing, fishing, camping, and hiking at the various public parks and recreation areas.

In terms of North Shore golfing facilities, there are the 9-hole Kahuku Municipal Golf Course and the existing 18-hole resort golf course at the Kuilima Resort and a planned 18-hole at Kuilima Resort. Several other semi-private golf courses are also planned with some nonmember play included.

Required Additional Facilities

Development of the Pupukea site would provide additional recreational facilities in the form of an 18-hole golf course, a tennis center, an equestrian ranch, campgrounds and parks, all of which will be available for public use.

Exhibit IV-G

LIHI LANI RECREATIONAL COMMUNITY

County Government Revenue and Expenditure Comparison

1995 to 2000

(Millions of 1990 dollars)

	1995	2000	Stabilized (2001)
New revenues (1)	10.59	0.91	0.91
New expenditures (2)	0.02	0.07	0.07
Net additional revenues	10.57	0.84	0.84
Revenue/expenditure ratio (3)	29.5	13.0	13.0

(1) From Exhibit IV-A.
(2) From Exhibit IV-D.
(3) New revenues divided by new expenditures.

Exhibit IV-H

LIHI LANI RECREATIONAL COMMUNITY

State Government Revenue and Expenditure Comparison

1995 to 2001

(Millions of 1990 dollars)

	1995	2000	Stabilized (2001)
New revenues (1)	$0.21	0.29	0.28
New expenditures (2)	0.03	0.17	0.17
Net additional revenues	$0.18	0.12	0.11
Revenue/expenditure ratio (3)	7.0	1.7	1.6

(1) From Exhibit IV-B.
(2) From Exhibit IV-F.
(3) New revenues divided by new expenditures.

The Lihi Lani Recreational Community, along with other existing and planned projects would expand the recreational opportunities in the Koolaulea and North Shore areas. The high demand for golf and other recreational activities could be absorbed at the new facilities and alleviate some of the overcrowding problems at public facilities such as municipal golf courses and other recreational areas.

APPENDIX U

JACK NICKLAUS GOLF SERVICES

A DIVISION OF GOLDEN BEAR INTERNATIONAL INC.

January 4, 1991

Mr. Jeff Overton
924 Bethel Street
Honolulu, Hawaii 96813

Re: Pupukea Northshore Golf Management Plan

Dear Jeff:

The following report will outline my thoughts on major aspects of golf course management at the Pupukea Northshore Golf Course. One of the main concerns that I must voice is that we not be locked into using this plan strictly as it reads. The management of any golf course is dynamic by nature, and Pupukea is no exception. Experience in managing the course acquired by the golf course superintendent will no doubt lead to some subtle changes in this plan, and possibly to some changes which are not so subtle. Thus, keep in mind that some deviations in the plan will occur as determined by the turf manager and/or the Nicklaus regional agronomist.

When proposing a management plan such as this, I feel the most important points to be addressed are as follows:

-Selection of a Golf Course Superintendent
-Description of the Maintenance Facility
-Turf Management Equipment
-Turf Types and Turf Areas to Be Managed
-Pesticides and Their Use
-Integrated Pest Management
-Fertilizers and Plant Nutrition
-Irrigation of the Course
-Other Cultural Practices

Creating a comprehensive management plan entailing exactly what is to be done at a specific time is not possible. However, the following descriptions relating to these major points should give any readers an outline of what the concept of golf course management is.

CORPORATE HEADQUARTERS, [illegible] NORTH PALM BEACH, FL 33408 • [illegible]
CHINA HONG KONG CITY [illegible] CANTON ROAD, KOWLOON, HONG KONG • TEL: [illegible]
OLD CHELSEA MEWS [illegible] DANVERS STREET, CHELSEA, LONDON [illegible] ENGLAND • TEL. [illegible]

Selection of a Superintendent.

The person you ultimately select as a golf course superintendent must be a highly motivated individual who is strong agronomically as well as politically. He or she must be a people manager and should be a golfer. It is very important that the superintendent be able to visualize care of the golf course from a golfer's perspective. The superintendent should have a turf management college degree, and should have experience at upscale golf developments. The superintendent should be certified by the national association, but this is not absolutely necessary. The superintendent should be mature enough to handle the pressures of the job, but must be young enough to not be set in their ways. They must be capable of continuously learning and keeping abreast of changes in the industry. The superintendent must be friendly and visible around the development, and should be treated as a professional person. The superintendent ideally should be fluent in appropriate foreign languages. Additionally, they should be computer literate. They should be well compensated and allowed to travel to as many educational conferences as possible without interfering with the day-to-day operation of the development.

In order to hire such an individual it will be necessary to advertise. Seeking advertising help from the Golf Course Superintendents Association of America will help. However, not every qualified individual will subscribe to the placement service provided by the organization. Thus, it may be in your best interest to advertise directly in Golf Course Management, Western Turf Management, Southern Turf Management, Golf Course News, Grounds Maintenance or other popular turf publications read by golf course superintendents. Hiring of the superintendent should commence with the installation of the irrigation system, but no hasty decisions should be made. I will be happy to assist with any aspects of the golf course superintendent hiring process.

Golf Maintenance Area.

It is in the best interest of the golf course to keep the routinely used people and equipment, the fertilizers and pesticides, and the management offices in a central maintenance location. The maintenance yard must be fully paved and completely fenced with limited access. It should be hidden from view from the course. There should be separate areas dedicated for people, the storage of fertilizers and pesticides, and storage and maintenance of the routine equipment such as mowers and hand tools.

There will be some critical concerns which must be taken into account when constructing the general maintenance area. The first of these concerns is the pesticide storage and mixing area. The pesticide storage area would be a room or small building dedicated solely to the storage of pesticides. There must be pesticide warning signs posted in all applicable languages affixed to this area. The area must be locked and have limited access. Only the golf course superintendent and the pesticide applicator should have keys. The pesticide storage area should be kept away from the management offices and employees general work areas. This storage area must be fireproof and well ventilated to outside air. There must be a fire extinguisher nearby. The storage area should be well lit and should have large, stable storage shelving. The pesticide storage area also should be self contained. That is to mean that absolutely no pesticide can be allowed to escape to the outside environment in the event of a pesticide spill in the area. Additionally, the pesticide storage area must be in close proximity to the pesticide mixing area, to minimize the distance pesticides are transported prior to tank mixing.

The pesticide mixing area would be an area of the maintenance yard dedicated solely to mixing pesticides. This area should also have limited access. The area should consist of a slightly concave cement basin large enough to permit the tank sprayers to rest within the area while mixing occurs. As with the storage area pesticide must not be allowed to escape to the outside environment in the event of a pesticide spill. The mixing area should also be shaded (with a rigid roof) and have some type of curb surrounding it to prevent rain water from entering the basin.

The fertilizer storage area should be dedicated only to storage of fertilizer products. The area must be dry and well ventilated, and large enough to accommodate bulk fertilizer storage. It must be well ordered, well lit, and contain pallets for the material to rest on. Walkways within the confines of the storage area must be wide, and fertilizer material must not be stacked too high. As with the pesticide storage area, the fertilizer storage area should have limited access. There must be no pesticide or fuel storage in this area.

The equipment storage area must be large enough to prevent collision of moving equipment in the morning and afternoon rush. There should be an adequate amount of floor drains so that periodic rinsing of the area can occur. The area must also be large enough to permit the orderly storage of all equipment. This area must also be well ventilated and well lit. There must be no pesticide or fuel storage in this area. Additionally, this area should be in relatively close proximity to the mechanic's work area.

A fuel depot will be necessary in the central maintenance yard. This will dispense both gasoline and diesel fuel, as well as serve as a storage facility for grease and oil. Again, it must be a limited access area. This area, like the pesticide mixing area, should also allow for recovery of petroleum products in the event of a spill. No gasoline, diesel fuel, oil or grease must be allowed to escape to the outside environment. The majority of fuel depots utilize underground storage tanks for their fuel supplies. Be advised that this will necessitate a large amount of liability insurance. You may want to consider above-ground fuel storage.

The equipment washing bay is also an area of concern. The area should be well away from the main building and should always be kept as clean as possible. There should be a steam pressure washer available. Oils and grease rinsed from the equipment must not be allowed to escape to the outside environment.

One of the central thoughts involving these critical concern areas is to prevent the discharge of pesticides, fertilizers, fuels, oils and grease into the outside environment. This may be construed as a fairly formidable task, but technology is such that I think there is a way to prevent the discharge of such compounds. This would involve the implementation of a sump/filter hazardous materials recovery system. This filter recovery system would be applicable to the pesticide storage and mixing area, the fuel depot, the equipment washing bay, and the equipment storage area including the mechanics work area. In essence, the filter would allow for the separation of oils, greases, pesticides and fertilizer contaminants from the water hence preventing their discharge into the environment. The unit can be configured into the basic design of the maintenance yard with minimal cost.

Turf Management Equipment

The following list is a typical inventory for 18 holes of golf:

QTY	EQUIPMENT
1	1/2 Ton Pick-up Truck (Chevy S-10)
2	Cushman Truckster 530 (3-wheel, 18 Hp, PTO, hydraulic pump)
3	Daihatsu w/Dump Bed or E-Z Go GT-7 Truckster Cushman Topdresser Attachment
1	1-1/2 Ton Dump Truck
1	Lely Spreader (ground driven, single flotation tires)
2	PGM Drop Spreader
3	Lesco's Rotary Spreader
1	Jacobsen Triplex Greensmower with Spiking Reels & Turf groomer attachment
7	Jacobsen or John Deere Greensmower (solid and Whiele rollers, brushes, etc.)
1	Smithco Easy Rider Trap Rake
1	72" Jacobsen Turf Cat or John Deere F935 Riding Rotary Mower
1	Jacobsen G-20 or John Deere 1050 Tractor (3 pt. hitch, PTO, draw bar, turf tires, etc.) or Jacobsen 4 x 4 32AP Tractor

QTY	EQUIPMENT
1	Industrial Tractor (attachments: loader, backhoe, and fork lift attachment) John Deere 210C
1	John Deere 1500 Utility Vehicle w/160 gallon sprayer w/18' folding boom, foam marker kit and spreader & agitator
1	Chain Saw (20" blade)
1	1-1/2" John Deere Mudhog Pump
2	84" National Mower each, with high speed reel kit, 6-bladed reels, front rollers and special tire option
1	John Deere Boxblade
1	John Deere Yorkrake
2	John Deere String Line Trimmers
4	Flymo
1	John Deere or Jacobsen Commercial 20" Rotary Mower
1	Ohio Hand Roller (18" x 24")
1	E-Z Go GX800 Cart, (Gas)
1	Jacobsen Model 40 Blower
	Miscellaneous Equipment (shovels, rakes, picks, hammers, spaces, axes, wheel barrow, etc.)
1	Tractor-Drawn Drop Spreader (E-Z flow or equivalent)
1	Chain Saw (20" Blade)

QTY	EQUIPMENT
1	Leaf Blower (8 hp)
2	John Deere Back Pack Blower
2	EZ-Go GX-800 Truckster (3-wheel) or Honda TR-X-250 w/Tow-Behind Trailor
1	Cushman Topdresser Attachment
1	Jacobsen Triplex Greensmower (including verticut units and Turf Groomer attachment)
3	Jacobsen HF-5 Hydraulic 5-Gang Mower with 10 bladed reels and front Whiele Rollers
1	Jacobsen G-20 or John Deere 1050 Tractor W, 3 pt. hitch, PTO, Draw Bar, Turf Tires with 5-Gang Ramlift with 6-bladed fairway reels for roughs
1	Lely Dethatching Rake 10'
1	Smithco Easy Rider (manual blade)
1	Ryan 18" Sodcutter
2	Ryan Greensaire II (window)
1	John Deere Trap Edger (4 hp)
3	John Deere Stringline Trimmers
2	Flymo Mowers
1	Ryan Mat-A-Way
1	FMC 300-gallon Fairway Sprayer with 20 gpm pump
1	Sweepster 72" 3-pt. Hitch Sweeper

QTY	EQUIPMENT
1	Jacobsen Model 590 Aerator with 3 pt. hitch, 3/4" coring tines, slicing tines
1	Toro Rake-O-Vac (PTO)
1	Mars Greens Sweeper
1	5-Gang Fairway Verticut 1 1/2" Knife spacing-Roseman or Brower
1	Mechanics Tools (large set, tool chest)$
1	Mechanics Tools (small set, tool box)
1	Air Compressor (3 hp, 80-gallon tank) Upright
1	Grease Gun (air and manual)
1	AC Arc Welder
1	Battery Charger (fast and trickle, booster cables
1	Large Grinder
1	Cutting Torch
1	2-Ton Hoist and Trolley
1	Large Vise
1	2-Ton Floor Jack (stands)
1	1/2" Pneumatic Impact Wrench
1	Pressure Washer
2	Foley Lapping Machine
5	Work Benches (3' x 10')

QTY	EQUIPMENT
1	Set Storage Shelves
1	Portable Air Tank
1	1/2" Electric Drill
1	1/4" Electric Drill
1	8" Circular Saw
1	Surveyors Instrument (tripod, rod, tape)
1	Pipe Tools
1	Generator
2	Fire Extinguishers
1	Wire Fault Tracker & Fault Finder
1	Engine Tuning Kit (compression tester), Tach-dewell, timing light)
1	Foley Spin Reel Grinder
1	Foley Bedknife Grinder
1	Drill Press (1/3 hp 10")
1	Paint Gun Kit

Turf Types and Turf Areas to be Managed.

The golf course turf should be viewed as four distinct areas, each with differing levels of management. The most intensely managed areas will be the greens surfaces. The green surfaces will be sprigged with Tifdwarf bermudagrass (Cynodon dactylon x Cynodon transvaalensis Burtt-Davey) at a rate of 30 bushels per 1,000 square feet. Green surfaces should be mowed daily at a height between 1/8 inch and 3/16 inch with standard greens mowers. Greens surrounds will be sprigged with Tifway 419 bermudagrass (same Latin designation) at a rate of 400 bushels per acre. The surrounds should be mowed at rough height, approximately 1.5 to 2.0 inches, with gang type mowers or triplex type mowers 3 to 5 times per week. The next most intensively managed area will be tee surfaces. Tee surfaces will be planted with Tifway 419 bermudagrass at 30 bushels per 1000 square feet. Tee surfaces should be mowed with greens type mowers daily at 3/8 to 1/2 inch. Tee shoulders, like green surrounds, will be sprigged with Tifway 419 at 400 bushels per acre, and mowed in the same manner. Fairways will be sprigged with Tifway 419 bermudagrass at a rate of 400 bushels per acre, and mowed daily or at a minimum of 5 times per week at 1/2 to 5/8 of an inch. Generally, a gang-type mower pulled by a tractor is used for this task. However, there has been a recent trend to use triplex type mowers on fine fairways. Likewise, roughs will be planted with the 419 bermuda at 400 bushels per acre and maintained at 1.5 to 2.0 inches as needed. Some areas of the golf course will also be planted with ornamental type grasses (i.e., fountaingrass). The roughs and areas to receive ornamental grasses could be considered very low maintenance areas, while green and tee complexes, and fairway areas, would be considered to be highly maintained.

Construction of greens will closely follow United States Golf Association guidelines. Construction of tees will utilize a modified U.S.G.A. guideline.

Pesticides and Their Use.

Since there are many, many potential pests of turfgrass in this area, and since factors such as the vigor of the turf, the weather, the season, the soil moisture level, and the amount of traffic the turf receives dictate pest related turfgrass stress, (i.e., the tolerable threshold) the pest management program cannot be rigidly established. Some years may see virtually no pest related problems, while in other seasons pest induced stress may be overwhelming. For example, if turf is healthy and weather patterns allow for substantial, unimpeded root growth the area might tolerate 30 grubs per square foot, whereas if turf is unhealthy and disease pressure is heavy the turf may only tolerate 25 grubs per square foot before pesticide application becomes necessary. Thus, I feel it is inappropriate to set up in this document a pesticide application schedule. Pesticide application should be a part of the overall integrated pest management program. This type of program utilizes the monitoring of pest populations and the dynamic setting of damage level thresholds to establish when pesticides are needed. The program also relies on using cultural and biological controls of pests to supplement the pesticide program, hence reducing somewhat the reliance on pesticides.

Pesticides are compounds which suppress the populations of pests. Common pests in turf situations include weeds, pathogenic micro-organisms, insects, nematodes, and small animals. Attached to this document you will find a listing of probable pesticides which might be considered for use at Pupukea. This list is very extensive but is not exclusive. There are many pesticides being developed and labelled all the time. These pesticides must be applied in strict accordance with the manufacturer's label. Only those pesticides which are labelled and approved for use in Hawaii will be used. The golf course superintendent must, however, have the flexibility to pick and choose from a wide array of pesticides in order to control turfgrass pests in the most prudent manner possible with least impact to the environment. In some instances, it may be better to use a more toxic pesticide if fewer applications using lower application rates can be utilized. Only direct on-site experience can dictate the full scope of the pest management program.

In addition, I should mention that a very close and ongoing relationship between the golf course superintendent and the Nicklaus regional agronomist will persist. This relationship will lead to the scrutiny and subsequent review of the cultural practices performed by the golf course superintendent. This would help to ensure that all hazardous materials are used in a consistent and judicious manner so that pesticide use does not become an issue in and of itself.

Integrated Pest Management.

Integrated pest management is not a new term. In fact, golf course superintendents have been using IPM for some time. For example, consider the fungal disease dollarspot (Lanzia spp.). Golf course superintendents have known for years that if soil moisture is maintained at an adequate level, if dew is removed from turf in the early morning, if adequate N fertility is maintained, and if the correct amount of the proper fungicide is applied, dollarspot can be controlled. The IPM concept can be applied to weeds, fungal pathogens, insects and nematodes, and small animals such as gophers.

Fertilizers and Plant Nutrition.

Fertilization involves the supplemental application of the major nutrients nitrogen (N), phosphorus (P), and potassium (K), as well as other major and minor nutrients such as sulfur (S), calcium (Ca), magnesium (Mg), iron (Fe), boron (B), etc. These nutrients are commonly applied via carriers, compounds which contain the nutrient. The fertilizer carriers most frequently applied to turf contain nitrogen, phosphorus, and potassium in various ratios. Nitrogen carriers would be the inorganic ions nitrate or ammonium, or organic compounds such as urea or IBDU. Phosphorus carriers would typically be various forms of phosphates, such as ammonium or calcium phosphate, or phosphoric acid. Potassium carriers could be inorganic compounds such as potassium sulfate, potassium oxide, or potassium chloride. Nitrogen is a vital component of plant chlorophyll, amino acids and proteins. It is an essential growth nutrient. Phosphorus is necessary for plant cell energy production. Vital cell functions are driven by oxidation of phosphorus compounds. Potassium functions in cell osmotic regulation. Adequate potassium is necessary for water regulation. Fertilization of turfgrass is necessary to culture a fine golf course.

The goal of the fertilization plan is to supply the optimal amount of each nutrient to achieve the desired plant growth with minimal fertilizer loss or environmental impact. This will involve the utilization of slow release organic sources of N such as IBDU, Osmocote, sulfur coated urea, or urea formaldehyde. These materials are considered slow release N sources due to decreased water solubility compared to inorganic carriers such as ammonium nitrate, which essentially ionize upon hydration. Slow release N sources have been previously shown to minimize nutrient leaching and runoff from the target site. Use of complete fertilizer products, as well as single nutrient carriers can supply the P and K. Phosphate is usually adsorbed to the soil complex and does not represent a significant environmental impact when applied at moderate levels. Likewise, potassium is held in the exchange complex and does not pose a significant threat when used judiciously.

Pre-plant addition of fertilizer is generally required in greensmixes. Usually, the amount of P and K to be added is based on soil testing results. Minor elements may also be added as indicated by soil testing. This minimizes the chance for waste of those nutrients via loss. The amount of N to be added is generally between 1 and 3 pounds N per 1,000 square feet with 50% to 60% being in a slow release form (i.e., IBDU).

Post-planting fertilization requirements will involve application of P and K according to routine soil and plant tissue testing. First year post plant N requirements will be 6 pounds of actual N per 1,000 square feet. This amount will be needed to generate sufficient plant density. For the first 8 weeks (eg. beginning in May) 0.75 pounds of N per 1,000 square feet will be applied twice monthly using a 29% slow release carrier (IBDU). From week 8 through week 12 there will be twice monthly applications of 0.5 pounds of N per 1,000 square feet alternating 50% and 70% slow release carrier (IBDU). From week 12 through week 20 there will be monthly applications of 0.5 pounds of N per 1,000 square feet again alternating 70% and 50% slow release (IBDU). A dormant feed in November will consist of 1.0 pound of N per 1,000 square feet with 85% IBDU. The 29% slow release carrier (IBDU) is an 10-18-22 analysis having 2.9% IBDU, 0.5% urea, 3.0% nitrate and 3.6% ammoniacal N. The 50% IBDU carrier is an 16-0-14 analysis with 8.0% IBDU, 1.5% urea, 6.5% nitrate. The 70% IBDU carrier is an 20-0-16 analysis with 13.9% IBDU, 2.5% urea, and 6% nitrate. The 85% IBDU is a 31-0-0 analysis with 26.3% IBDU and 4.7% urea. Total P application will be 2.7 pounds of P per 1000 square feet and total K application will be 6.7 pounds of K per 1,000 square feet. Phosphorus and K deficiencies indicated by soil testing can be made up with phosphoric acid and potassium sulfate respectively.

For the second year greens will again receive P and K according to soil and plant tissue testing. Nitrogen will be applied twice monthly May through October, with a dormant feed again in November. Nitrogen will be applied at 0.5 pounds per 1000 square feet in May using 29% slow release (IBDU). In June N will alternate between 50% and 70% slow release (IBDU) also at 0.5 pounds per 1,000. For July through August the N will be applied as a 100% urea foliar application at 0.25 pounds per 1,000. In September and October the N will again be applied as a 50% slow release (IBDU) at 0.5 pounds per 1,000. The dormant feed will be 1 pound per 1,000 of 85% slow release (IBDU). The foliar urea is a 28-8-18 analysis with 3.05% ammoniacal, 6.0% nitrate, and 15.95% urea N. Nutrient totals for year 2 are 6 pounds of N, 1 pound of P and 5 pounds of K per 1,000 square feet. Again P and K nutrient deficiencies can be made up with appropriate carriers.

Pre-plant fertilization of fairways with P and K should be based on soil testing results. Addition of N during preplant fertilization is usually at 40 to 100 pounds of N per acre. Half of the N should be in a slow release form.

Post-plant guidelines for the first year would include applying 6.5 pounds of N per 1,000 using 50% and 95% slow release (SCU), and 100% Osmocote. Applications of 1.0 pound of N after turf reaches the 2 leaf stage, then 0.5 pounds each on weeks 2, 4, 6, with the 50% material, 0.5 pound applications of the 95% material on weeks 8, 12, 16, and 20, and finally a dormant feed of 2.0 pounds of N in November with 100% Osmocote would be made. The 50% slow release SCU is a 12-24-14 analysis with 6% SCU, 1% urea, 5% ammoniacal N and is a high grade material for fairways. The 95% material is a 21-4-11 analysis with 20.15% SCU and 0.85% ammoniacal N. The Osmocote is a 16-8-12 material with 7.6% ammoniacal and 8.4% nitrate N. The nutrient totals would be 6.5 pounds of N, 2 pounds of P, and 3.5 pounds of K per 1,000 square feet. Phosphorus and K deficiencies can be made up with appropriate carriers depending on soil and plant tissue test results.

On year two, the fairways would receive 4 pounds of N per 1,000 square feet using the 50% and 95% slow release (SCU) N source, and the 100% Osmocote N source. Applications of 0.5 pounds per 1,000 would be made monthly in May through October. A dormant feed of 1 pound of N per 1,000 with Osmocote would then follow in November.

Roughs would, like fairways, be fertilized pre plant with P and K according to soil test results. Nitrogen applications would be 40 to 100 pounds of N per acre with half being slow release.

For year one post-plant, rough turf (and amenity rough) would receive 6 pounds of N per 1,000 square feet. Nitrogen would be applied in increments of 1 pound per 1,000 when the turf reached the 2 leaf stage, and 0.5 pound per 1,000 increments on weeks 2, 4, 6, and 8. A 1 pound application on weeks 12, and 16 with a 1 pound per 1,000 dormant feed in November would also be applied. For the initial application, and on weeks 2, 4, 6 and 8 a 60%

slow release (SCU) would be used. For weeks 12 and 16 a 100% SCU would be used and the dormant feed would utilize Osmocote. The 60% material is a 14-14-14 analysis with 8.55% SCU, and 5.45% ammoniacal N. The 100% SCU is a 28-3-9 analysis with 26.7% SCU, and 1.3% ammoniacal N. Nutrient totals would be 6 pounds per 1,000 square feet of N, 1.6 pounds per 1000 P, and 3.5 pounds per 1,000 of K. Phosphorus and K deficiencies can be made up with appropriate carriers depending on soil and plant tissue test results.

For the second year and after the roughs would receive 3 pounds of N per 1,000 square feet. This would involve 0.75 pounds of N applied in June and August with 0.5 pounds N applied in October. A dormant feed of 1 pound of N per 1,000 would commence in November. The June and August applications would utilize the 60% slow release (SCU) while the October application would utilize the 100% slow release (SCU) and the dormant feed would utilize Osmocote. Nutrient totals would be 3 pounds of N per 1,000 square feet, 1 pound of P and 2 pounds of K. Again, nutrient deficiencies can be made up with appropriate carriers according to soil and plant tissue testing.

Irrigation on the Course.

Supplemental irrigation is a primary cultural practice for fine turf. Generally, it is the goal of the irrigation schedule to replace the amount of soil moisture which is lost to evapotranspiration (i.e., evaporation of the soil water plus water lost by the plant through transpiration). Like the use of pesticides, the application of water should be considered dynamic. That is, there will be a greater or lesser need for water based on weather patterns and rainfall. Thus, until weather patterns for the site are firmly established, it will be difficult to make accurate projections on water use quantity. However, experience tells us that in the neighborhood of 500,000 to 750,000 gallons of water per day might be utilized especially during the turf grow in period.

Water for irrigation will be distributed using a state of the art computerized system. The advantages of using the computerized system include having the ability to compensate for rainfall, the ability to program for differing areas of the site, the ability to monitor water use as well as electricity consumption, and having a more efficient water distribution.

Other Cultural Practices.

Other maintenance practices to be considered on fine turf include various cultivation techniques, such as core aerification, vertical mowing, topdressing, spiking, grooving, and application of various wetting agents and organic amendments. These finer points of golf course management are generally up to the golf course superintendent to implement. However, as a general rule, core aerification of greens, tees and fairways would be done twice yearly in spring and fall. Topdressing would be applied to greens and tees every three weeks at 1/3 cu yd per 1,000 square feet, and vertical mowing of the greens, tees and fairways would be done at least monthly. In this endeavor, the golf course superintendent would work closely with the regional Nicklaus agronomist for at least two years after turf establishment.

Jeff, I hope this document helps you in the preparation for plan submission. It is difficult to prepare such a document, in that I have not very much time to devote to it. If there are any gaps that need to be filled let me know as soon as possible. Again, please be reminded that any part of the plan is subject to change per the golf course superintendent or the regional Nicklaus agronomist.

Sincerely,

W. Lee Berndt, Ph.D.
Director of Environmental
Services/Agronomist

WLB/vh

Attachment: List of Probable Pesticides

cc: Mr. Edward A. Etchells
Mr. Warren T. Sasser

WARM SEASON TURFGRASSES

INSECTICIDES

Compounds	Pests Controlled
bendiocarb (Turcam)	grubs, chinchbugs
carbaryl (Sevin)	ants, cutworms, leafhoppers
carbophenothion (Trithion)	bermudagrass mites, scale
chloropyrifos (Dursban)	ants, billbugs, mole crickets
ethoprop (Mocap)	grubs, webworms
fensulfothion (Terracur)	grubs
isazofos (Triumph)	mole crickets, grubs
isofenphos (Oftanol)	grubs, turfgrass weevil
malathion (Malathion)	mosquitos
trichlorfon (Dylox)	army worms, grubs

FUNGICIDES

Compounds	Pests Controlled
anilizine (Dyrene)	dollar spot*, rust
benomyl (Tersan 1991)	spring dead spot, brown patch
chloroneb (Terraneb SP)	Pythium*, brown patch
chlorothalonil (Daconil 2787)	leaf spot, brown patch
ethazole (Koban)	Pythium
fenarimol (Rubigan)	spring dead spot, dollar spot
fosetyl Al (Alliette)	Pythium
flutolanil (Prostar)	fairy ring
iprodione (Chipco 26019)	melting out, dollar spot
mancozeb (Fore)	leaf spot, melting out
maneb (Maneb-4)	rust, smut
metalaxyl (Subdue)	Pythium, yellow tuft
propamocarb (Banol)	Pythium
propiconazole (Banner)	powdery mildew, rusts
thiophanate ethyl (Cleary's 3336)	melting out, dollar spot
thiophanate methyl (Fungo 50)	spring dead spot
thiram (Tersan 75)	rust, brown patch
triademefon (Bayleton)	spring dead spot, rust
vinclozalin (Vorlan)	dollar spot, melting out

*resistance is a problem

HERBICIDES

Compound**	Pests controlled
Xeulam (Asulox)	grassy weeds
atrazine (AAtrex)*	broadleaves, grassy weeds
benifin (Balan)*	grassy weeds
bensulide (Betasan)*	grassy weeds
bentazon (Basagran)	nutsedge
DCPA (Dacthal)*	grassy weeds, sandburr
dicamba (Banvel)	broadleaves
dichlorprop (Weedone DPC)	broadleaves
DSMA (Crab Kleen)	grassy weeds
glyphosate (Roundup)	non-selective
imazaquin (Image)	purple nutsedge
MCPA (Weedar)	broadleaves
MCPP (MCPP)	clover, broadleaves
metribuzin (Sencor)	goosegrass
MSMA (Bueno)	grassy weeds
oxadiazon (Ronstar)*	grassy weeds
pronamide (Kerb)*	annual grasses
sethoxydim (Poast)	grassy weeds
simazine (Princep)*	grasses, broadleaves
triclopyr (Turflon)	broadleaves, grasses

*preemergent control
**many herbicides are sold as mixtures--these are not included

FUMIGANTS

Compounds	Pests Controlled
Metam-sodium (Vapam)	non-selective, ground pearls

NEMATACIDES

Compounds	Pests Controlled
fenamiphos (Nemacur)	nematodes
fensulfothion (Dasanit)	nematodes

RODENTACIDES

Compounds	Pests Controlled
warfarin (Warfarin)	rats, mice
pival (Pindone)	rats, rodents
strychnine	gophers, moles